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Evaluation of Water Uptake Capacity of *Cissus populnea* Stem Bark (CPSB) Membrane

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Abstract: This study investigated some physical properties of *Cissus populnea* membrane (CPSB) by determining the water uptake under different conditions (concentration, temperature, pH, contact time, and ionic strength). The modified tea bag method was used to determine the water uptake capacities. The results showed that *Cissus populnea* Stem bark membrane has higher water uptake capacity up to 500%. It also showed that the water uptake increased with increase in concentration and pH, and decreased with increase in ionic strength and temperature. The contact time increased from 1hr to 6hrs and gradually decreased from 8hrs to 24hrs with the percentage uptake of water. This study revealed that CPSB membrane could be used as an adsorbent for treatment of waste water from aqueous solution.

Keywords: *Cissus populnea*, Membrane, Water, Uptake, Capacity.

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1.0 Introduction

Water is a source of energy and most important natural resources which make life and living meaningful the world over. As a source of energy water is fundamentally one of the basic needs for human and other organisms. The availability of fresh clean and quality drinking water remains one of the most critical environmental and sustainability issues in many societies across the world. People really need a source of water that is not always available but safe and dependable. This is necessary because water is an essential requirement for sustainable development and quality of life. In most countries of the world, rapid population expansion and industrialization that are usually characterized by unplanned urbanization cum other environmental factors have largely contributed to water pollution (Osemeahon *et al.*, 2016). Poor disposal system contaminates the soil and water bodies thereby making them undesirable for human needs. Heavy metals in waste water are increasingly discharged directly or indirectly in to the environment. Unlike organic contaminants heavy metals are not biodegradable and tends to accumulate in living organisms. Many heavy metals ions are known to be toxic or carcinogenic. Heavy metals are sources of water pollution and largely responsible for environmental problems in developing countries (Singh and Verghese, 2016;

Mousavi *et al.*, 2010). The toxic effects of heavy metals accumulate through the food chain there by affecting users /consumers. The presence of heavy metal ions in drinking water constitute serious danger to consumers particularly, zinc, copper, nickel, mercury, cadmium, lead and chromium that causes risk for human health and environment (Oyaro *et al.*, 2007; Abas *et al.*, 2013). These heavy metals also have crucial biological functions in plants and animals as their chemical coordination and oxidation reduction properties sometimes give them additional benefits to escape control mechanisms such as homeostasis, transport, compartmentalization and binding to required cell constituents (Jaishankar *et al.*, 2014). Similarly, Flora *et al.*, (2008) noted that the deterioration of biological molecule is primarily due to binding of heavy metals to the DNA and nuclear protein.

Studies in physical chemistry and biological process revealed that removal of heavy metal ions from waste water has been previously achieved by various method such as ion exchange, precipitation, oxidation reduction, reverse osmosis electro chemical filtration (Gupta and Nyaka, 2012; Santhi and Manomani, 2012; Santuraki and Muazu, 2015). Most of these methods were found to have some limitations such as production of hazardous by –product, ineffective and expensive for general public. Hence the growing need for efficient and cost effective methods or techniques for the removal of heavy metal ions in waste water. This situation calls for the need to adopt a more economical and effective methods. Biosorption of heavy metals from aqueous solution is relatively a new technology for the treatment of waste water. The advantage of using this method include; cost effectiveness, affordability, availability and environmental friendliness. These methods could be used as alternative to the expensive waste water treatment processes. Plants are known to be sources of materials which possess properties that are important to waste water management. To this end, therefore this study is designed to use membrane derived from a plant *Cissus populnea* and evaluate the water uptake capacity of CPSB membrane under different condition.

2.0 Materials and Methods

2.1 Collection of Materials

The chemicals used in this research include: Sodium alginate, Methanol, Glutaraldehyde, Hydrochloric acid, Sodium chloride, all are product from British Drug House (BDH). The plant *Cissus populnea* was obtained from Mbamba area of Yola South Local Government Area of Adamawa State Nigeria. All the chemicals used in this research are of analytical grades and were used as supplied.

2.2 Preparation of Plant Sample

The dissolution of the powdered sample of *Cissus populnea* Stem Bark (CPSB) was made by weighing 4.00g powdered stem bark in to 100cm^3 that was mark with distilled water and labelled mixture A and kept in a separating funnel for 12 hours to observed the possible separation into various fractions (Osemeahon *et al.*, 2007).

2.3 Preparation of Sodium Alginate

Sodium alginate was prepared by weighing 4.00g and making it up to 100 cm^3 mark with distilled water in a volumetric flask, labeled B and kept overnight for complete dissolution.

2.4 Membranes Preparation

CPSB solution of (20ml) and sodium alginate of (80ml) with 0.1ml of glutaraldehyde (25%) were mixed. This mixture was stirred for 2hrs at 30 ^{0}C and then poured uniformly on a plastic tray. The membrane was allowed to dry at room temperature for 3days. The cast membrane was cross linked by immersing in a 1% HCI solution taken in an equimolar mixture of methanol and water for 24 hours. It was washed thoroughly in water and allowed to dry at room temperature for three days. (Barminas *et al.*, 2005).

2.5 Determination of water uptake

The water uptake of *Cissus populnea* Stem Bark membrane was determined using modified "Tea bag" method as reported by Barminas and Eromosele (2002) was adopted in this study. This involved the insertion of 2g of clean dried membrane samples into a transparent polyethylene bag, the gross combination was pre weighed before adding 100ml of distilled water, after which it was sealed and kept undisturbed for 24hrs at room temperature to attain equilibrium. At the end of the equilibrium period, the excess solution was carefully sucked out using micro syringe; the polyethylene bag with the wet sample was weighed. The percentage water uptake was determined using the following equation;

Water uptake (%) = [(Wy-Wx/Wx)] x 100/1; where Wx and Wy represent weight of dry and wet membrane samples respectively, (Barminas *et al.*, 2005).

2.6 Effect of concentration of *Cissus populnea* on water uptake

Two grams (2g) of the clean dried membrane of CPSB of different concentrations (2%-20%) was inserted into a polyethylene bag and weight before adding 100ml of distilled water, this were then sealed and allowed to stay for 4 hours. At the end of the equilibrium period, the excess water was sucked out using a micro syringe, the polyethylene bag with the wet sample was re-weighed again (Osemeahon *et al.*, 2007). The percentage water uptake will be determined using the formula reported earlier, by Barminas and Eromosele (2003).

2.7 Determination of the effect of pH on water uptake

The water uptake behaviour of CPSB membrane at different pH values (4–9) was investigated at 30C^0 for 24 hours using the modified tea bag method. Standard solution of 2.0M HCI and 1.0M NaOH was used to adjust the solutions to the required pH values. At the end of the equilibrium period, the excess solution was sucked out using a micro syringe; the polyethylene bag with the wet sample was re-weighed. The percentage water uptake was determined at different pH to ascertain the influence on water uptake by the membrane.

2.8 Determination of the effect of Time on water uptake

A mass of 2g of *CPSB* membrane was inserted into a polyethylene bag and weighed. Meanwhile, 100ml of distilled water was added. The modified tea bag method as earlier stated was used. At the end of the equilibrium period, the excess water was sucked out using a micro syringe, the polyethylene bag with the wet sample was re-weighed. The percentage of water uptake was determined at different time intervals, ranging from 1hour to 24 hours.

2.9 Determination of the effect Ionic Strength on water uptake

A mass of 2g of the dried membrane of *Cissus populnea* stem bark was inserted into a polyethylene bag and weight. 100ml of sodium chloride solution of various concentrations (0.1M–1.0M) was added as the need arises. At the end of the equilibrium period 24 hours at 30^{0}C, the excess solution was sucked out using a micro syringe the polyethylene bag with the wet sample was re-weighed. The percentage of water uptake will be determined using the formula reported earlier (Barminas *et al.*, 2005).

2.10 Determination of the effect of Temperature on water uptake

A mass 2g of *CPSB* membrane was inserted into a polyethylene bag and weighted. After which 100ml of distilled water was added, sealed and allowed to stay for 24hours. The assembly was kept at a constant temperature using a regulated water bath. At the end of the equilibrium period, the excess water was sucked out using a micro syringe the polyethylene bag with the wet sample were weighed which gave rise to the percentage of water uptake. The procedure was repeated for various temperatures ranging from 20^0C to 70^0C, in each case the average of three determinations was taken (Barminas *et al.*, 2005).

3.0. Results and Discussion

3.1 Water uptake Capacities of *Cissus populnea* Membrane

Figure 1 presents the water uptake capacities of *Cissus populnea* Stem Bark (CPSB) membrane, at room temperature of 30^0C for a period of 24 hours. The water uptake capacity of the sample showed that the CPSB has an uptake capacity of up to 500%. The water uptake capacity of the membrane can be attributed to the amount of cellulose content of the plant stembark. The degree of crystallinity of the polymer membrane can also affect the water uptake capacity. The less crystalline the polymer network is; and the more water it will absorbed (Osemeahon, 2016).

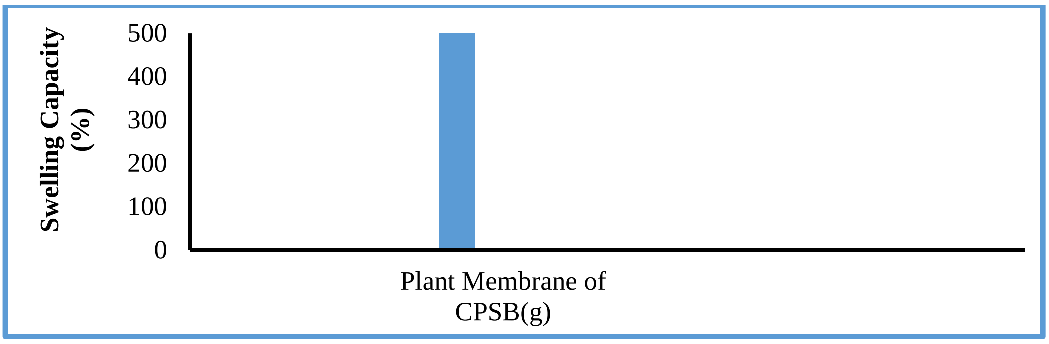

Figure 1. Plant membrane of CPSB

3.2 Effect of *Cissus populnea* Stem Bark Concentration on Water Uptake Capacity

Figure 2 shows the effect of *Cissus populnea* Stem Bark concentration on water uptake capacity. The study revealed that the water uptake increases as the concentration of the CPS increases from 2g to 20g. (135% to 506%). This result is in agreement with the finding of the study conducted by Aguoru *et al.,* (2014), which showed that the rapid increase in water uptake with increasing adsorbent dosage is due to increase in the availability of more adsorptive surface. Further increment in adsorbent dosage beyond maximum adsorption capacity resulting in decrease in uptake capacity. This reduction in capacity could be due to overlapping of the adsorption sites as a result of overcrowding of adsorbent. Particles beyond the optimize dose (Zhu *et al.*, 2009).

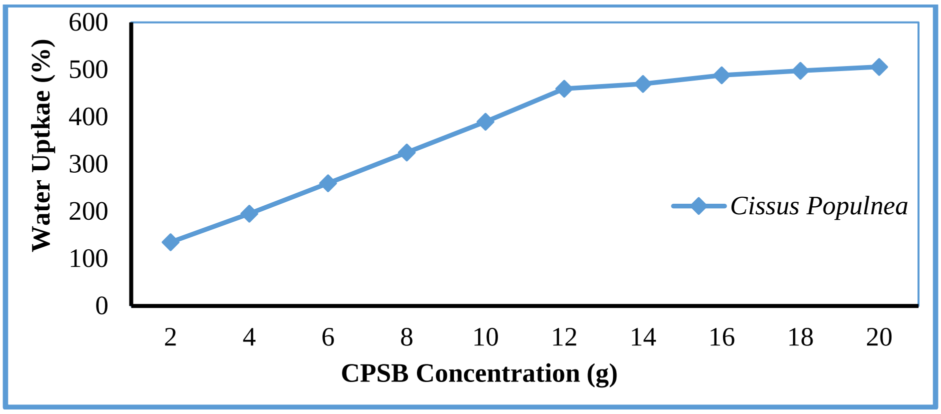

Figure 2. Effect of Concentration on water uptake

3.3 Effect of pH on water uptake by CPSB

The effect of pH on water uptake.is presented in figure 2 at pH range from 4.0 to 9.0. The percentage of water uptake changed from 198% to 273% for the CPSB. This showed an incremental difference of 75%. from pH 4.0 to 5.0. However, the percentage of water uptake jumped from 273% to 481% of the CPSB from pH 5.0 t0 9.0.

The membrane showed very sharp differences in increment of water uptake. The amount of water uptake absorbed by the pH values of 7.0 to 9.0 are two times the water uptake between pH values of 4.0 to 5.0 for the CPSB. It showed that the percentage water uptake increases with increasing pH values. This is due to the presence of the–OH group in solution with increasing pH value. Similarly, the low level of water uptake by adsorbent at low pH could be attributed to the increase in [H$^{+]}$ (Amrita *et al.*, 2016).

The variation in water uptake by biomass of CPSB at different pH could be due to the differences in the sensitivity of cell wall molecules of the plant cells to pH. This is due to the formation of more hydroxides with increase pH. The differences in the surface chemistry of the different membranes (cations and anions) could also explains the reason for variation in water uptake by CPSB at different pH values (Paul, 2013).

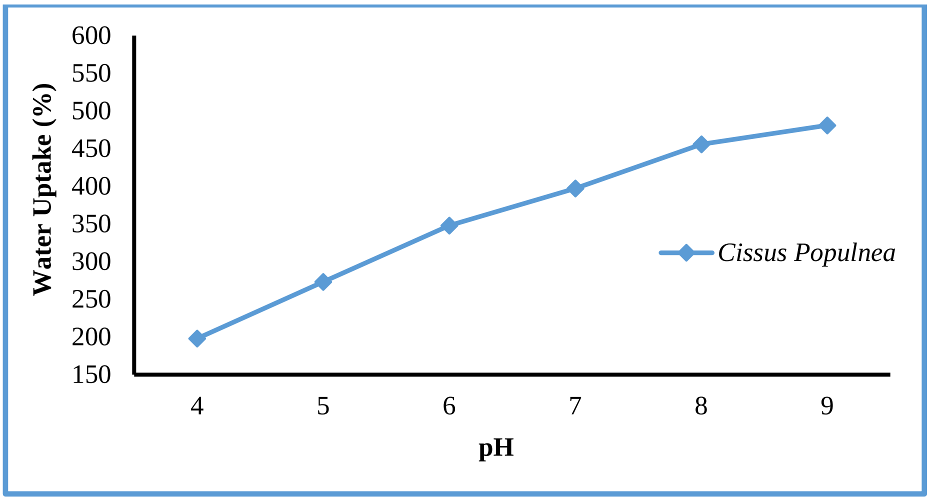

Figure 3. Effect of pH on water uptake

3.4 Effect of Contact Time on CPSB Water Uptake

The effect of contact time on CPSB. water uptake by is displayed in figure 4. It showed that the rate of water uptake increased gradually from 1 hour to 6 hours with a percentage change from 274% to 389% respectively which marked the saturation point of the membrane. The water uptake then decreases from 8 hours to 24 hours when equilibrium was reached. It was observed that the process of absorption was high at the initial stage and became slower while approaching the equilibrium stage.

This development is due to the fact that more number of vacant negatively charged sites were available initially on the surface of the adsorbent with sites gradually filled up while approaching the equilibrium and completely filled at equilibrium (Oladummi *et al.*, 2012). Crystallinity of the polymer membrane can also affect the rate of diffusion of water molecules into the membrane, and the high crystallinity means less void space between polymer molecule hence a reduction in diffusion rate of water molecules into the polymer membrane.

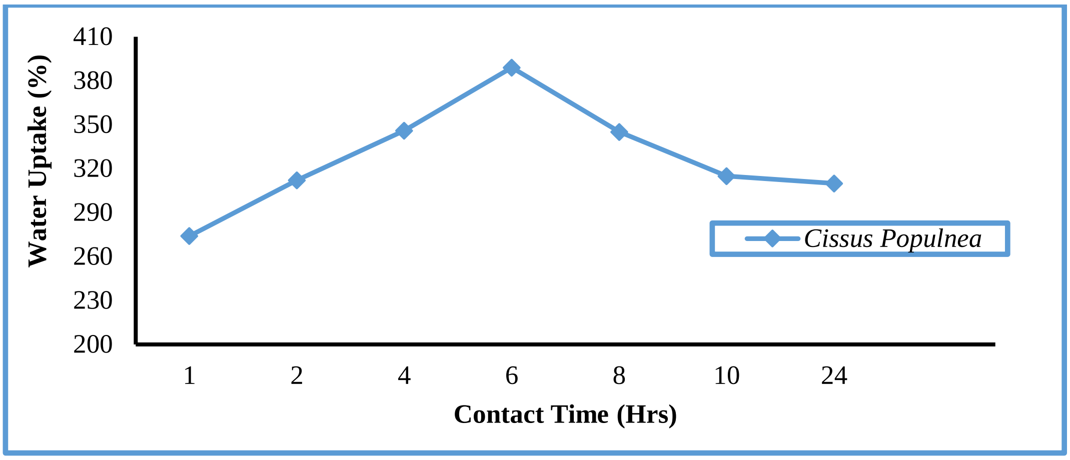

Figure 4. Effect of contact time on water uptake

3.5 Effect of Temperature on CPSB Water Uptake

Figure 5 present the Effect of Temperature on water uptake by CPS. The result showed that water uptake decreases from 20^0C to 70^0C by the CPS. It indicates a decrease from 418% to 197%. The trend of this result could be as a result of contraction of pores of the membrane with increase in temperature. This contraction of the pore size and some binding sites limit the access of water molecule into the membranes which translate to decrease in water uptake. This is equally due to the dissolution of low molecular weight polymer and non-cross linked polymer at high temperature making the pore size to be narrower and suction sites be hidden (Santuraki and Muazu, 2015). The percentage change is also attributed to either an increase in the number of active surface sites available for adsorption on the adsorbent or a decrease in the thickness of the boundary layer surrounding the adsorbent with rise in solution temperature, so that the mass transfer resistance of adsorbent in the boundary layer decreases (Hikmat *et al.*, 2014; Kishore *et al.*, 2012).

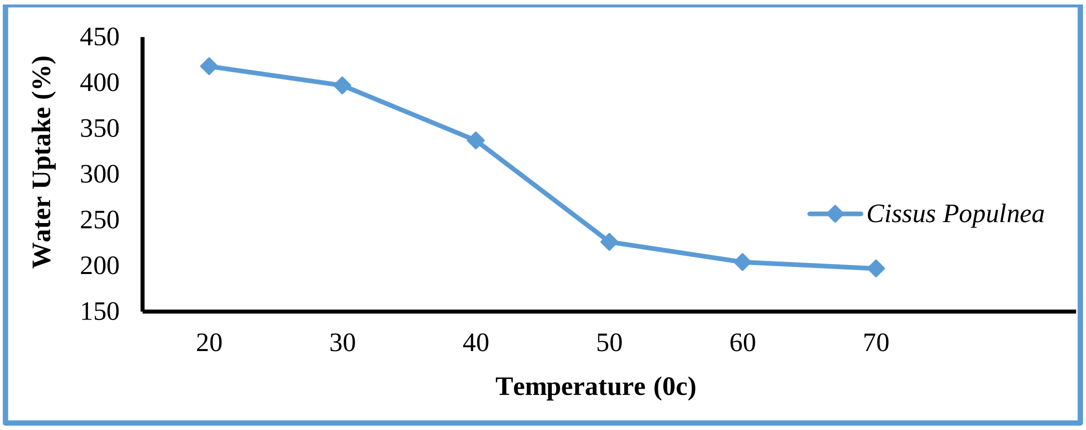

Figure 5. Effect of Temperature on water uptake

3.6 Effect of Ionic Strength on CPSB Water Uptake

Figure 6 presents the effect of ionic strength on water uptake. It is found that the water uptake decreased with increasing concentration of NaCl. This result is attributed to the decrease in the expansion of the polymer network, by repulsive forces of the counter ions on the polymeric chain shielded by the ionic charge. The percentage uptake change from 0.0 grams to 1.0 gram shows a decrease from 387%, to 223%. The osmotic pressure between the external solution and the polymer network decreased with increase in the ionic strength of the saline concentration (Adeyinka *et al.*, 2017). In this regard, the percentage of water uptake by the membrane of CPSB decreases when the ionic strength of the external solution increases (Kyzas *et al.*, 2013). This study indicated that presence of ions in water could interfere with the performance of CPSB membrane sorbents.

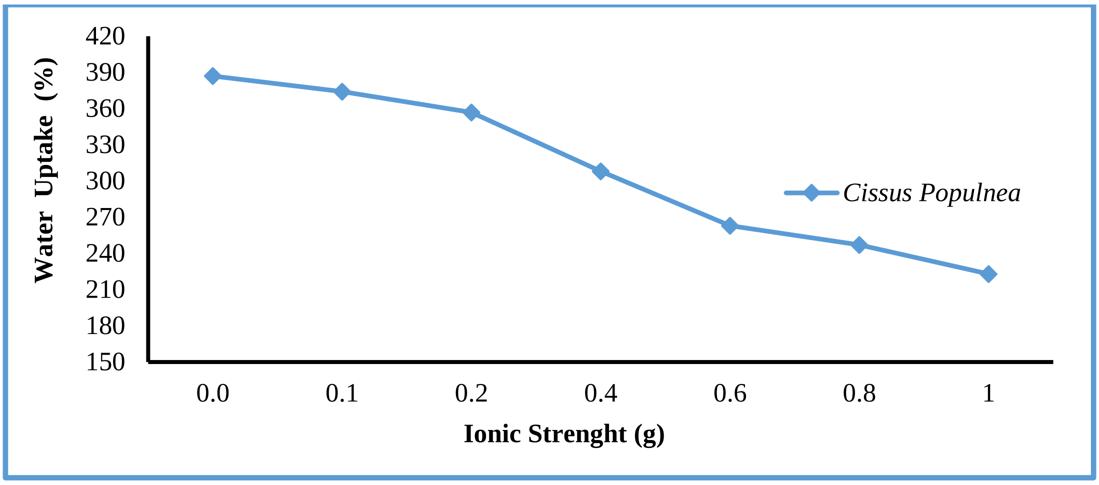

Figure 6. Effect of NaCl on water uptake

4.0 Conclusion

This study investigates some physical properties of the membrane of *Cissus populnea* stem bark plant and determined the water uptake under different conditions using the modified tea bag method. The sample showed higher water uptake capacity of up to 500%. It showed an increase in water uptake with increased in concentration and pH, and then uptake decreased with increase in ionic strength and temperature. The contact time increased from 1hr to 6hrs and gradually decreased from 8hrs to 24hrs until equilibrium was achieved. The study found that CPSB membrane could be used as an adsorbent for the treatment of waste water from aqueous solution. Thus it could serve as a viable and cost effective alternative in providing portable water.

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