International Journal of Basic and Applied Chemical Sciences ISSN: 2277-2073 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jcs.htm
2015 Vol. 5 (3) July-September, pp.79-91/Akpor et al.
Research Article

EFFECT OF CARBONATED DEAD BIOMASS OF A NON-EDIBLE MUSHROOM (*TRAMETES VERSICOLOR)* ON NUTRIENT ADSORPTION FROM WASTEWATER AND AQUEOUS SOLUTION

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ABSTRACT
This study was aimed at assessing the efficiency of the dead biomass of *Trametes versicolor* in phosphate, sulphate and nitrate adsorption from aqueous solution and wastewater. The study was carried out using a batch setup and investigated the effects of contact time, adsorbent quantity, pH and temperature on nutrient adsorption. The results revealed that decreases in sulphate concentration were observed after 4 h and 5 h contact with the *Trametes* in wastewater and aqueous solution, respectively. Also, a high sulphate decrease was observed at a pH of 2. Higher pH was not observed to show any remarkable decrease in sulphate level, rather there were increases in some cases. This trend was irrespective of the wastewater or aqueous solution. In the case of temperature, the observation in this study was remarkable adsorption at temperature between 50 ºC and 60 ºC for nitrate and between 40 ºC and 50 ºC for sulphate. At the different adsorbent concentration investigated, the observation in this study was that increase in sulphate and nitrate adsorption with increase in adsorbent concentration up to a similar limit after which it did not follow any pattern. The study was able to provide information on the nutrient adsorption efficiency from wastewater and aqueous solution with the dead biomass of the *Trametes* under the experimental conditions investigated.

***Keywords**: Trametes Versicolor, Phosphate, Nitrate, Sulphate, Wastewater, Aqueous Solution*

INTRODUCTION

Water pollution is responsible for the death of 25 million individuals annually (Niemczynowicz, 1999) and leads to destruction of the aquatic environment. The main source of water pollution is wastewater, particularly urban waste; these urban wastes comes from varied sources such as domestic waste from homes, hospitals and commercial uses moreover as agricultural and industrial waste. These wastes contain inorganic pollutants like nutrients and heavy metals and causes pollution to the surface water. So several studies were run to eliminate or reduce these pollutants before its discharge or reuse for irrigation. Also, improper disposal of waste matter has led to outbreaks and widespread of diseases in different parts of the world and therefore needs waste matter management and proper treatment. Wastewater may contain high levels of nutrients, which when excessively released into the environment will result in the undesirable growth of microorganisms and therefore eutrophication (Akpor *et al.*, 2008).

Globally, the damaging effects of pollution caused by the discharge of excess nutrients and heavy metals into receiving water bodies are sources of concern. The two major eutrophic nutrients are phosphorus and nitrogen (Rocca *et al.*, 2007), whose presence in excess amounts in water bodies results in eutrophication, with ripple effects on aquatic and human life (Hwang *et al.*, 2004). In recent years, there is a larger environmental awareness on the necessity to treat wastewater effluents before discharging into receiving water bodies. This has necessitated an excellent deal of analysis into finding efficient strategies for the removal of contaminants from effluent (Zahra, 2012).

The impacts of untreated or poorly treated wastewater effluents can be acute or additive. The acute impacts effluents are indicated to produce usually high levels of ammonia and halogens, high numerous oxygen-demanding materials or virulent concentrations of significant metals and organic contaminants while the additive impacts produce the gradual build-up of pollutants in receiving water, that solely

become apparent once a particular threshold is exceeded (Chambers *et al.*, 1997). To safeguard the environment and avoid the negative impacts of eutrophication, there is need to scale back the concentrations of those nutrients to levels set by restrictive bodies before discharging into receiving water bodies (Kassim, 2002; Ayyasamy *et al.*, 2009; Jalal *et al.*, 2011).
The standard practices within the removal of nutrients from contaminated waters are chemical and biological. Due to the high capital and operational prices which can be related to the generation of secondary waste that present treatment issues, like volume of sludge made throughout chemical treatment, the tactic is not advocated in recent years (Kumar, 2006).

Additionally, adsorption with agricultural and industrial wastes, similarly as changed wastes has been utilized for phosphate, sulphate and nitrate removal from wastewater (Krishnan *et al.*, 2008).

Despite the fact that phosphorus, which is common in fertilizers, detergents, human and animal waste may be a nutrient required within the soil for plant growth, once in excess quantity, it leads to algal blooms and big amounts of aquatic growth.

This might lead to the depletion of water quality and could additionally cause harm to fish and alternative aquatic organisms (Coleman, 1994). The presence of nitrate in water is indicated to boost health issues significantly owing to its link to disorder in blood, therefore touching infants and different inclined people. A high level of nitrates in water is additionally known to cause an increase in risk of specific cancers and adverse procreative outcomes.

To safeguard infants against the chance of methemoglobinemia, which occurs when one is exposed to excessive nitrate concentration, the World Health Organisation has given a principle of 11mg/L nitrate specifically as prescription for cover against infant's methemoglobinemia (Jalal *et al.*, 2011).

It is argued and proposed that fungi are higher alternatives to bacteria in nutrient removal as a result of the manufacture of a lot of valuable by-products and are able to withstand repressive product throughout the method of nutrient removal.

Varieties of fungi have been concerned in the bioremediation of contaminated wastewater effluents (Mahmoud *et al.*, 2013). Previous studies by previous workers shows that fungi produce a large variety of extracellular proteins, organic acids and other metabolites and are able to resist inhibitory chemicals in wastewater making them highly promising and efficient in nutrient removal studies (Guest *et al.*, 2002). Although some studies have reported on the field demonstrations of mycoremediation for removal of fecal coliform bacteria and nutrients (Thomas *et al.*, 2009), there is paucity of information on the role of mushrooms in the adsorption of nutrients from water.

This study was therefore aimed at assessing the efficiency of carbonated dead biomass of a non-edible mushroom (*Trametes versicolor*) in phosphate, nitrate and sulphate adsorption from aqueous solution and wastewater.

MATERIALS AND METHODS

The adsorbent used for this study was a non-edible mushroom (*Trametes versicolor*). The mushroom was collected from one of the dead woods in the environment of Landmark University located in Omu-aran, Kwara State, Nigeria. The wastewater used was obtained from the Landmark University Commercial Farms in Omu-Aran, Kwara State, Nigeria.
After collection of the mushroom, it was washed with clean water to remove sand and other debris before sun-drying for one week. The dried samples were then cut into smaller pieces with a metal scissors and pulverised using a laboratory grinder. The ground samples were then placed in a crucible and placed in a furnace at a temperature of 460°C for 20min for carbonation. The carbonated dead biomass of the *Trametes versicolor* was then smoothened employing a laboratory mortar and pestle, before storing in a plastic container at room temperature till when needed.

The effect of contact time, weight of adsorbent, pH of aqueous solution or wastewater and temperature of aqueous solution or wastewater on nutrient adsorption by the adsorbent was 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 flasks were placed in a rotary shaker at a shaking speed of 100 rpm at 25 ºC± 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 filtered paper. The filtrates were then analyzed for phosphate, nitrate and sulphate, using standard procedures (APHA, 2011).

When investigating 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 ºC± 2 ºC for 3 h. After 3 h, the filtered sample was used in the determination of phosphate, sulphate and nitrate concentration, using standard methods.

With regards to the effect of adsorbent quantity on nutrient adsorption by the adsorbent, 0.5 – 4 g quantities of the adsorbent were weighed into respective flasks containing 100 mL each of aqueous solution or wastewater in 250 mL capacity Erlenmeyer flasks and incubated in a shaker at a shaking speed of 100 rpm at 25 ºC± 2 ºC for 3 h. At the end of the 3 h incubation time, the samples were filtered, with the respective filtrates used for the estimation of phosphate, nitrate and sulphate, using standard procedures.

RESULTS AND DISCUSSION

Results

At the end of 6 h contact time, there were increases in phosphate from initial concentrations of 374.88 mg/L to 413.28 mg/L and from 261.05 mg/L to 288.35 mg/L in the aqueous solution and wastewater, respectively.

This translates to increases of 10.24 % and 10.29 %, respectively. Throughout the 6 h period of contact, no remarkable changes in phosphate levels were observed in the experimental treatments (Figure 1, Table 1).

In the case of sulphate, in presence of the carbonated dead biomass of the *Trametes versicolor*, concentrations were observed to decrease in aqueous solution and wastewater from 740.38 mg/L to 360.80 mg/L and 517.40 mg/L to 360.80 mg/L, respectively at the end of the 6 h contact time. In the aqueous solution, remarkable decreases were only observed after 5 h of contact with the *Trametes* while in the wastewater, remarkable decreases were observed after 3 h of contact with the *Trametes*. At the end of the 6 h contact period with the *Trametes*, sulphate decreases of 26.84 % and 30.27 % were observed in the aqueous solution and wastewater, respectively (Figure 1, Table 1).

For nitrate level in the aqueous solution, a decrease of 14.48 % was observed at the end of the 6 h contact time with the *Trametes* while in the wastewater, a decrease of 13.69 % was observed. At the end of the 6 h contact period with the *Trametes*, nitrate levels showed variations from 649.31 mg/L to 550.30 mg/L and from 622.60 to 537.36 mg/Lin the aqueous solution and wastewater, respectively (Figure 1, Table 1).

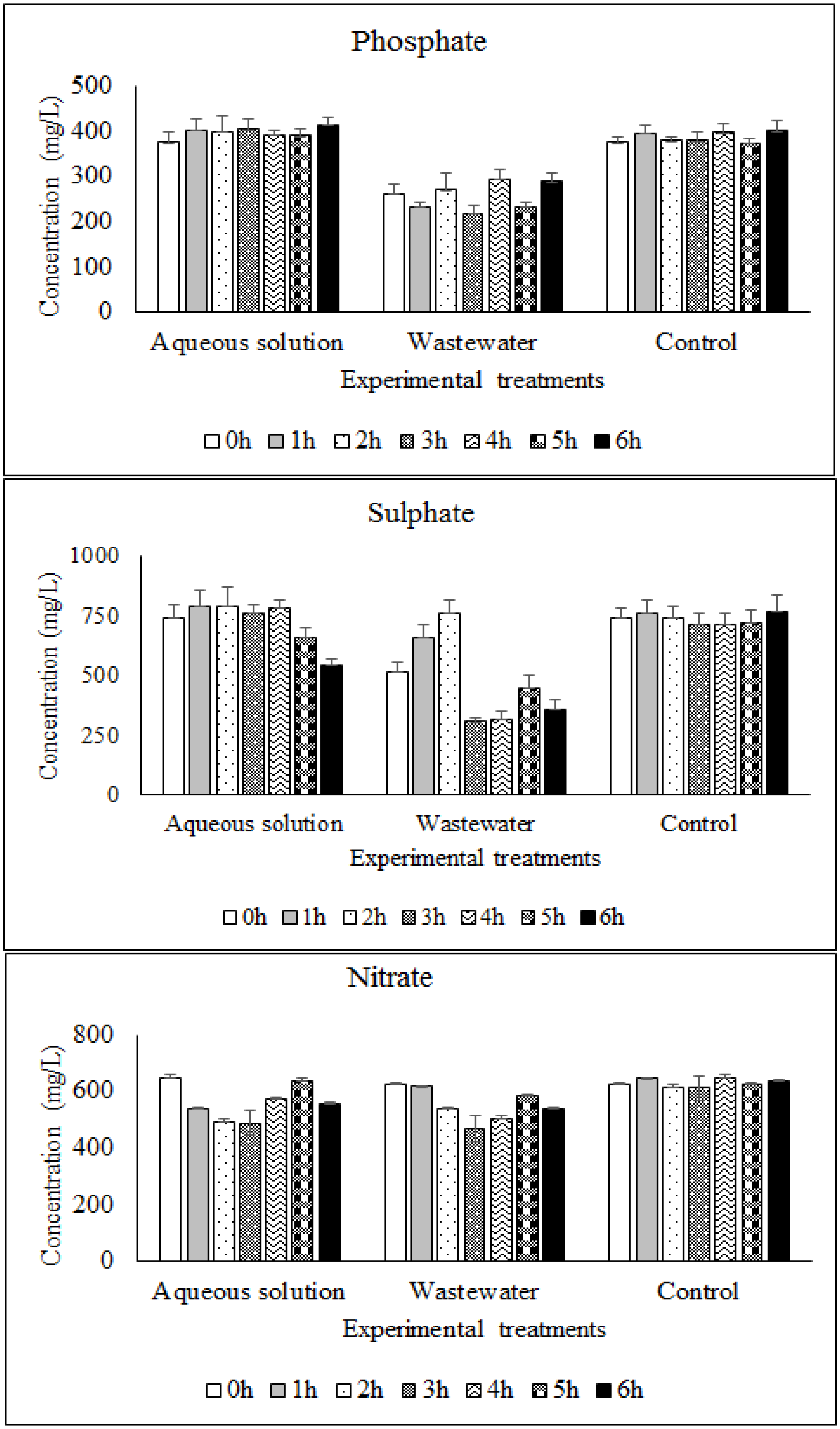

Figure 1: Effect of contact time on nutrient adsorption by the dead biomass of the *Trametes versicolor* in aqueous solution and wastewater

Table 1: % change in nutrient concentration in the aqueous solution and wastewater during the period of contact with the dead biomass of the *Trametes*

Contact time	Aqueous solution	Wastewater	Control
Phosphate			
1 h	-7.02	11.68	-4.99
2 h	-6.43	-3.22	-0.85
3 h	-7.53	17.20	-0.76
4 h	-4.23	-12.13	-5.58
5 h	-3.81	11.06	0.68
6 h	-10.24	-10.29	-6.78
Sulphate			
1 h	-6.93	-26.92	-3.03
2 h	-6.93	-46.85	-0.43
3 h	-3.03	40.59	3.55
4 h	-5.75	38.38	3.38
5 h	11.26	14.03	2.68
6 h	26.84	30.27	-3.55
Nitrate			
1 h	17.21	1.03	0.57
2 h	23.96	13.83	5.37
3 h	24.89	24.67	5.85
4 h	11.92	18.89	0.17
5 h	2.11	6.13	3.52
6 h	14.48	13.69	1.84

Control represents aqueous solution without the dead biomass of the *Trametes*. Positive and negative values represent % decreases and increases, respectively.

In presence of the different quantities of the *Trametes* dead biomass in the aqueous solution, phosphate concentration was observed to range from 308.95 mg/L to 413.26 mg/L, with the lowest and highest concentrations observed at 4.0 g and 2.0 g, respectively. In the wastewater, phosphate concentration at the different quantities of the *Trametes* ranged from 289.96 mg/L to 393.17 mg/L, at 4.0 g and 1.0 g, respectively (Figure 2). In the aqueous solution, when compared with the control, phosphate levels in the aqueous solution were observed to show increases, except at 4.0 g where a decrease of 6.06 % was shown. In the wastewater, when compared with the concentration of the control at 358.89 mg/L, phosphate levels showed decreases of 10.93 %, 14.56 % and 19.21 % at 3.0 g, 3.5 g and 4.0 g of the *Trametes*, respectively (Table 2).

For sulphate levels in the aqueous solution in presence of the different quantities of the *Trametes*, from a concentration of 811.65 g in the control setup, concentrations were observed to range from 830.13 mg/L to 575 mg/L, with maximum observed at 1.0 g and 4.0 g, respectively. Generally, decreases in sulphate levels were observed in the aqueous solution in the presence of *Trametes* quantity from 1.0 g and above. The highest decrease of 29.16% was observed at 4.0 g. In the wastewater, from a concentration of 870.63 in the control set, sulphate level was observed to range from 630.63 mg/L to 344.22 mg/L, with highest and lowest concentrations observed at 0.5 g and 3.5 g of the *Trametes*, respectively. In presence of the different *Trametes* quantities used for investigation, sulphate concentrations in the wastewater were observed to show remarkable decreases. A highest decrease of 60.46 % was however observed at 3.5 g (Figure 2, Table 2). In the case of nitrate levels in the aqueous solution, in presence of the different quantities of *Trametes* used for investigation, concentration was observed to range from 292.14 mg/L to 547.48 mg/L, with lowest and highest observed at 2.0 g and 3.0 g, respectively. In all the setups, nitrate levels in the aqueous solution were observed to show remarkable decrease. A highest decrease of 49 % was however observed at 2.0 g.

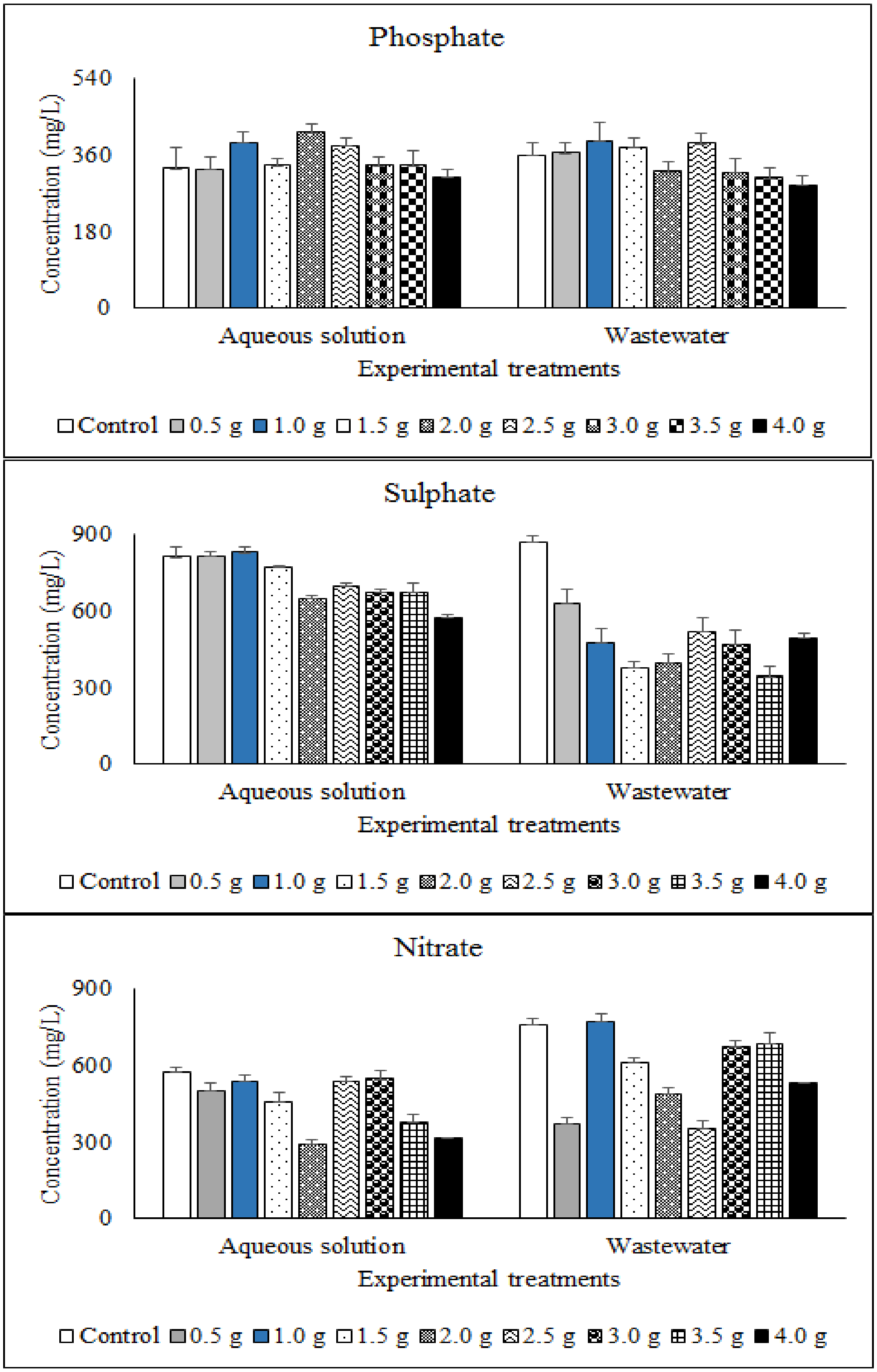

Figure 2: Effect of quantity of the dead biomass of the *Trametes* on nutrient adsorption in aqueous solution and wastewater

In the wastewater, nitrate levels in presence of the different quantities of *Trametes* were observed to range from 353.45 mg/L to 773.56 mg/L, with the lowest and highest concentrations observed at 2.5 g and 1.0 g, respectively.

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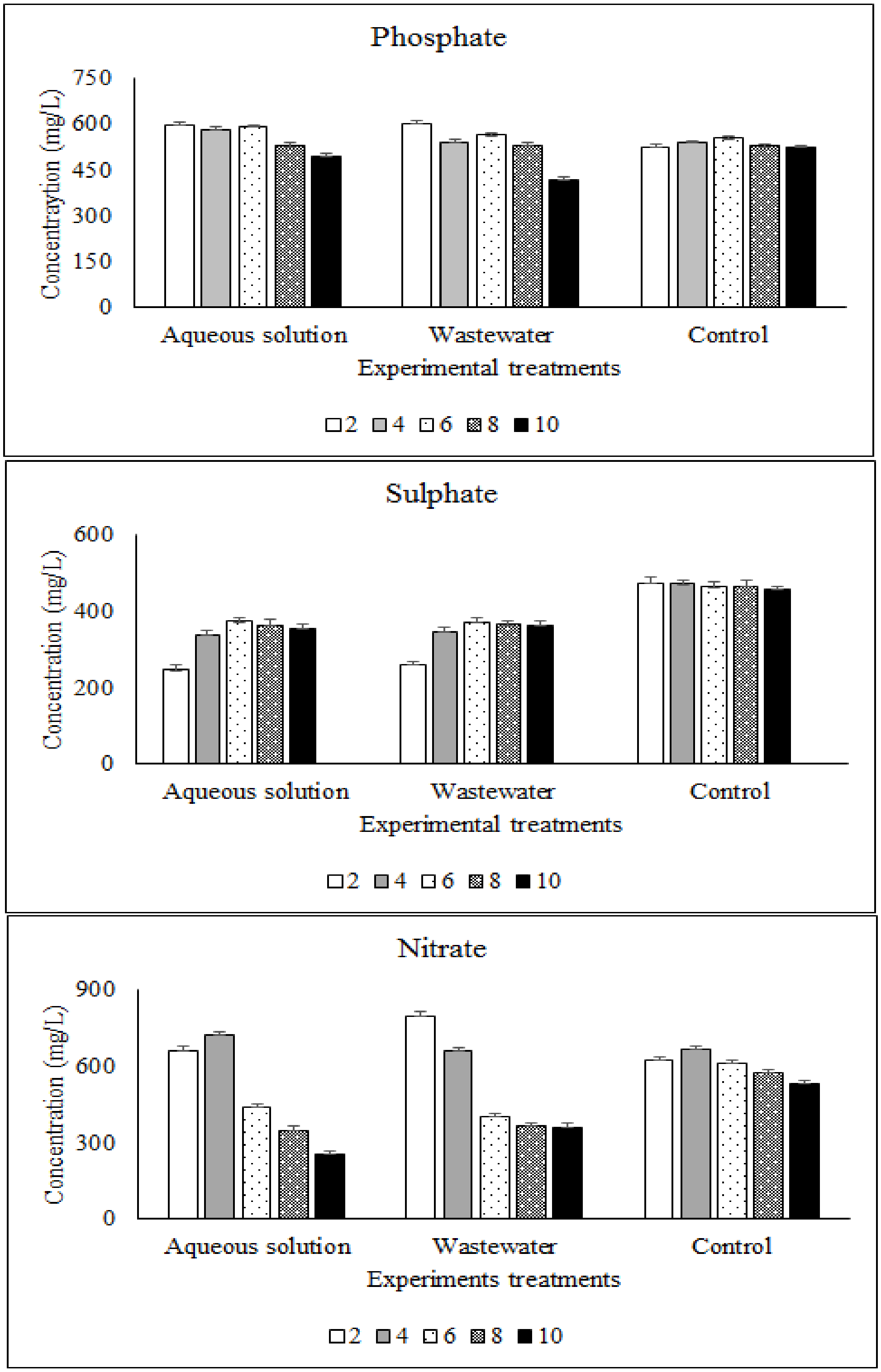

Figure 3: Effect of pH on nutrient adsorption in aqueous solution and wastewater in presence of the dead biomass of the *Trametes*

A highest decrease of 53.48 % was observed at 2.5 g of the *Trametes* (Figure 2, Table 2). At the different pH, phosphate levels in presence of the *Trametes* was observed to range from 495.56 mg/L to 595.58 mg/L and from 416.47 mg./L to 603.21 mg/L, in the aqueous solution and wastewater, respectively.

The highest and lowest phosphate concentrations were observed at pH 2 and 10, respectively (Figure 3). For sulphate, concentrations in presence of the *Trametes* at the different pH showed a ranged between 246.3 mg/L and 373.12 mg/L in the aqueous solution and between 261.13 and 371.16 mg/L in the wastewater. The highest and lowest sulphate levels were observed at pH 6 and 2, respectively (Figure 3).
In the case of nitrate, concentrations at the different pH in presence of the *Trametes* was observed to range from 254.02 mg/L to 720.69 mg/L and from 359.20 mg/L to 797.70 mg/L in the aqueous solution and wastewater, respectively. The highest and lowest concentrations were observed at pH 2 and 10, respectively (Figure 3).

Table 2: % change in nutrient concentration in the aqueous solution and wastewater in presence of different quantities of the dead biomass of the *Trametes*

Quantity	Aqueous solution	Wastewater
Phosphate		
0.5 g	1.06	-1.94
1.0 g	-18.13	-9.55
1.5 g	-2.22	-5.41
2.0 g	-25.65	10.59
2.5 g	-16.11	-7.99
3.0 g	-2.29	10.93
3.5 g	-2.19	14.56
4.0 g	6.06	19.21
Sulphate		
0.5 g	-0.30	27.62
1.0 g	-2.28	45.13
1.5 g	5.23	56.36
2.0 g	20.07	54.17
2.5 g	13.99	40.14
3.0 g	17.23	45.83
3.5 g	16.84	60.46
4.0 g	29.16	43.42
Nitrate		
0.5 g	12.78	51.36
1.0 g	6.46	-1.82
1.5 g	20.24	19.29
2.0 g	49.00	35.33
2.5 g	6.16	53.48
3.0 g	4.43	11.65
3.5 g	34.19	9.61
4.0 g	45.01	30.03

Positive and negative values represent % decreases and increases, respectively

At the different temperatures investigated, no remarkable decrease in phosphate concentration was observed in the aqueous solution or wastewater in presence of the *Trametes*.

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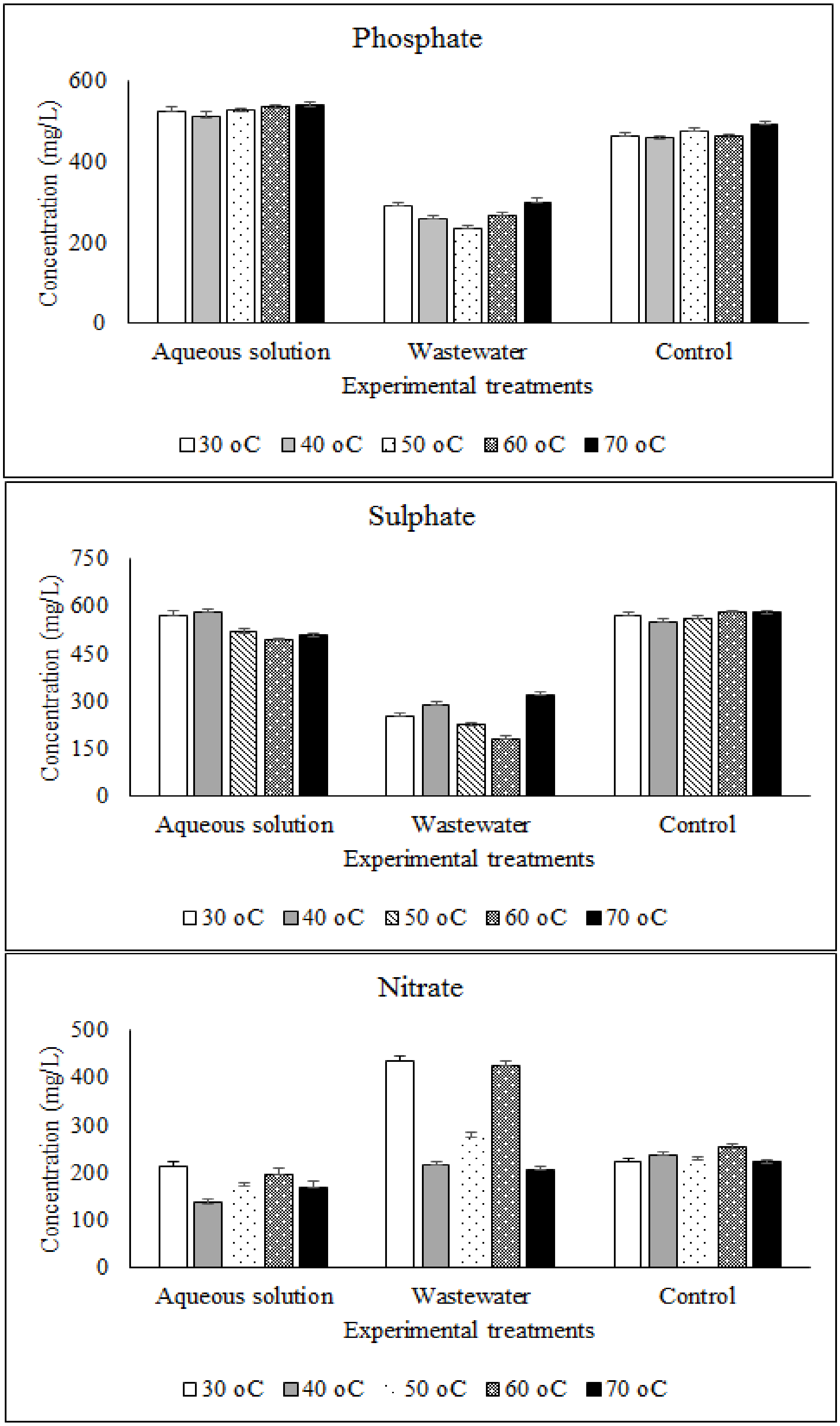

Figure 4: Effect of temperature on nutrient adsorption in aqueous solution and wastewater in presence of the dead biomass of the *Trametes*

Phosphate level at the different temperatures in the wastewater was observed to range from 234.94 mg/L to 299.68 mg/L at 50 ºC and 70 ºC, respectively. In the aqueous solution, the variation in phosphate levels was from 510.04 mg/L to 538.55 mg/L at 40 ºC and 70 ºC, respectively (Figure 4).

In the case of sulphate concentrations at the different temperatures in presence of the *Trametes*, the observed ranges were 181.4 mg/L to 320.8 mg/L in the wastewater and from 492.60 mg/L to 582.3 mg/L in the aqueous solution. The lowest concentration was observed at 60 ºC in both the wastewater and aqueous solution while the highest concentration was observed at 70 ºC and 40 ºC in the wastewater and aqueous solution, respectively (Figure 4).

For nitrate concentration in the aqueous solution at the different temperatures in presence of the *Trametes*, variation was from 137.36 mg/L to 213.79 mg/L, at 40 ºC and 30 ºC, respectively. In the wastewater, nitrate levels at the different temperatures showed a variation from 205.75 mg/L to 435.06 mg/L at 70 ºC and 30 ºC, respectively (Figure 4).

Discussion

In the present study, decreases in sulphate concentration were observed after 4 h and 5 h contact with the *Trametes* in wastewater and aqueous, respectively. In a study by Costa and Leite (1991), when investigating the efficiency of cadmium (II) and lead (II) adsorption by an adsorbent in aqueous solution, decreases in the metal concentrations were observed with time up to a certain period. This was attributed to likely availability of active binding sites on the biomass at the initial stage but with gradual occupancy of these sites, sorption became less efficient in the later stages (Costa and Leite, 1991). It is reported that observable time for maximum adsorption is between 60-100 min, with further contact time being time wasting (Shukl and Pai, 2005).

The present study revealed a high sulphate decrease at a pH of 2. Higher pH were not observed to show any remarkable decrease in sulphate level, rather there were increases in some cases. This trend was irrespective of the wastewater or aqueous solution. On the other hand, nitrate adsorption was observed to be remarkable in presence of the *Trametes* at higher pH. Highest adsorption of nitrate was observed at pH 10.

This trend was also irrespective of the wastewater or aqueous solution. This indicated that pH is probably the major factor influencing metal biosorption process (Esposito *et al.*, 2003; Velkova *et al.*, 2012). The removal of nutrients from aqueous solution and wastewater by adsorption is highly dependent on the pH of the solution. Some studies conducted on heavy metal sorption indicated that a decrease in ion sorption at acidic pH might be due to an increase in competition with protons on active sites. At alkaline pH, it is postulated that the different effects may arise due to other processes, such as the predominant presence of hydrated species of heavy metals, changes on the surface and precipitation of the appropriate salts (Ibrahim *et al.*, 2006).

Contrary to the observation in this study, with respect to nitrate adsorption, decreases in bisorption at higher pH have been reported (Sari and Tuzen, 2008). Decreases in biosorption at higher pH values (pH > 5) is said to be attributed to the formation of anionic hydroxide complexes of metal ions and their competition with the active sites. Similar findings were reported for other types of biosorbents (Sari and Tuzen, 2008). The effect of pH on biosorption capacity and uptake of Cu (II) ions onto *Gigartinaacicularis*as a function of pH was studied. In the report, it was indicated that the pH of a solution influence both metal binding sites on the cell surface and the chemistry of metal in solution (Dursun, 2006).

With respect to temperature, the observation in this study was remarkable adsorption at temperature between 50 ºC and 60 ºC for nitrate and between 40 ºC and 50 ºC for sulphate. Singh and co-workers (2011) have studied the effect of temperature (range within 25-40 °C) on the removal of zinc ion using chitosan (Singh *et al*., 2011). While keeping other parameters, such as dose of adsorbent and pH of solution constant, it was observed that the low temperatures are in favour of zinc ion removal. This was indicated to be due to the tendency of the zinc ions to escape from the solid phase to the bulk phase with an increase in temperature of the solution (Prakash, 2012). It is reported, the isotherm of Zn (II) onto carbon is either independent of temperature or the effect of temperature is so minimal as to be masked by experimental error. An increase in temperature from 25-40 ºC, is said to decrease removal of zinc ions from 93.7 % to 72.4 % (Rodda, 1993).

When investigating the effect of adsorbent concentration on nutrient adsorption, the observation in this study was that increase in sulphate and nitrate adsorption with increase in adsorbent concentration up to a similar limit after which it did not follow any pattern. It is indicated that the number of available sites and exchanging ions for adsorption depends upon the amount of adsorbent in the biosorption process (Wilde *et al.,* 1993). Earlier researchers have indicated that there was an increase in the biosorption percentage as dosage of biosorbent increases to certain level, after which there will be decreases. This is said to be attributed to the availability of more binding sites in the surface of the biosorbent for complexation of ions in the solution (Muthusamy *et al.,* 2012).

In a study on the removal efficiency of copper using an adsorbent, it was reported that adsorption improved on increasing adsorbent doses. This was reported to be due to the fact that the higher dose of adsorbents in the solution provides the greater availability of exchangeable sites for the ions. The study indicated that there was no additional increase in adsorption after 200 mg of adsorbent was added. The maximum % removal of Cu (II) was about 88.17% at the dosage of 200 mg. This finding could indicate that once equilibrium have been reached, any further increase in adsorbent will have no effects since the amount of ions bound to the adsorbent and the amount of free ions in the solution remain constant even with further addition of the dose of adsorbent (Khan *et al.,* 2010).

Conclusion

The study was able to reveal the following:

- At the different parameters investigated, no remarkable decreases in phosphate in the wastewater or aqueous solution were observed in presence of the *Trametes*. However sulphate and nitrate adsorption were observed in both the wastewater and aqueous solution under certain conditions.
- Remarkable nitrate and sulphate adsorption were observed in presence of the *Trametes* at alkaline and acidic pH, respectively. Highest nitrate and sulphate removal were observed at pH 10 and 2, respectively. This trend was irrespective of whether it is wastewater or aqueous solution.
- At the different temperatures investigated, remarkable adsorption was observed between 50 ºC and 60 ºC for nitrate and between 40 ºC and 50 ºC for sulphate.
- A significant decrease in sulphate concentration was observed during the 6 h contact time and also in nitrate within the first 3 h, whereas phosphate had no remarkable change.
- The quantity of adsorbent used did not show any remarkable decrease in phosphate level. In the case of nitrate and sulphate, increase in adsorbent quantity gave a corresponding increase in adsorption up to a certain level, after which there was no noticeable pattern. This trend was irrespective of whether it is wastewater or aqueous solution

Although the study cannot be considered to be exhaustive, it has information on the nutrient adsorption efficiency from wastewater and aqueous solution with the dead biomass of the *Trametes* under the experimental conditions investigated.

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