

Adsorption of Nickel (II) by a Novel low-cost adsorbent Prepared from Ball Clay-TiO₂-Sodium Alginate Polymer-Nano Composite (BC-TiO₂-SAP-NC)

C.AMUDHA¹ and Dr. M. SANTHI²

^{1&2}-Assistant Professor, PG and Research Department of Chemistry, Erode Arts and Science College [Autonomous], Erode-9, Tamil Nadu, India

Abstract: This paper presents the feasibility of removal of Ni (II) from aqueous solutions by using a low-cost BC-TiO₂-SAP-NC. Batch adsorption experiments were carried out as a function of pH, contact time, initial concentration of the adsorbate, adsorbent dosage and temperature. Adsorbent used in this study are characterized by FT-IR, XRD and SEM analysis.

Keywords: Ni (II), BC-TiO₂-SAP-NC, Batch adsorption studies.

Date of Submission: 25-06-2022

Date of Acceptance: 07-07-2022

I. Introduction

Water is an essential natural resource since it is one of nature's most abundant and essential elements. Due to rising industrial, agricultural, and household activity, it is very polluted¹. Any metallic element that has a relatively high density and is hazardous and toxic even at low concentrations is considered to as a heavy metal². The existence of heavy metals in the environment is primarily induced by the weathering of rocks, which are natural components of the earth's crust³. The effluents from the production of batteries, electroplating, paint and pigment, printed circuit boards, coating, smelting, alloy preparation, wood preservation, plating, tanning and mining, petroleum refining, and other activities are some sources of heavy metals in water. Since these heavy metals are really not biodegradable, their existence in streams and lakes creates bioaccumulation in living organisms, which has a serious negative impact on the health of animals, plants, and mankind^{4,5}. These heavy metal ions do not break down into inert by-products like organic contaminants do⁶. Even at low concentrations, they have a propensity to bioaccumulate in the food chain⁷. Because nickel causes bone, nasal, and lung cancer at high concentrations, it was chosen as an adsorbate^{8,9}. Nickel salts are acknowledged to cause cancer at extremely high exposure levels¹⁰. As a result, industrial effluents containing Ni²⁺ ions must be treated before being released into receiving water bodies. Due to their increasing flow, poisonous nature, and other negative impacts on receiving water, the presence of heavy metals in the aquatic environment has been of major concern to scientists and engineers¹¹.

There are numerous traditional techniques that have been published in the literature to remove heavy metals from wastewater, including oxidation, membrane filtration, coagulation, reverse osmosis, absorption, ion exchange, and precipitation. When the waste stream has relatively low metal concentrations (1-100 mg/l) dissolved in huge volumes, these procedures may be inefficient or prohibitively expensive¹². Adsorption can be considered of as one of the most widely used techniques for removing heavy metals from wastewater because they are affordable, widely available, biodegradable, easy to develop, and have a high removal efficiency¹³. The biggest challenge for many researchers, however, is picking the right adsorbent. The market may indeed, however, offer a wide range of inexpensive and easily accessible adsorbents, which would include zeolite¹⁴, fly ash^{15&16}, blast furnace slag¹⁷, saw dust^{18,19}, orange peel²⁰, neem leaf²¹, eggshell membrane²², soy meal hull²³, rice husk²⁴, cashew nutshell²⁵, clay-polymer nanocomposites²⁶, starch-nanocomposite²⁷ and AC-MnO₂-NC²⁸ etc.,

Finding a trustworthy, affordable alternative adsorbent is crucial for the effective adsorption of harmful wastewater. Here, Ball-Clay-TiO₂-Sodium alginate nano composite (BC-TiO₂-SAP-NC) is used as an adsorbent.

II. Materials and Methods

Preparation of Nanocomposite adsorbent (BC-TiO₂-SAP-NC):

3g of Ball clay was allowed to swell on a 15 ml of water-free alcohol and stirred for 2 hours at 25 ° C. In the same way, 3g of sodium Alginate polymer and TiO₂ was dissolved separately by adding 15 ml of water-free alcohol and stirred for 2 hours. The mixture of sodium alginate and TiO₂ was added slowly to the solution of Ball clay. Lastly, alcohol 5 ml and 0.2 ml of deionized water were added slowly. Then it is further stirred for 2

hours. After the stirring was over the mixture was kept in a vacuum oven for 6 hours at 80°C and it was labelled as BC-TiO₂-SAP-NC.

Preparation of Adsorbate:

By dissolving 4.478g of nickel sulphate in 1000ml double distilled water, a stock solution of (1000mg/L) of Nickel (II) solution was created. All the chemicals used in this experiment were of analytical grade. To produce the solutions, double-distilled water was employed.

III. Characterization of Adsorbent

3.1. SEM Analysis:

It is used to find the surface morphology of the adsorbent. The SEM image of different magnifications of BC-TiO₂-SAP-NC are shown in Figure. 1 to 5. The figure clearly indicates the porosity of the adsorbent. Due to its high porosity the metal species are highly cached by the adsorbent.

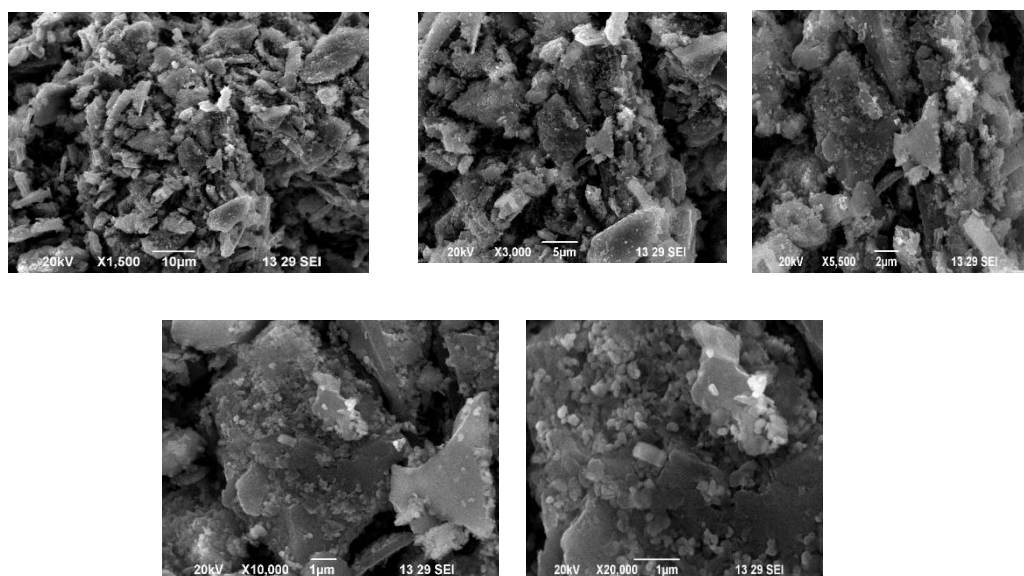


Figure. 1 to 5. SEM images of BC-TiO₂-SAP-NC at different magnifications

3.2. XRD Analysis (Powder X – Ray Diffraction Analysis)

It is shown in Figure.6. It provides the broad peak at 20.5, and almost the absence of sharp peak indicates the amorphous nature of the adsorbent.

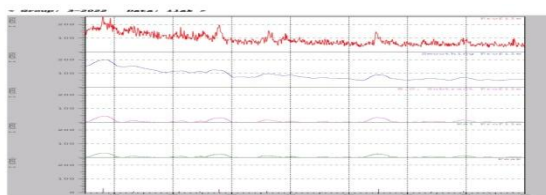


Figure. 6. XRD image of BC-TiO₂-SAP-NC

3.3. IR Spectroscopy:

It is in the following Fig: 7. The absorption bands are arised due to various stretching and bending vibrations of the group

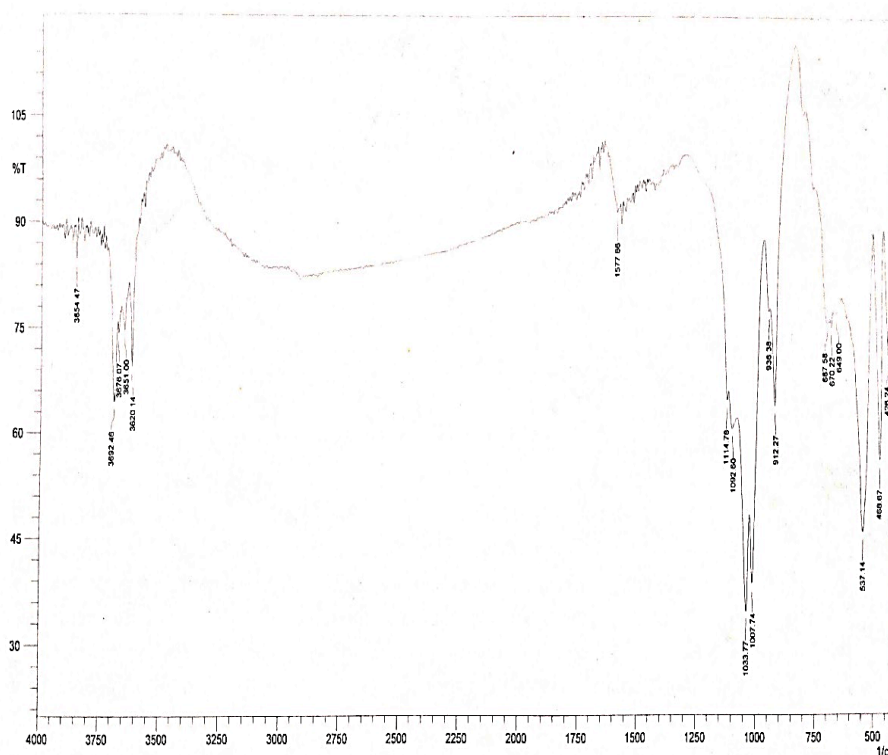


Figure-7 IR image of BC-TiO₂-SAP-NC

IV. Batch Adsorption Experiments

Experimental methods

In each adsorption experiment, 50 mL of metal solution with a known concentration was added to 100 mg of BC-TiO₂-SAP-NC in a 250 mL glass-stoppered flask at 30 ± 0.5 °C and the mixture was stirred on a mechanical shaker at 150 rpm min⁻¹. The samples were withdrawn during stirring at preset time intervals and the adsorbent was separated from the solution by centrifugation (Research centrifuge, Remi Scientific Works, Mumbai) at 4500 rpm min⁻¹ for 5 min. The absorbance of the supernatant solution was estimated to determine the residual metal concentration and was measured before and after treatment with double beam spectrophotometer (HITACHI U 2000 spectrophotometer). All experiments were carried out twice, and the concentrations given are average values. The initial metal concentration in the test solution and the adsorbent dosage were varied to investigate their effect on the adsorption kinetics. The effect of pH was observed by studying the adsorption of metal over the pH range from 3 to 13. The pH of the metal solution was adjusted by using NaOH or HCl solution and a pH meter. The sorption studies were carried out at different temperatures (30°, 40°, 50° and 60 °C). This is used to determine the effect of temperature on the thermodynamic parameters. The amount of sorption at time t, qt (mg/g), was calculated using the following formula:

$$q_t = (C_0 - C_t) V / W \text{ ----- (1)}$$

Where C_t (mg L⁻¹) is the liquid phase concentrations of metal at any time, C₀ (mg L⁻¹) is the initial concentration of the Metal in solution. V is the volume of the solution (L), and W is the mass of dry adsorbent (g). The amount of equilibrium adsorption, q_e (mg/g), was calculated using the formula.

$$q_e = (C_0 - C_e) V / W \text{ ----- (2)}$$

Where, C₀ and C_e (mg L⁻¹) are the liquid-phase concentrations of metal initially and at equilibrium. The metal removal percentage can be calculated as follows:

$$(\%) \text{ of dye removal} = [(C_0 - C_e) / (C_0)] \times 100 \text{ ----- (3)}$$

Where, C₀ and C_e (mg L⁻¹) are the initial and equilibrium concentrations of the metal in solution.

V. Results and Discussion

5.1. Effects of agitation time and initial metal concentration

Effects of agitation time and initial metal concentration (10, 20, 30 and 40 mg/L) on removal of Ni (II) are presented in Figure. 8. The percent adsorption increased as the original metal concentration increased, indicating that adsorption is strongly dependent on the initial metal concentration. The initial q_e Count number of metal molecules to the accessible surface area ratio is low at lower concentrations. As a result, fractional adsorption is no longer dependent on the initial concentration. However, when the concentration increases, the number of accessible adsorption sites decreases, and the amount of metal removed is proportional to the starting concentration. For all concentrations, equilibrium was reached after 90 minutes. The curves are single, smooth, and continuous, leading to saturation, implying that the metal might cover the monolayer on the surface.

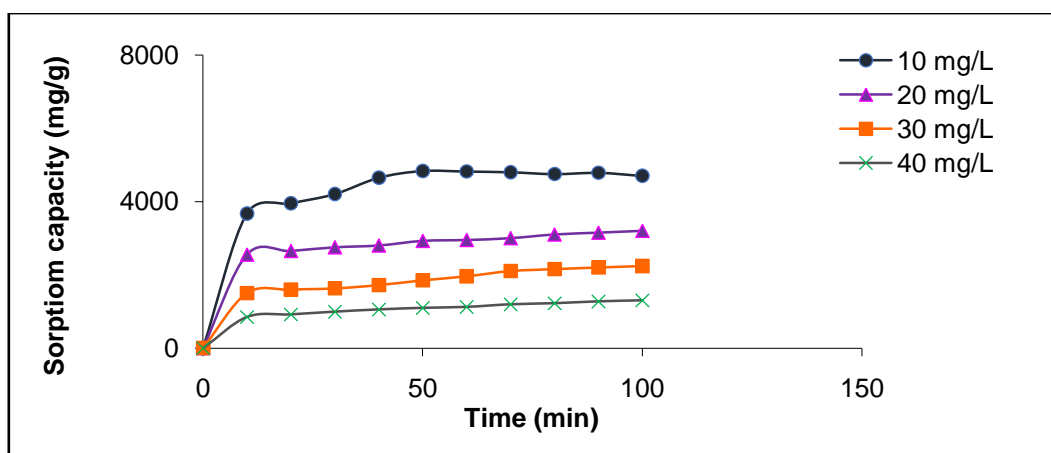


Figure .8. Effects of agitation time and initial Ni(II) concentration by BC-TiO₂-SAP-NC

5.2 Effect of adsorbent Dose

The adsorption of Nickel (II) was investigated by changing the adsorbent dose (10-40 mg/50 mL) at metal values of 10-40 mg/L. The percentage of adsorption increased with increasing adsorbent concentration in both nanocomposite and clay. This was due to an increase in the surface area of the adsorbent and the availability of more adsorption sites.

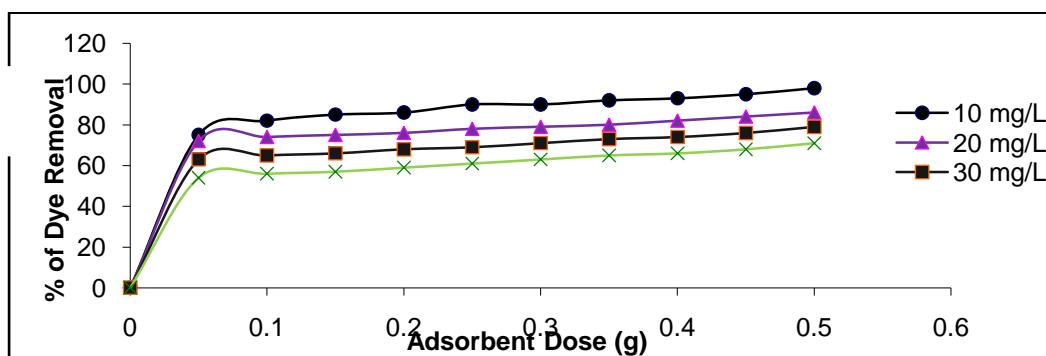


Figure. 9. Effect of adsorbent dosage for Ni (II) by BC-TiO₂-SAP-NC

5.3. Effects of Temperature

Figure 10 shows the findings of investigations on the effect of temperature on the removal of Nickel (II) by nanocomposite and clay. When the temperature was raised from 303 K to 315 K, the amount of metal adsorbed increased, showing that the adsorption process was endothermic. This could be due to an increase in the rate of adsorbate molecules diffusing between the external boundary layer and internal pores of the adsorbent particle when the temperature rises.

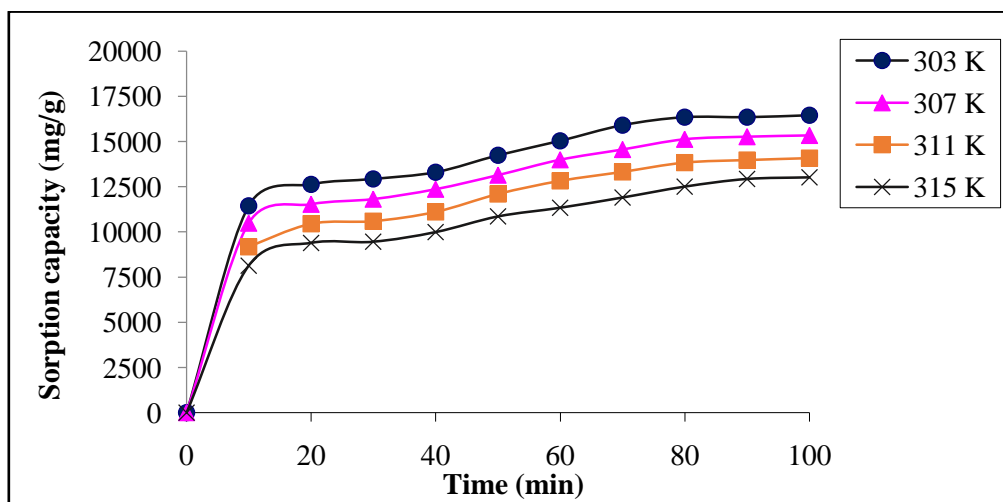


Figure. 10. Effect of Temperature for Ni (II) by BC-TiO₂-SAP-NC

5.4. Effect of pH

As the pH rises, the number of positively charged sites decreases, resulting in an increase in adsorption. The adsorbent surface acquires a negative charge at higher pH values, and the electrostatic attraction between the negatively charged adsorbent surface and the metal increases, resulting in maximal adsorption.

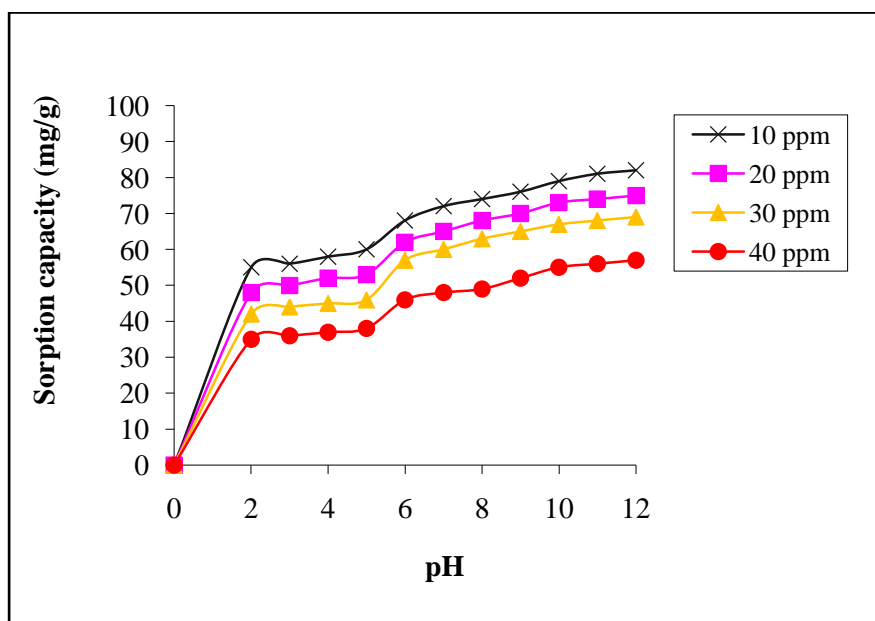


Figure.11. Effect of pH for Ni (II) by BC-TiO₂-SAP-NC

VI. Conclusion

The present study shows that BC-TiO₂-SAP-NC is an effective adsorbent for the removal of Ni (II) from aqueous solution.

- SEM image revealed that the BC-TiO₂-SAP-NC composite phase was in the nano range.
- IR provides the structure of nano composite.
- From XRD amorphous nature & nano structure of BC-TiO₂-SAP-NC was confirmed.

Complete removal of the metal can be achieved using an appropriate dosage of the adsorbent and pH for waste waters. The results would be useful for the fabrication and designing of wastewater treatment plants for the removal of Ni (II). Since the raw material is freely available in large quantities and the treatment method, seems to be economical.

References

- [1]. <http://greentumble.com/water-pollution-facts-causes-effects-solutions/> August 11, 2015
- [2]. Lenntech, Water treatment and air purification, Water treatment, 2004, published by Lenntech, Rotterdamseweg, Netherlands.
- [3]. H.L., Bohn, B.L., Mc Neal, G.A., O Connor, Soil Chem., John Wiley, New York, USA, 1985.
- [4]. S., Ong, C., Seng, P., Lim, Kinetics of adsorption of Cu (II) and Cd (II) from aqueous solution on rice husk and modified rice husk, Electronic J. Environ. Agri. Food Chem., 6[2], 2007, 1764-1774.
- [5]. H.I., Ceribas, U. Yetis, Biosorption of Ni (II) and Pd (II) by *Phanerochaete chrysosporium* from binary metal system- Kinetics, Water Soil Air, 27[1], 2001, 15-20.
- [6]. V.K., Gupta, M., Gupta, S., Sharma, Process development for the removal of lead and chromium from aqueous solution using Red mud, an aluminium industry waste, Water Res., 35[5] 2001, 1125-1134
- [7]. D., Mohan, K.P., Singh, Single and multiple component adsorption of cadmium and zinc using activated carbon derived from bagasse-an agricultural waste, Water Res., 36, 2002, 2304-2318
- [8]. H.L., Ceibas, U. Yetis, Biosorption of Ni(II) and Pb(II) by *Phanerochaete chrysosporium* from binary metal system-kinetics. water SA, 27[1], 2001, 15-20.
- [9]. B. Volesky, Z.R., Holan, Biosorption of heavy metals, Biotechnol Progress, 11[3], 1995, 235-250.
- [10]. F.H.A., Rodrigues, Fast dye removal from water by starch-based nanocomposites, J. Colloid Interface Sci. 454, 2015, 200-209, <https://doi.org/10.1016/j.jcis.2015.05.026>.
- [11]. S., Anima, Dadhich, Shaik khasim Beebi and G.V., Kavitha, Adsorption of using agro waste – rice husk, Journal of environ science & engg, 46[3], 2004, 179-185.
- [12]. Y. Bulut, Z. Baysal, Removal of Pb (II) from wastewater wheat bran. J. environ. manag., 78, 2006, 107-113.
- [13]. M. Chandra shekar, Removal of lead from aqueous effluents by adsorption on coconut shell carbon, J. Journal of environ. Science & Engg., 50[2], 2008, 137-140.
- [14]. A.B. Engin, O. Ozdemir, M. Turan, A.Z. Turan, Color removal from textile dyebath effluents in a zeolite fixed bed reactor: determination of optimum process conditions using Taguchi method, J. Hazard. Mater. 159 [2-3], 2008, 348-353, <https://doi.org/10.1016/j.jhazmat.2008.02.065>.
- [15]. D. Sun, X. Zhang, Y. Wu, X. Liu, Adsorption of anionic dyes from aqueous solution on fly ash, J. Hazard. Mater. 181 [1-3], 2010, 335-345, <https://doi.org/10.1016/j.jhazmat.2010.05.015>.
- [16]. P. Janos, H. Buchtova, M. Ryznarova, Sorption of dyes from aqueous solutions onto fly ash, Water Res. 37 [20], 2003, 4938-4944, <https://doi.org/10.1016/j.watres.2003.08.011>.
- [17]. Y.J. Zhang, L.C. Liu, L.L. Ni, B.L. Wang, A facile and low-cost synthesis of granulated blast furnace slag-based cementitious material coupled with Fe₂O₃ catalyst for treatment of dye wastewater, Appl. Catal. B Environ. 138-139, 2013, 9-16, <https://doi.org/10.1016/j.apcatb.2013.02.025>.
- [18]. V.K. Garg, M. Amita, R. Kumar, R. Gupta, Basic dye (methylene blue) removal from simulated wastewater by adsorption using Indian Rosewood sawdust: a timber industry waste, Dyes Pigm. 63 [3], 2004, 243-250, <https://doi.org/10.1016/j.dyepig.2004.03.005>.
- [19]. V.K. Garg, R. Gupta, A.B. Yadav, R. Kumar, Dye removal from aqueous solution by adsorption on treated sawdust, Bioresour. Technol. 89[2], 2003, 121-124, [https://doi.org/10.1016/S0960-8524\(03\)00058-0](https://doi.org/10.1016/S0960-8524(03)00058-0).
- [20]. C. Namasivayam, N. Muniasamy, K. Gayatri, M. Rani, K. Ranganathan, Removal of dyes from aqueous solutions by cellulosic waste orange peel, Bioresour. Technol. 57 [1], 1996, 37-43, [https://doi.org/10.1016/0960-8524\(96\)00044-2](https://doi.org/10.1016/0960-8524(96)00044-2).
- [21]. K.G. Bhattacharyya, A. Sarma, Adsorption characteristics of the dye, Brilliant Green, on Neem leaf powder, Dyes Pigm. 57 [3], 2003, 211-222, [https://doi.org/10.1016/S0143-7208\(03\)00009-3](https://doi.org/10.1016/S0143-7208(03)00009-3).
- [22]. M. Arami, N. Yousefi Limaee, N.M. Mahmoodi, Investigation on the adsorption capability of egg shell membrane towards model textile dyes, Chemosphere 65 [11], 2006, 1999-2008, <https://doi.org/10.1016/j.chemosphere.2006.06.074>.
- [23]. M. Arami, N.Y. Limaee, N.M. Mahmoodi, N.S. Tabrizi, Equilibrium and kinetics studies for the adsorption of direct and acid dyes from aqueous solution by soy meal hull, J. Hazard. Mater. 135 [1-3], 2006, 171-179, <https://doi.org/10.1016/j.jhazmat.2005.11.044>.
- [24]. M.A. Rahman, S.M.R. Amin, A.M.S. Alam, Removal of methylene blue from waste water using activated carbon prepared from Rice Husk, Dhaka Univ, J. Sci. 60 [2], 2012, 185-189, <https://doi.org/10.3329/dujs.v60i2.11491>.
- [25]. R. Subramaniam, S. Kumar Ponnusamy, Novel adsorbent from agricultural waste (cashew NUT shell) for methylene blue dye removal: optimization by response surface methodology, Water Resour. Ind. 11, 2015, 64-70, <https://doi.org/10.1016/j.wri.2015.07.002>.
- [26]. E.I. Unuabonah, A. Taubert, Clay-polymer nanocomposites (CPNs): adsorbents of the future for water treatment, Appl. Clay Sci. 99, 2014, 83-92, <https://doi.org/10.1016/j.clay.2014.06.016>.
- [27]. R.F. Gomes, A.C.N. de Azevedo, A.G.B. Pereira, E.C. Muniz, A.R. Fajardo,
- [28]. M. Santhi, P.E. Kumar and B. Muralidharan, Removal of Malachite Green Dyes By Adsorption onto Activated Carbon – MnO₂ – Nanocomposite – Kinetic Study and Equilibrium Isotherm Analyses, *IOSR Journal of Applied Chemistry (IOSR-JAC) e-ISSN: 2278-5736. Volume 8, Issue 4 Ver. I. (Apr. 2015), PP 33-41.*

C.AMUDHA, et. al. "Adsorption of Nickel (II) by a Novel low-cost adsorbent Prepared from Ball Clay-TiO₂-Sodium Alginate Polymer-Nano Composite (BC-TiO₂-SAP-NC)." *IOSR Journal of Applied Chemistry (IOSR-JAC)*, 15(07), (2022): pp 30-35.