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Nutrient Adsorption from Aqueous Solution and Wastewater by Activated Dead Biomass of a Non-Edible Mushroom(*Trametes versicolor*)

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ABSTRACT---- ***The objective of this study was to investigate the nutrient adsorption potential of activated carbonated dead biomass of a non-edible mushroom (Trametes versicolor) in aqueous solution and wastewater. The study was carried out in batches by investigating the effects of contact time, temperature and pH on phosphate, sulphate and nitrate adsorption by the Trametes. The results revealed that at the end of the 6 h contact period with the activated Trametes, phosphate concentration in the aqeuous solution was observed to increase from an initial concentration of 362.19 mg/L to 405.96 mg/L while nitrate concentrations at the different contact hours were observed to be lower than what was obatined at the initial. A lowest decrease in nitrate concentration from 627.38 mg/L to 91.53 mg/L was observed after the 5 h contact period before there was an increase to 141.30 mg/L after 6 h contact time. In the wastewater, after the 6 h contact period with the activated Trametes, the final concentration of phosphate was recorded as 200.00 mg/L from an initial concentration of 261.45 mg/L. In the case of sulphate, no decreases in concentration were observed in the wastewater in the presence of the Trametes throughout the period of contact. At the different temperatures used for investigation, phosphate levels in the aqueous solution containing the Trametes were not observed to show any remarkable decreases. With respect to sulphate in the aqueous solution at the different temperatures, concentrations in the experimental setups were observed to range from 728.74 mg/L to 1305.75 mg/L.The highest and lowest sulphate concentration were observed at 40 °C (1305.75 mg/L) and 50 °C (728.74 mg/L), respectively. The lowest and highest decreases in nitrate levels were observed at 30 °C and 50 °C, respectively. At 40 ^{o}C, phosphate concentration increased from 330.12 mg/L in the control setup to 370.28 mg/L in the setup with the Trametes. For sulphate levels at the different temperatures, remarkable increases in concentrations were observed at all the temperatures investigated in the setups with the Trametes, no decrease in nitrate concentration was observed in presence of the Trametes at the different temperatures investigated. A highest phosphate increase from 539.36 mg/L in the control to 634.94 mg/L in presence of the Trametes was observed at pH 4. In the case of sulphate, decreases in concentrations were observed in presence of the Trametes at the different pH investigated. A remarkable decrease from 1587.93 mg/L to 686.21 mg/L was observed at pH 8. The study was able to reveal the optimum conditions for nutrient adsorption from water by the activated dead biomass of the Trametes versicolor.***

Keywords--- *Trametes versicolor,* nutrient adsorption, wastewater, aqueous solution

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1. INTRODUCTION

Due to increasing population, land use change, practices from food production, poor water use practices and rise in standard of living, water quality can be affected. The proper management of wastewater is essential because it has a direct effect on survival of aquatic ecosystems, affecting the life support system, ranging from urban development to production of food and industry. The impact of waste water can be very dangerous starting from humans, plants and animals (UN-water).In recent time, poor sanitation and lack of drinking water of high quality is estimated to be the main global cause of approximately 4,000 deaths per day(Jong*et al.*,2012).

Waste water discharge with high phosphate, sulphate and nitrate levels can result in eutrophication of receiving water bodies (Zub*et al.*, 2014).These nutrients are able to affect the health of individuals.Nitrate is a primary health concern because of the formation of nitrite by the reduction of nitrate in the digestive tract by nitrate-reducing bacteria. Absorption of nitrite in the bloodstream occurs and itcombines with hemoglobin leading to the formation of methemoglobin. Methemoglobin can be life threatening since they do not have the ability of carrying oxygen. The

oxygen level in tissues decreases and people and livestock are stressed. Methemoglobinemia is also referred to as blue baby syndrome, as a result of the development of blue color around the mouth and eyes.
High levels of nutrients present in the environment are capable of leading to undesirable growth of microorganisms and enhancing eutrophication.In preventing negative effects of eutrophication and also to ensure a safe environment there is an urgent desire to reduce the levels of nutrients to the acceptable levels set by regulatory bodies before they are released into water bodies (Akpor *et al*., 2013).The removal of phosphorus, nitrate and sulphate when in high concentration is carried out in a variety of ways. In the aspect of nitrate the two major and effective methods used are ion-exchange denitrification and heterotrophic denitrification, while phosphate and sulphate removal involves chemical and biological methods. In the biological methods, microorganisms that aid in the removal of these nutrients are used while chemicals are used in order to ensure adequate removal of phosphate and sulphate (Zub *et al.*, 2008).

In various studies, agricultural waste has been used in the production of low-cost carbon adsorbents. This activated carbon can be used in the treatment of wastewater. These adsorbents have been used for the removal of dye. The application of agricultural waste provides income to marginal farmers, landless agricultural labourers, and generation of employment especially in the developing countries (Banerjee*et al.,* 2012).

The investigation of agricultural wastefor removal of color from wastewater both for the issues pertaining to health and aesthetic purpose is less expensive compared to other methods. Dyes are usually majorly recycled and generated in industries such as rubber, cosmetics and leather. The use of activated carbon is the most recommended adsorbent for the removal of dye because it has high adsorption capacity, high degree of surface reactivity and micro pore structures. The available commercial activated carbon is very expensive and has increased regeneration cost while being used. The application of agricultural waste is of great significance (Choubert*et al.*, 2005). This study was therefore aimed at assessing the efficiency of *Trametes versicolor*, a non-edible mushroom in the adsorption of phosphate, sulphate and nitrate in aqueous solution and wastewater.

2. MATERIALS AND METHODS

2.1 SOURCE AND PREPARATION OF ADSORBENT

The mushroom used for the study was *Trametes* sp (a non-edible mushroom that grows in the wild) dead biomass. The mushroom dead biomass was collected from one of the dead log of wood in the vicinity of Landmark University, Omu Aran.

For preparation of the material for adsorption studies, it was first washed with clean water to remove sand and other debris before air drying in an oven at 60 ^oC for 6 days. After drying, the mushroom was pulverized using a laboratory blender before carbonating in a furnace at 460 ^oC for 20 min.

For activation, a known quantity of the carbonated *Trametes* dead biomass was first weighed into a 1000 mL capacity beaker, after which concentrated sulphuric acid (1:2 w/v) added and left to stand for 1 h. At the end of the 1 h contact, the acid was washed off several times with distilled water. The washing continued until all traces of the acid was removed. This was confirmed by inserting a litmus paper. A red colouration on the litmus paper was an indication of the presence of acid. The washing continued until the litmus paper showed no change in colour.

After washing off the acid, the activated *Trametes* dead biomass was recovered by filtering through Whatman No 1 filter paper. The filtrate was then oven-dried at 100 ^oC for 8 h to remove all traces of water. The dried activated *Trametes* dead biomass was then stored in a dried plastic container and stored in dried continuous at room temperature until when needed. In the study, the dried activated *Trametes* dead biomass is referred to as adsorbent.

2.2 NUTRIENT ADSORPTION IN AQUEOUS SOLUTION AND WASTEWATER

Nutrient adsorption studies was carried out both in aqueous solution and in wastewater. In the respective studies the effect of contact time, pH and temperature of aqueous solution or wastewater on nutrient adsorption by the adsorbent were investigated.

To investigate the effect of contact time on adsorption by adsorbent, 5 g each of the adsorbent was weighed into six 250 mL capacity flasks containing 100 mL of aqueous solution or wastewater. Control flasks containing only aqueous solution or wastewater were also set up for each of the experimental flasks. Both the experimental and control flask were placed in a rotary shaker at a shaking speed of 100 rpm at 25 $^oC \pm 2$ ^oC. Every one hour, for the next six hours, two flasks (experimental and control flasks) were withdrawn and content filtered through Whatman No 1 filter paper. The filtrates were then analyzed for phosphate, nitrate and sulphate in them, using standard procedures (APHA, 2012).

While detecting the effect of temperature variation in the presence of the adsorbent, 5 g of adsorbent was measured into a 250 mL capacity Erlenmeyer flask containing 100 mL of either aqueous solution or wastewater at different temperatures and incubated in water bath shakers for 3 h. The regulation of temperature was achieved with the aid of a laboratory water bath at temperatures of 30 °C, 40 °C, 50 °C, 60 °C and 70 °C for 3 h. After 3 h the various samples were filtered and determination of phosphate, nitrate and sulphate was analyzed using standard procedures.

In the investigation of the optimum pH for nutrient removal, the study was carried out using pH 2, 4, 6, 8 and 10. The pH of the aqueous solution or wastewater was adjusted using 1 M HCl (for acidic ranges) or 1 M NaOH (for alkaline ranges). After adjusting the pH of the aqueous solution or wastewater, 5 g of the adsorbent was introduced into 250 mL capacity Erlenmeyer flask containing 100 mL of the aqueous solution or wastewater and incubated in a rotary shaker at a shaking speed of 100 rpm at 25 ^{o}C± 2 ^{o}C for 3 h. After 3 h, the filtered sample was used in the determination of phosphate, sulphate and nitrate concentration, using standard methods.

All experiments were carried out in duplicates. The reagents used were of analytical grades.

3. RESULTS

3.1 Effect of contact time

As shown in Fig. 1, at the end of the 6 h contact period with the activated *Trametes*, phosphate concentration in the aqeuous solution was observed to increase from an initial concentration of 362.19 mg/L to 405.96 mg/L. Apart from after 1 h of contact when a minute decrease from 362.19 mg/L to 356.80 mg/L in phopshate concentration was observed, throughtout the period of contact, phosphate levels in the aqueous solution were observed to be higher than what was obtained at the initial. For sulphate concentration in presence of the *Trametes*, concenration was observed to show remarkable increases in the different hours of contact. In the case of nitrate, concentrations at the different contact hours were observed to be lower than what was obatined at the 0 h. A lowest decrease in nitrate concentration from 627.38 mg/L to 91.53 mg/L was observed after the 5 h contact period before there was an increase to 141.30 mg/L after 6 h contact time (Fig. 1).

In the wastewater, after the 6 h contact period with the activated *Trametes*, the final concentration of phosphate was recorded as 200.00 mg/L from an initial concentration of 261.45 mg/L. A lowest phosphate concentration of 104.02 mg/L was obtained after 3 h of contact. In the case of sulphate, no decreases in concentration were observed in the wastewater in the presence of the *Trametes* throughout the period of contact. At the end of the 6 h contact period, sulphate levels showed an increase from 155.75 mg/L to 1694.25 mg/L. For nitrate concentration in the wastewater in presence of the *Trametes*, remarkable decreases in concentration were observed with time from 2 h contact time. After the 6 h contact period, nitrate level was observed to decrease from 1034.17 mg/L to 446.54 mg/L. A lowest decrease to 58.04 mg/L was observed after 4 h contact time before further increases were observed with time (Fig. 2).

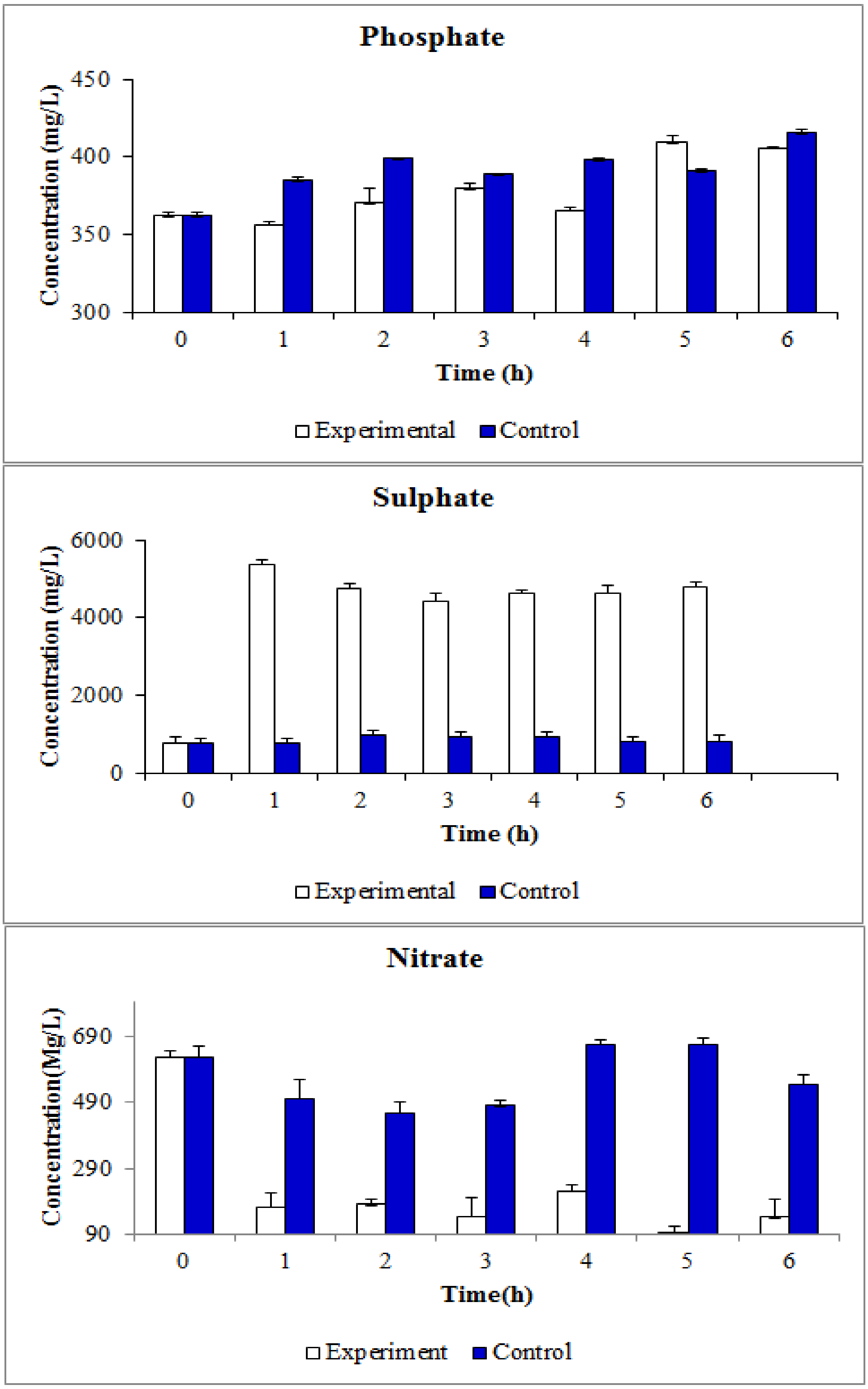

Fig. 1: Effect of contact time on nutrient adsorption from the aqueous solution in presence of the activated *Trametes dead* biomass

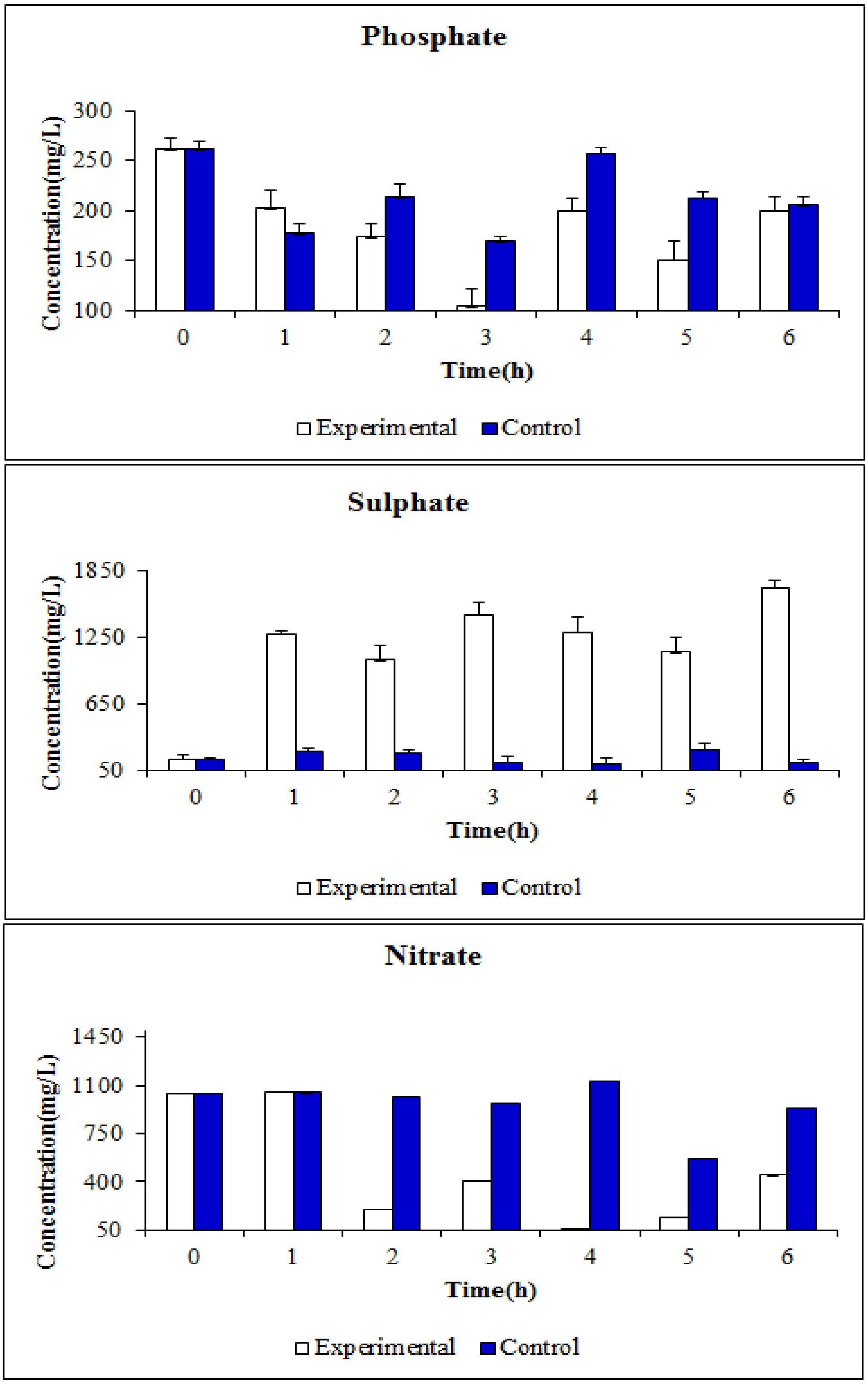

Fig. 2: Effect of contact time on nutrient adsorption from the wastewater in presence of the activated *Trametes* dead biomass

3.2 Effect of temperature

At the different temperatures used for investigation, phosphate levels in the aqueous solutioncontaining the *Trametes* were not observed to show any remarkable decreases. A lowest decrease from 535.34 mg/L (in control) to 464.66 mg/L (in presence of *Trametes*) was observed at 40 ^{o}C. At 30 ^{o}C and 70 ^{o}C, phosphate levels in the experimental setups were observed to be remarkably higher than the respective controls. With respect to sulphate in the aqueous solution at the different temperatures, concentrations in the experimental setups were observed to range from 728.74 mg/L to 1305.75 mg/L .The highest and lowest sulphate concentration were observed at 40 °C (1305.75 mg/L) and 50 °C (728.74

mg/L).In comparison with the control setups, nitrate concentrations in the aqueous solution showed remarkable lower values in presence of the *Trametes*. This observation was irrespective of the temperature investigated. The lowest and highest decreases in nitrate levels were observed at 30 °C and 50 °C, respectively. At 50 ^{o}C, nitrate levels in the experimental and control setups were observed to be 196.83 mg/L and 604.43 mg/L, respectively (Fig. 3).

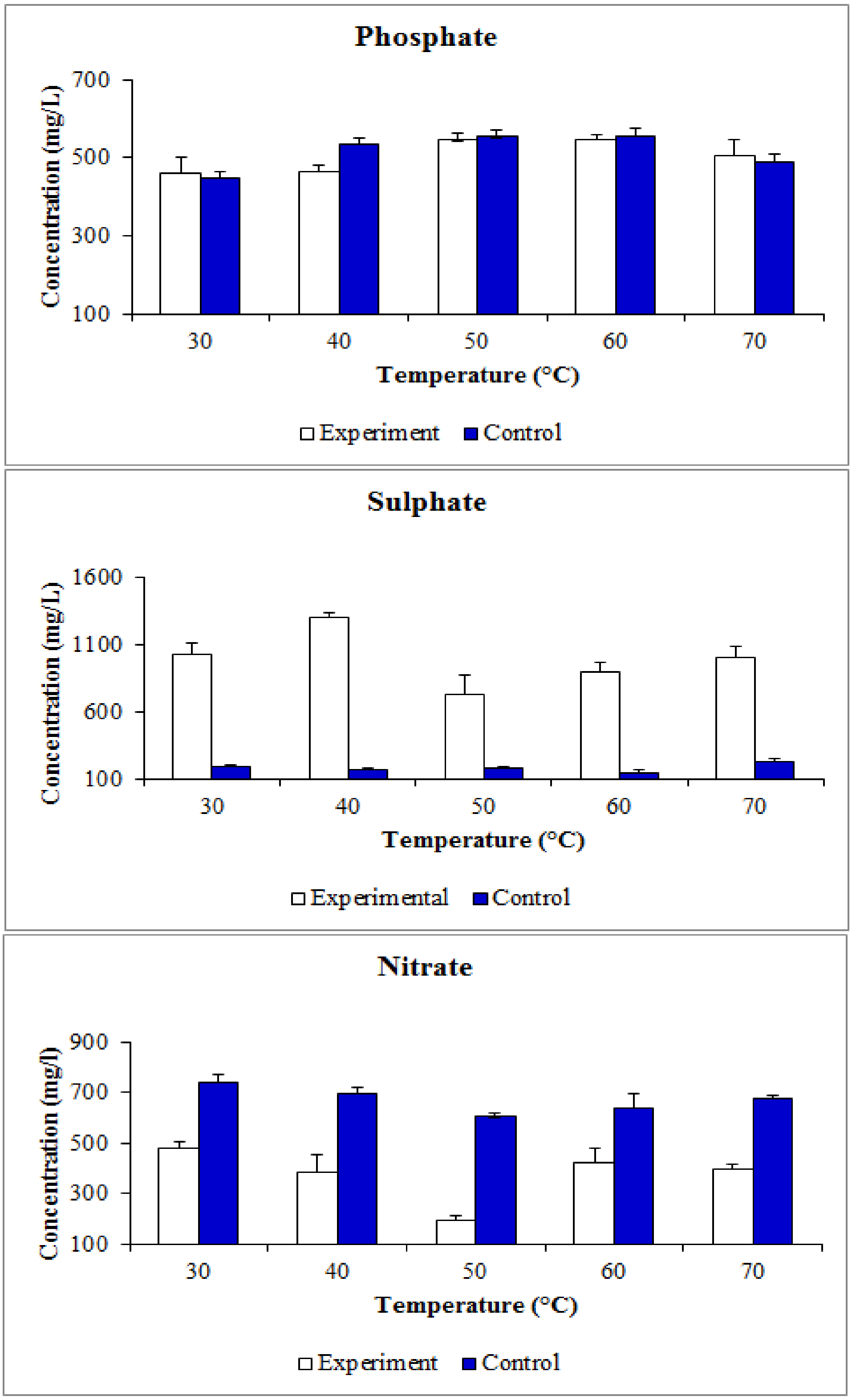

Fig. 3: Effect of temperature on nutrient adsorption from the aqueous solution in presence of the activated *Trametes* dead biomass

In the wastewater, phosphate concentrations at the different temperatures in presence of the *Trametes* were observed to show increases or minute decreases when compared with the control setups. At 40 ^{o}C, phosphate concentration increased from 330.12 mg/L in the control setup to 370.28 mg/L in the setup with the *Trametes*.For sulphate levels at the different temperatures, remarkable increases in concentrations were observed at all the temperatures investigated in the setups with the *Trametes*. A highest increase from 77.01 mg/L in the control setup to 966.67 mg/L in presence the *Trametes* was observed at 60 ^{o}C .As was observed for sulphate, no decrease in nitrate concentration was observed in presence of the *Trametes* at the different temperatures investigated (Fig. 4).

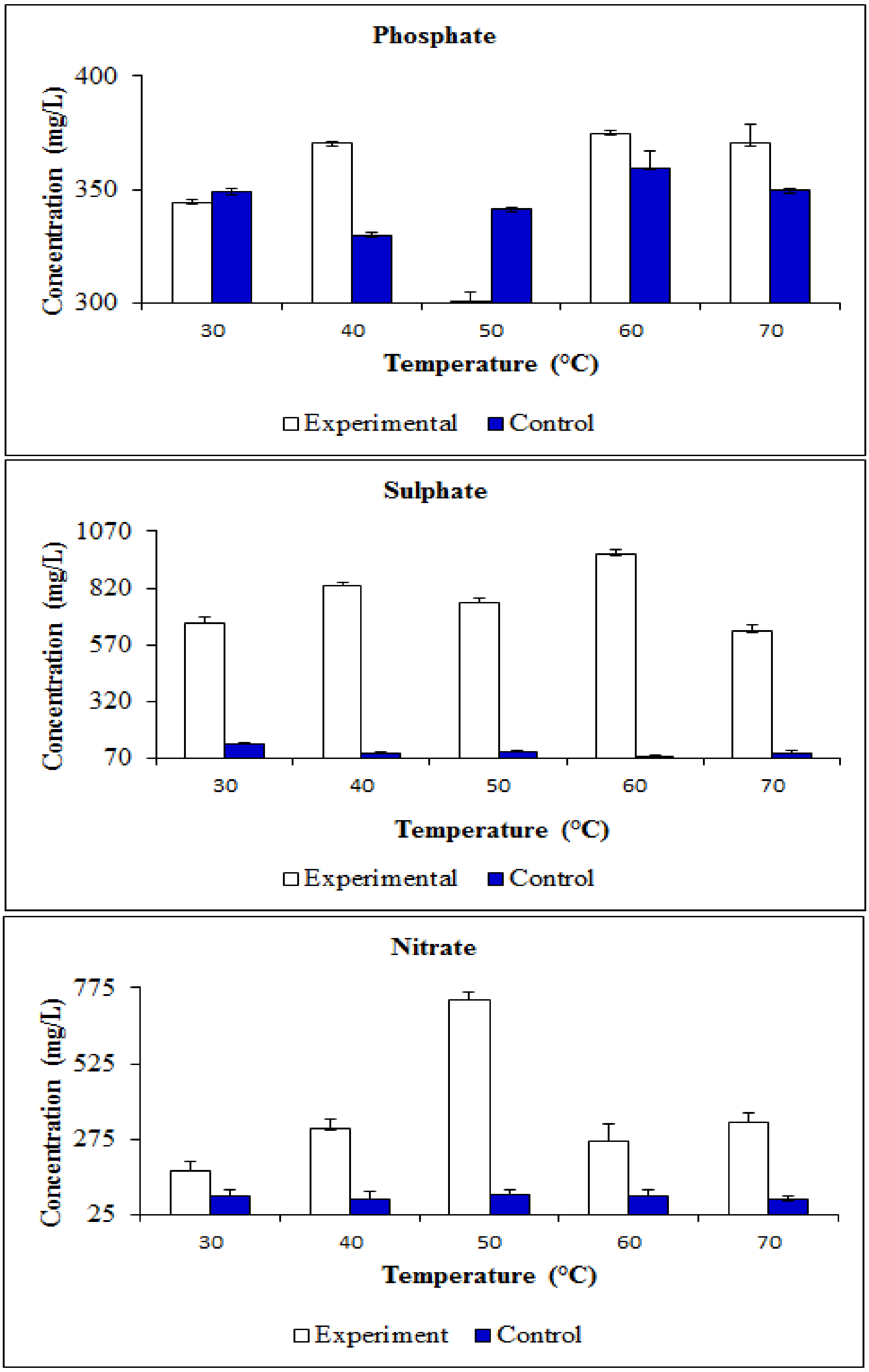

Fig. 4: Effect of temperature on nutrient adsorption from the wastewater in presence of the activated *Trametes* dead biomass

3.3 Effect of pH

As shown in Fig.5, at the different pH, phosphate concentrations in the aqueous solution in the presence of *Trametes* were observed to show no decreases when compared with the control setups, except at pH 8 where only a slight decrease was observed. A highest increase from 539.36 mg/L in the control to 634.94 mg/L in presence of the *Trametes* was observed at pH 4. In the case of sulphate, decreases in concentrations were observed in presence of the *Trametes* at the different pH investigated. A remarkable decrease from 1587.93 mg/L to 686.21 mg/L was observed at pH 8. As regards nitrate, when compared with the control setups, remarkable decreases in concentration were observed at the different pH in the experimental setups (Fig. 5).

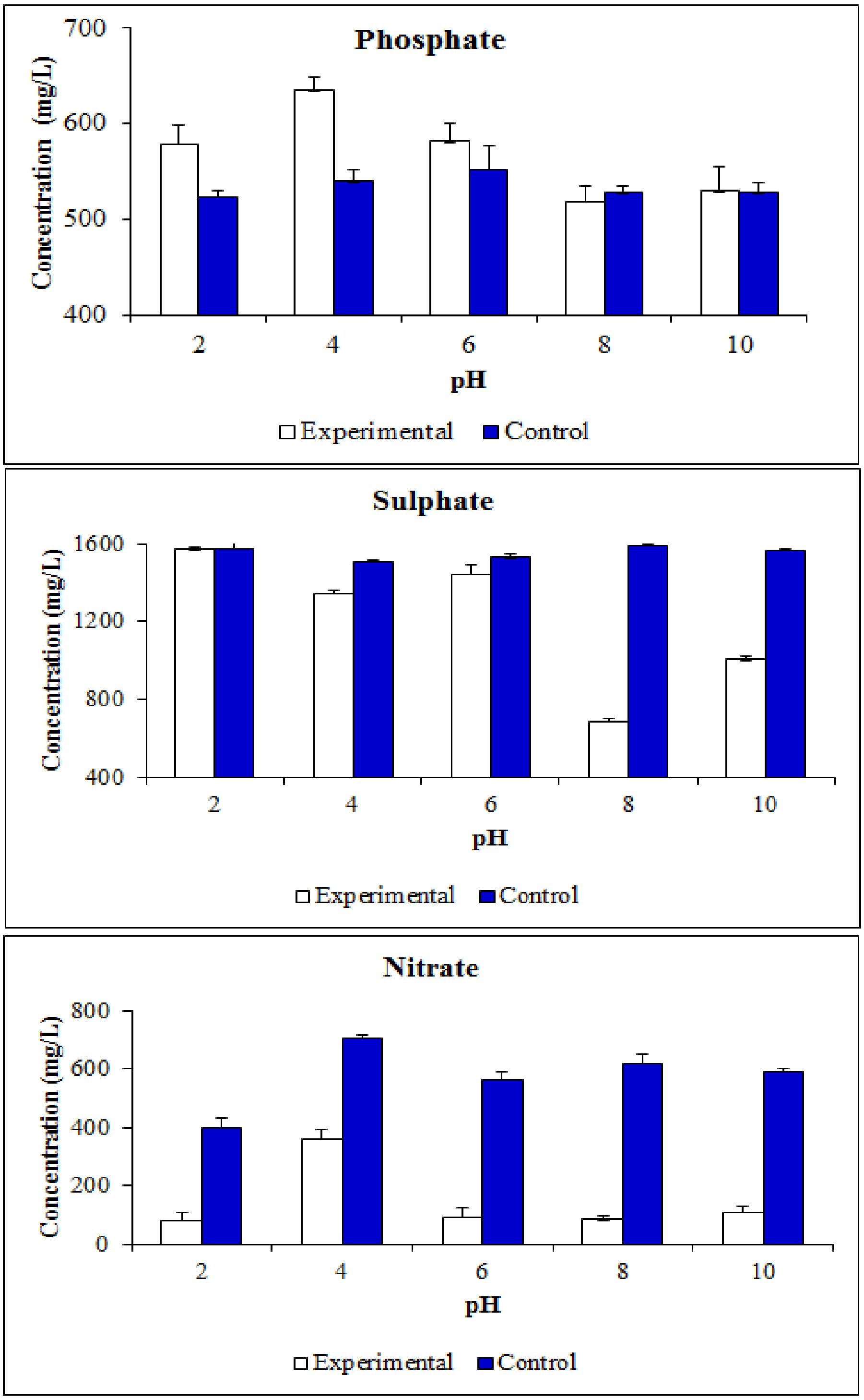

Fig. 5: Effect of pH on nutrient adsorption from the aqueous solution in presence of the activated *Trametes* dead biomass

In the wastewater, decreases in phosphate concentrations in presence of the *Trametes* were observed at the different pH investigated. A highest decrease from 596.39 mg/L in the control to 507.63 mg/L in the setup containing the *Trametes* was observed at pH 2. In the case of sulphate, increases in concentrations were observed at the different pH in presence of the *Trametes*. For nitrate levels in the wastewater, remarkable decreases in concentration were observed at the different pH. A highest decrease from 524.63 mg/L in the control setup to 69.68 in the setup containing the *Trametes* was observed at pH 8 (Fig. 6).

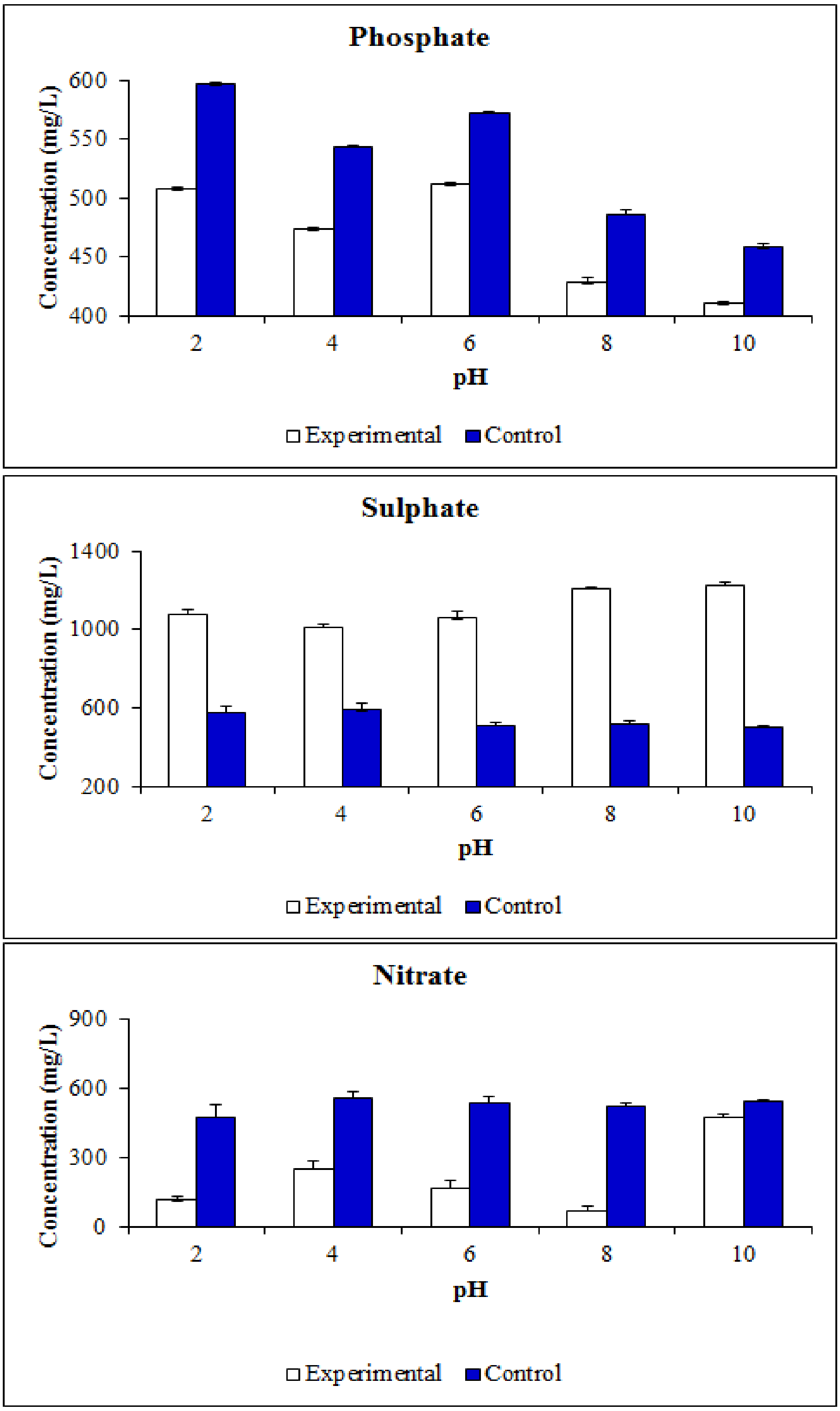

Fig. 6: Effect of pH on nutrient adsorption from the wastewater in presence of the activated *Trametes* dead biomass

4. DISCUSSION

The present study revealed remarkable decreases in nitrate concentration with contact time. This observation was irrespective of the aqueous solution or wastewater. It is hypothesized that during adsorption, removal rate is higher when sorption sites are vacant after which when sites become reduced, there is reduced uptake (Mousavi *et al.,* 2010; Surchi.2011). According to Akshayshende *et al.,* (2014) stated that nutrient removal increases with increase in contact time, but however some concentration becomes almost constant. The equilibrium time required for the adsorption of phosphate and nitrate using sea grass beads have been reported (Soumya *et al.,* 2015). In the study, removal of phosphate and nitrate was observed to increase sharply with increase in contact time and attains maximum at 120 min.

At different temperatures investigated, there was no remarkable decrease in phosphate levels in either the aqueous solution or wastewater in presence of the test adsorbent. It is indicated that removal rates of nutrients double with approximately every 10 ºC increase in temperature until the optimum temperature is reached. The pH of the wastewater is an important factor that has an effect on the removal of nutrients because the stability of the waste water is affected (Al-Zuhair *et al.,* 2008). Mulkerrins *et al.,* (2003) stated that temperature does not only have influences on the metabolic functions but it also affects gas-transfer rates and settling characteristics of the biological solids. The effect of temperature on heavy metal adsorption have been reported in the past. When investigating the effect of temperature on Cu(II) adsorption in wastewater at 30, 40 and 50 ^{o}C, Banerjee*et al.,* (2012) observed that an increase in temperature enhanced adsorption. An adsorption process is said to be endothermic in nature when an increase in adsorption is observed with increase in time. Increase in adsorption with an increased temperature is indicated to be ascribed to decreases in the boundary layer thickness that surrounds an adsorbent or increases in the number of active surface sites (Meena *et al*., 2005).

In this study, maximum sulphate adsorption was observed at pH 8 in the aqueous solution while in the wastewater, remarkable removal was observed at the different pH investigated. The pH of the wastewater is known to be an important factor that affects nutrient removal in wastewater since the stability of the wastewater is affected (Al-Zuhair *et al*., 2008). In a study by Akpor and co-workers (2014), high sulphate removal was achieved at alkaline pH while acidic pH reduced sulphate removal rate.This may have been due to the residual dissolved oxygen at the start of each experiment, the accumulation of CO_2 from respiratory activity using residual dissolved oxygen is reported to cause a decrease in pH (Lee *et al*., 2001). It is reported that the pH of a solution is a vital factor that regulates the surface charge of an adsorbent and the degree of ionization of the adsorbent in a solution. In a study by El- Kholy et al., (2013), on the competitive adsorption of Co(II) in a binary and tertiary system with metal ions Cr(III) and Ni(II) on Lewatite S-100 cation exchange resin, they indicated that maximum uptake of Co(II) ions occurred at initial pH of 4.5 ± 0.5. They further revealed that the adsorption capacity of the resin was directly proportional to the pH of the aqueous solution.

5. CONCLUSION

This present study, which was aimed at assessing the efficiency of activated dead biomass of *Trametes versicolor* in nutrient adsorption from wastewater and aqueous solution was able to reveal the following:
In the aqueous solution, phopshate concentration was observed to be higher than what was obtained at the initial. For sulphate concentration in presence of the *Trametes*, concentration was observed to show remarkable increases in the different hours of contact while nitrate levels at the different contact hours were observed to be lower than what was obatined at the 0 h.

In the wastewater, no remarkable decreases in phosphate concentrations were observed during the period of contact with the *Trametes*. In the case of sulphate, no decreases in concentration were observed in the wastewater in the presence of the *Trametes* throughout the period of contact. For nitrate concentration in the wastewater in presence of the *Trametes*, remarkable decreases in concentration were observed with time from 2 h contact time.

At the different temperatures used for investigation, phosphate levels in the aqueous solution containing the *Trametes* were not observed to show any remarkable decreases while the highest and lowest sulphate concentration were observed at 40 °C and 50 °C. In comparison with the control setups, nitrate concentrations in the aqueous solution showed remarkable lower values in presence of the *Trametes*. The lowest and highest decreases in nitrate levels were observed at 30 °C and 50 °C, respectively.

In the wastewater, phosphate concentrations at the different temperatures in presence of the *Trametes* were observed to show increases or minute decreases when compared with the control setups.Sulphate levels at the different temperatures were observed to show remarkable increases at the temperatures investigated in the setups with the *Trametes* while nitrate levels showed no decreases in concentration in presence of the *Trametes* at the different temperatures investigated

At the different pH, phosphate concentrations in the aqueous solution in the presence of *Trametes* were observed to show no decreases when compared with the control setups, except at pH 8 where only a slight decrease was observed. For sulphate levels, decreases in concentrations were observed in presence of the *Trametes* at the different pH investigated. In the case of nitrate, when compared with the control setups, remarkable decreases in concentration were observed at the different pH in the experimental setups.

In the wastewater, decreases in phosphate concentrations in presence of the *Trametes* were observed at the different pH investigated while sulphate levels showed increases in concentrations at the different pH in presence of the *Trametes*.

The study was able to provide information on the possible use of the dead biomass of the *Trametes versicolor* for nutrient adsorption in water.

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