International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Radiation Grafting of Peanut Shell Cellulose-Acrylamide Monomer for Production of Hydrogel to be used in Industrial Wastewater Treatment

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Abstract- *Many efforts have been made to isolate cellulose from various biomass sources. Recently, particular attention has been paid to producing pollutant adsorbents from cellulosic polymers due to their advantages of being abundant, rapidly renewable, and biodegradable in nature. Current research is based on modification of peanut shell cellulose through radiation graft copolymerization with acrylamide monomer for the synthesis of hydrogel and it can be used a waste water absorber. Monomer ratio was varied from 1:1 up to 1:2, and various radiation doses (10-30 kGy) were applied for grafting. The structures and properties of the original cellulose and the prepared grafted cellulose-acrylamide were characterized using different analytical tools such as scanning electron microscopy (SEM) and fourier transformed infrared spectrometer analysis (FTIR). The effect of radiation dose and monomer concentration on grafting efficiency and swelling degree were also studied. The grafting efficiency increased with the increasing in radiation dose which was found to be inversely proportional to swelling degree. The increasing in monomer concentration was directly proportional to the grafting efficiency, however, led to decreasing in swelling degree. The adsorption capacity of hydrogels toward heavy metals and dye has been investigated. The maximum adsorption capacity and removal of hydrogel for Pb were 14 mg/g and 64 %. The removal of hydrogel for dye was 37 %. This study provides a solution to the discharge of different pollutants from wastewater.*

Keywords- *Peanut shell, Cellulose, Radiation Grafting, Fourier Transformed Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM) and Atomic Absorption Spectrometry (AAS).*

I. INTRODUCTION

Industrial and domestic wastewater containing heavy metal ions are increasingly discharged into the environment, especially in developing countries. They are responsible for causing damages to the environment and can also easily enter the food chain through a number of pathways and adversely affecting the health of people [1]. Synthetic chemicals including dyes have been extensively used in many industries such as textile, plastic, leather tanning, paper production, food technology, printing and cosmetic. They are toxic to some aquatic organisms and are of serious health risk to human beings [1], [2]. For their removal from contaminated water, several methods such as physical, chemical and biological methods have been investigated [3].

Graft copolymerization is an effective method to modify the chemical and physical properties of polymeric materials [4].Graft copolymerization can be performed by some methods such as ionizing radiation, ultraviolet light, chemical initiator etc. Among these methods radiation grafting is a promising method because of its penetration in the polymer matrix, resulting in rapid and uniform formation of active sites for initiating grafting throughout the matrix and it can effectively and conveniently be carried out at room temperature [5]. Ionizing radiation has provided a clean method of activating a polymer substrate. Radiation graft polymerization has also many advantages over other conventional methods, such as, chemical and photochemical grafting. For instance, the method is relatively simple and no catalyst is required to initiate the reaction [5], [6].

Nowadays, waste are scattered all around. Burning them is one of the ways to hasten waste but it can only add pollution to our environment. After harvesting peanuts, they are then transported to a processing facility where they are dried and stored. Peanut shell is abundant and inexpensive by-product of peanut processing operation [7].

Peanut shells have been used as fuel for moving boilers in manufacturing processes, bedding, mulch in poultry houses, kitty litter, soil conditioners, carriers for chemicals and fertilizers, and most important to this paper, peanut shells are often used as a roughage source in cattle diets [7], [8].

Myanmar is an agricultural country, and agriculture sector is the backbone of its economy. Main sources of agro waste are paddy straw, sugar cane biogases, peanut shells, coffee husk, rice husk and maize husk [9]. However, in our country the management of agricultural waste is very low resulting in environmental issues. By utilizing the potential benefits of these crop residues, useful products can be made such as hydrogel, super water absorbent and control release fertilizer.

Many studies have been performed to obtain low-cost adsorbents with greater adsorption capacities to remove dyes from waste effluents. For this purpose, a variety of agricultural wastes have been tested due to their unique advantages, such as nontoxicity, biocompatibility, biodegradability, low cost and high availability [10].

Polysaccharides such as starch, chitin/chitosan and their water soluble derivatives have a variety of application in many fields owning to their unique structure, distinctive properties, safety and biodegradability [11]. Cellulose is one of the most abundant naturally occurring polymers. It is commonly found in the cell walls of plants [4]. In recent years, a number of monomers have been grafted onto cellulose by copolymerization in order to improve swelling property, reduce production costs and ensure biodegradability. Those monomers include ethyl acrylate, styrene, allyldimethyl-hydantoin, and vinyl acetate, among others. Acrylamide is one of the favourite choices due to its excellent compatibility with cellulose, ease of preparation, non-arcinogenicity, low cost, biocompatibility, and biodegradability in nature [12].

The adsorbent products are usually prepared in the form of hydrogels owing to their three-dimensional porous inner structure, readily swelling behaviour, and strong adsorption capacity toward heavy metals, dyes and organic contaminants. Hydrogels are responsive to external stimuli such as pH, temperature, electric field, and external environment and may find applications as artificial muscles, robot actuators, and adsorbers of toxic chemicals [13]. Hydrogels, which are cross-linked, three-dimensional hydrophilic networks that swell but not dissolve when brought into contact with water, are useful in applications such as biomedicine, biotechnology, pharmaceutical, veterinary, food industry, agriculture and other fields.

In the present study, the grafting of acrylamide onto peanut shell cellulose was performed by irradiation method. The effect of acrylamide monomer concentration and irradiation doses on hydrogels characterization such as grafting efficiency, swelling properties in distilled water were discussed. The main purpose of this research was for the removal of heavy-metal ions and dye from wastewater by using peanut shell cellulose-acrylamide hydrogel. In this research, the main progress was based on the laboratory scale experiment.

II. Materials and Method

2.1. Materials

Peanut shells were obtained from peanut field in Nyaung Oo, Mandalay region, Myanmar. Acrylamide monomer was extrapure analysis grade, and sodium hydroxide (NaOH), sodium hypochlorite (NaOCl), nitric acid (HNO_3) and ethanol were used.

2.2. Preparation of Cellulose Pulp from Peanut shells

The peanut shells were washed with tap water to remove dirty particles and other contaminants. They were sundried for three days to remove moisture. Dried shells were then ground into powder form using a mill and stored in a plastic bag.

The sample powder was treated with NaOH (750 ml, 1M) for two hours at 95˚C with continuous stirring. The dark slurry obtained was filtered and washed several times with distilled water and then dried. The dried powder was refluxed with a mixture containing 20% (v/v) of nitric acid in ethanol. This treatment was carried out thrice and the colour changed from brown to yellow in successive steps. The mixture was then filtered and washed with cold distilled water till the solution becomes neutral. The yellow coloured residue was then bleached with sodium hypochlorite to get off-white cellulose. It was then oven dried over night at 60˚C to obtain constant weight. Finally, the dried cellulose was ground and kept in polyethylene bags. Preparation of peanut shell cellulose-acrylamide graft copolymerization by gamma irradiation is shown in Fig. 1.

2.3. Preparation of Cellulose-Acrylamide Monomer Graft Copolymerization by Gamma Radiation

The prepared cellulose was firstly mixed with distilled water and stirred at about 350 rpm at room temperature for about 1.5 hours. Different ratios of acrylamide monomer (1:1, 1:1.5 and 1:2), was added to the cellulose mixture and poly-ethylene bags were used for the mixed samples to be irradiated. Graft copolymerization of cellulose-acrylamide monomer was carried out using Gamma Chamber (Cobalt-60, GC-5000) with the variation of doses ranging from 10 kGy to 30 kGy at room temperature (27˚C). The irradiated samples were cut into small pieces, dried at room temperature for measurement of grafting efficiency and swelling degree.

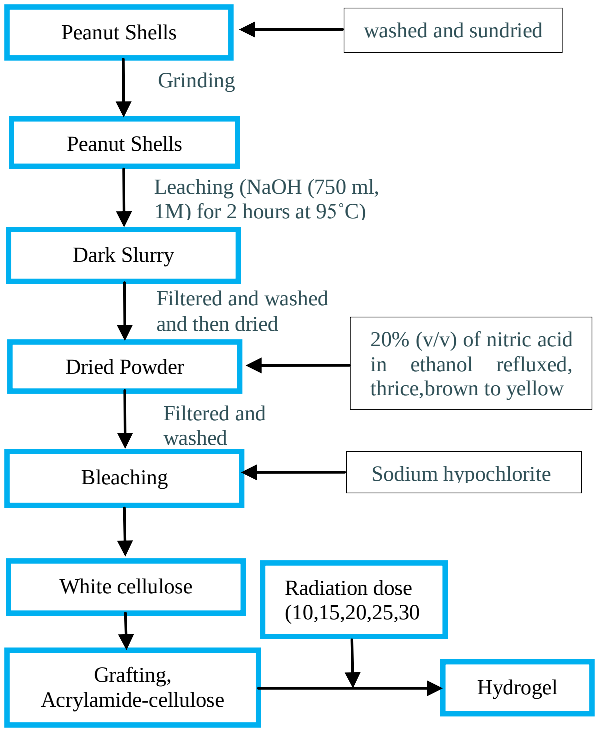

Fig. 1. Preparation of peanut shell cellulose-acrylamide graft copolymerization by simultaneous gamma irradiation

III. Analytical Method

3.1. Determination of Grafting Efficiency

Cellulose-acrylamide graft copolymers were washed with deionised water and separated. Then the product was dried in an oven at 65°C for 24 hours. Grafting efficiency was calculated by the following equation.

$$\text{GraftingEfficiency} = \frac{W_h - W_s}{W_m} \times 100 \quad (1)$$

W_h is weight of cellulose-acrylamide graft copolymer, and W_s is weight of cellulose, and W_m is weight of acrylamide monomer.

3.2. Determination of Swelling Degree

Hydrogel is firstly immersed in deionised water for about 48 hours at room temperature. After swelling, the copolymerized hydrogel product is filtered and weighed after

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

removing the surface water by soft tissue paper. The swelling degree (SD) of the product is calculated as shown in the following equation.

$$\text{Swelling Degree} = \frac{W_{ss} - W_d}{W_d} \times 100 \quad (2)$$

W_{ss} is weight of hydrogel in swollen state and W_d is the weight of dry hydrogel

3.3. Fourier Transformed Infrared Spectroscopy (FTIR)

Fourier Transform Infrared Spectroscopy (FTIR) identifies chemical bonds in a molecule by producing an infrared absorption spectrum. The FTIR spectrum was used to identify functional group of the active components based on the peak value in the region of infrared radiation. The FTIR spectra of the original cellulose and grafted cellulose-acrylamide were recorded by FTIR Spectrophotometer (IR-Prestige-21, Shimadzu, Japan) in the wave number range 500–4000cm-1. The FTIR spectrum was taken in a transmittance mode.

3.4. Scanning Electron Microscope (SEM)

Scanning electron microscope (SEM) was used to compare the morphological structures of original peanut shells cellulose and radiation grafted copolymer.

3.5. Effect of Stirring Rate

Rate at the adsorbent and adsorbate interact is one of the important feature in adsorption study. The effect of stirring rate was studied by conducting adsorption experiment at stirring speed of 200 rpm with dye concentration 50 ml and the adsorbent dosage of 1 g, and by putting hydrogel 1g into the dye concentration 50 ml for about five hours.

3.6. Effect of Contact Time

To know the effect of contact time, batch adsorption experiment was carried out at room temperature ranging from three to nine hours without pH adjustment. Exactly 50 ml of the dye solution of a known initial concentration was shaken at a certain agitation speed (200 rpm) with 1 g of the adsorbent.

3.7. Adsorption studies

To investigate the tendency of the hydrogel for the removal of heavy metal ions such as Cu, Pb and Cd in aqueous solutions, constant weight of dried adsorbents were used in batch experiments. Experiments were performed at room temperature by using mixture of 1g hydrogel and 50 ml metal ion solution in separate flasks which were stirred for one hour. After the adsorption was completed, the mixture was filtered, and the residual metal-ion content in the filtrate was determined by Atomic Absorption Spectrometry (AAS). The amount of metal ion adsorbed for experiment, the adsorption capacity (Q, mg/g) was calculated according to the equation:

$$Q = \frac{(C_o - C_A).V}{w} \quad (3)$$

where, C_0 and C_A are the concentration (mg/L) of metal ion in the initial solution and in the aqueous phase after adsorption, respectively, V is the volume of the aqueous phase (L) and W is the weight of the adsorbent (1 g). The efficiency for ions adsorption from the solution (R [%]) was calculated using Equation:

$$R = \frac{C_o - C_A}{C_o} \times 100 \quad (4)$$

3.8. Dye Adsorption Study

Batch adsorption experiments were carried out at room temperature for five hours without pH adjustment. Exactly 50 ml of the dye solution of a known initial concentration was shaken at a certain agitation speed (200 rpm) with 1 g of the adsorbent. After the desired contact time, the mixture was centrifuged and the remaining concentration of the dye was measured. The concentration of the dye at equilibrium C_e was determined using a UV-visible spectrometer. The calibration curve was determined by UV absorption intensity measurements for dye solution concentrations. Therefore, $\mathbf{q_e}$ values were calculated from the following equations:

$$q_e = \frac{(C_o - C_e).V}{w} \quad (5)$$

where C_0, and C_e is initial and equilibrium concentrations of the dye **(**mg/L**)**, respectively and w is the weight of the adsorbent (g) and V is the volume of dye solution (L). The removal percentage of the hydrogel was calculated using Equation:

$$R = \frac{W}{W_o} \times 100 \quad (6)$$

where W is the amount of adsorbed dye and W_0 the initial amount of dye.

IV. RESULTS AND DISCUSSIONS

4.1. Effect of Alkaline Concentration on Yield of Peanut Shells Powders

The yields of peanut shell powders after leaching process were studied using various concentrations (2%, 4%, and 6%) of sodium hydroxide as shown in Table I.

The results from Table I show that yield of leached peanut shell powders were the highest when 2% concentration of sodium hydroxide was used. The lowest yield was obtained when 6% concentration of sodium hydroxide was used.

TABLE I. Effect of Alkaline Concentration on Yield of Peanut Shells Waste Powders.

Sample No.	Peanut shell powders (g)	Weight of NaOH (g)	Volume of Water (mL)	Concentration (%) of NaOH	Yield (%)
1	25	15	750	2	62
2	25	30	750	4	52
3	25	45	750	6	51

There was no significant difference in the yield of samples and quality of cellulose by changing the concentration of alkaline solution, however, it means that the higher the concentration, the lower the yield of samples. An increase in the concentration of reactants results in an increase in the reaction rate. At higher concentration, the molecules of the reactants are closer to each other; therefore, collisions occur more frequently, a higher percentage of collisions are effective, and the reaction rate increases. According to my research 4%

Myo Khaing and Khin Khin Lay, “Radiation Grafting of Peanut Shell Cellulose- Acrylamide Monomer for Production of Hydrogel to be used in Industrial Wastewater Treatment,” *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 1, pp. 154-159, 2019.

of sodium hydroxide was the most suitable not only in regard to yield and quality but also in regard to the consumption of alkali. All the treatments were done at reaction temperature 95 ˚C and reaction time was two hours.

4.2. Effect of Radiation Doses on Grafting Efficiency and Swelling degree

The grafting efficiency and swelling degree were investigated with different irradiation doses ranging from 10 kGy up to 30 kGy using ratio of cellulose to acrylamide (1:1.5) as shown in Table 2.

In Table 2, it can be seen that the grafting efficiency increased with increasing radiation dose and attained 68.35 % at the radiation dose of 20 kGy. After that the irradiated cellulose-acrylamide is not significantly affected by further radiation dose increase. An increase in the radiation dose enhances the formation of radicals in the reaction mixture of acrylamide monomer, cellulose, and water. The high total dose can induce enough active grafting sites on the cellulose backbone for the grafting of monomer. Therefore increasing the total dose reduces the homopolymer content and increases the grafting efficiency.

It was found that the swelling of hydrogel increased with the increased radiation dose from 10 to 15 kGy. But the swelling degree decreased by increasing radiation dose from 15 to 20 kGy. These could be explained that the increasing radiation dose enhances the number of free radicals on the cellulose chain and, therefore, form more cross-linking between cellulose chains. Higher in crosslink density reduces the free volume available for swelling by increasing the tightness of the network structure.

At initial radiation dose (10 to 15 kGy), the produced free radicals may not be enough to increase the crosslink density in the network. At a saturation point or maximum crosslink density, the irradiated cellulose-acrylamide is not affected remarkably by further additional radiation doses. This may be due to some destruction of cellulose. The swelling degree linearly decreased with the increasing in radiation dose and crosslink density.

TABLE II. Effect of Radiation Doses on Grafting Efficiency and Swelling Degree (ratio of cellulose to acrylamide (1:1.5))

Radiation Doses (kGy)	Grafting Efficiency (%)	Swelling Degree (%)
10	59.55	640
15	62.1	658
20	68.35	561
25	68.54	514
30	69.35	505

4.3. Effect of Ratio of Cellulose to Acrylamide on Grafting Efficiency and Swelling degree

The effect of cellulose to acrylamide ratio on the grafting efficiency and swelling degree of the hydrogels was investigated at 20 kGy of gamma radiation dose as shown in Table 3.

The results show that the grafting efficiency increased with the increasing monomer ratio from 1 up to 2. This behaviour can be attributed to the increase of monomer ratio in the surrounding of cellulose backbone and greater availability and enhancement chances for molecular collisions of the reactants.

TABLE III. Effect of Ratio of Acrylamide on Grafting Efficiency and Swelling Degree at 20 kGy.

Cellulose : Acrylamide Ratio	Grafting Efficiency (%)	Swelling Degree (%)
1:1	63.38	682
1:1.5	68.35	561
1:2	70.23	480

At higher ratio of monomer, the free radicals come closer than lower concentration of monomer and that tends to form more cross-links. Therefore, with increased cross-linked density, swelling ratio decreased due to reduced vacant space of cross-linking network for free solvent to enter into it.

4.4. Characterization of Peanut Shells Cellulose and Grafted Copolymers using FTIR Spectroscopy

One way to evaluate the success of grafting of acrylamide onto cellulose is by comparing the functionality of the original cellulose with that of the grafted cellulose. For this purpose, the original cellulose and grafted cellulose were characterized using FTIR spectroscopic technique. Infrared spectroscopy was applied to identify the chemical structure of the original cellulose and the prepared hydrogels.

The FTIR spectrum of the original cellulose of peanut shell was shown in Fig. 2 and the spectrum of radiation grafted copolymer was presented in Fig. 3. Fundamental vibrations in the 4000-2500 cm^{-1} region are due to O-H, C-H and N-H stretching. O-H stretching produces a broader band and N-H stretching is usually observed between 3400 and 3300 cm^{-1}. According to the results of FTIR spectroscopy, spectra of both peanut shell cellulose and grafted cellulose showed nearly the same profile. The IR spectra of the cellulose-acrylamide grafting composite cross-linked by gamma irradiation indicate the disappearance of some absorption bands and the appearance of others, as shown in Fig. 3.

In Fig. 2, the absorption peak at 3288.63 cm^{-1} is assigned to the stretching of –OH groups, which was diminished after graft-copolymerization. It can be explained that the partial hydrogen bond of cellulose was destroyed enhancing the new formation of cross-links with acrylamide monomer. The changed spectra can be seen with the peaks at 3271.27 cm^{-1} in Fig. 3. Those bands indicate the N-H stretching of the amide bands, which are characteristics of the $–CONH_2$ group present in the acrylamide monomer.

The another obvious characteristic of the grafted cellulose spectra which distinguished them from the spectrum of the original cellulose (at 2893.22 cm^{-1}) was the sharp presence of absorption bands at 2850.79 cm^{-1}in Fig. 3 which indicated the presence of amide secondary amine group. These changes provided strong evidence of the grafting of acrylamide onto cellulose. The spectrum of grafted cellulose also shows band at 1600 $cm^{–1}$ and 1651 cm^{-1}.Those bands indicate the N–H bending of the amide bands, which are presented in the acrylamide. The peaks at 1446.61 and 1317.38 cm^{-1} represent the bending vibration for CH_2 and CH_3 groups of acrylamide.

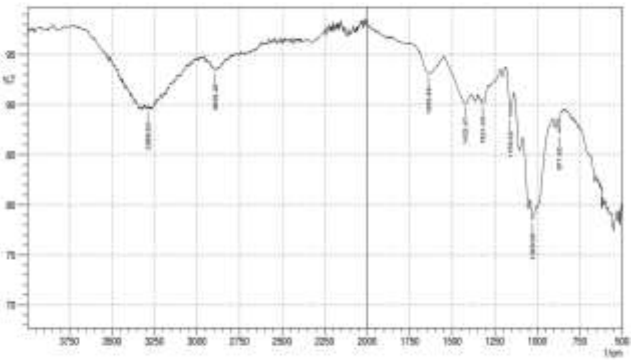

Fig. 2. The FTIR spectra (4000-500 cm^{-1}) of the original peanut shells cellulose

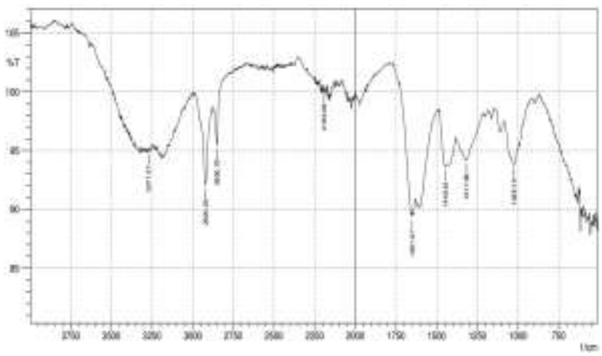

Fig. 3. The FTIR Spectra (4000-500 Cm^{-1}) of Radiation Grafted Copolymer

4.5. Characterization of Peanut Shells Cellulose and Grafted Copolymer Hydrogels using Scanning Electron Microscope (SEM)

The scanning electron microscopes of peanut shell cellulose and grafted copolymer hydrogels are shown in Fig 4 and Fig 5.

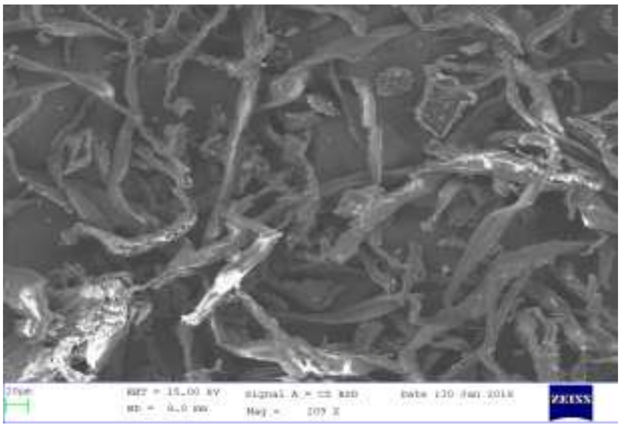

Fig. 4. SEM Picture of Original Peanut Shell Cellulose

The morphology of peanut shell cellulose and grafted copolymer hydrogel were examined by means of scanning electron microscope (SEM) with the aim of detecting qualitatively the presence of connected micro porosity. According to the figures, it can be seen that interconnected micro porosity seems to be present after radiation grafting of acrylamide monomer onto the cellulose backbone. Interconnected pores provided more available regions for the diffusion of water molecules, and thus, the hydrogel may demonstrate a higher water absorption capacity.

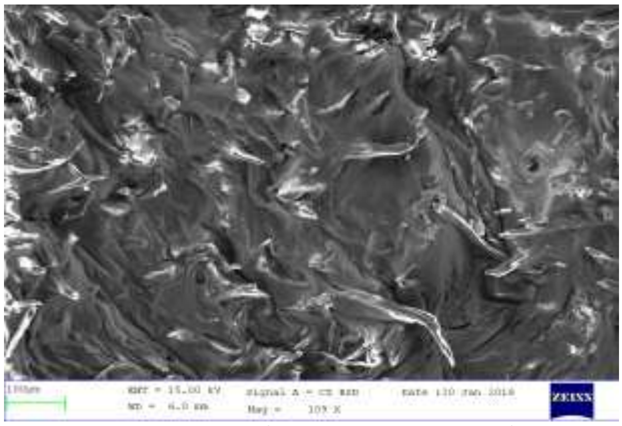

Fig. 5. SEM Picture of Cellulose -Acrylamide Grafting

4.6. Effect of Stirring Speed on Adsorption Process

Effects of stirring speed on the adsorption capacity and removal efficiency are shown in Table 4. It is observed that there is no considerable difference in the removal efficiency and adsorption capacity of dyes.

TABLE IV. Effect of stirring speed for the adsorption of dye by peanut shell cellulose-acrylamide hydrogel

Sample No:	Stirring speed (rpm)	Removal efficiency (%)
1	200	39
2	0	38

4.7. Effect of Contact Time

The contact time between adsorbent and adsorbate is an important factor when doing adsorption study. There is no significant different in the adsorption capacity and removal efficiency of peanut shell cellulose-acrylamide hydrogel with increasing the contact time as shown in Table 5. The dyes get attached to the adsorption sites very easily [13]. However, as the times goes the adsorption of the dyes became slowly which is as a result of the increased of the concentration of the dyes in the adsorption sites. The contact time five hours is chosen although the results are not different because the value of adsorption capacity and removal efficiency is high.

TABLE V. Effect of contact time for the adsorption of dye by peanut shell cellulose-acrylamide hydrogel

Sample No:	Time (hr)	Removal efficiency (%)
1	3	35
2	5	41
3	7	36
4	9	39

4.8. Adsorption of Heavy Metal Ions

A promising adsorbent material has to be able to remove considerable amounts of adsorbate at low doses. This feature is paramount to reduce operational costs and minimize the risks related to the secondary pollution. Under the experimental conditions, the adsorption capacity of the chelating hydrogel for the tested metal ions of Cu, Pb and Cd and the percentage removal of dye are presented in Table 6. It was observed that the percentage removal of dye with Cu is 45%, Pb is 64% and Cd is 48%, respectively. On the other hand, the adsorption capacity with Cu is 5 mg/g, Pb is 14 mg/g and Cd is 10 mg/g, respectively. In the literature, different affinity sorbents with a wide range of adsorption capacities for heavy metal ions have been reported. Shreedhara-Murthy and Ryan found 5–27 mg/g Cu(II) removal by cellulose dithiocarbamate resins [11].

TABLE VI. Various heavy metal result of the testing solutions on the adsorption capacity (Q), percentage (R[%]) and desorption (%) for the tested metal ions.

Heavy Metal	Adsor-bent Dose (g)	Initial Concentra-tion (mg/g)	After Adsorp-tion (mg/g)	Adsorp-tion Capacity (mg/g)	Removal (%)
Cu	1	204.8	111.88	5	45
Pb	1	436	155.25	14	64
Cd	1	396	204.60	10	48

4.9. Dye removal

The value of equilibrium adsorption capacity (qe), the percentage removal of dye and desorption study are presented in Table 7. The result for the dye, the removal efficiency is 37% achieved.

TABLE VII. Black dye result of the testing solutions on the adsorption capacity (Q), percentage (R[%]) and desorption (%) for the tested dye

Adsorbate	Adsorbent Dose(g)	Initial Concentrat ion	Final Concentrat ion	Removal (%)
Black Dye	1	0.498	0.314	37

V. CONCLUSIONS

Cellulose was isolated from peanut shell which is an agro waste by alkaline treatment followed by bleaching. Peanut shell cellulose has been successfully modified through graft copolymerization with acrylamide monomer by using gamma radiation as efficient free radical initiators. In respect to degree of grafting, 20 kGy radiation dose and monomer ratio (1:1.5) can be considered as a suitable radiation dose and ratio for the preparation of acrylamide grafted cellulose. FTIR analysis showed that acrylamide had been grafted onto cellulose successfully. The higher the radiation dose the higher the grafting efficiency of cellulose-acrylamide hydrogels. However, swelling degree was found to be inversely proportional with radiation doses. The increasing of acrylamide monomer ratio increases the grafting efficiency but also inversely proportional to the swelling degree. In this study, we can see the synthesis of significantly capable hydrogel for the removal of heavy metal ions such as Cu, Pb and Cd from aqueous solution. These results suggest that the prepared hydrogel is good heavy metal ions adsorbents and can have great potential applications in environmental protection. In addition, the capacity of dye removal of the hydrogel was investigated. It is found that the adsorption capacity of the prepared hydrogel is mainly dependent on type of chemical structures of the pollutants.

ACKNOWLEDGMENT

The author would like to express sincere thanks to technical staff members in the analytical laboratory at Pyin Oo Lwin (GTI) for the help in FTIR and SEM analysis methods. He would like to extend his gratitude to Dr. Tin Tin Myint, other teachers and friends from Department of Nuclear Engineering, Mandalay Technological University who helped him directly or indirectly in this paper. I would like to express special thanks to Daw Thin Thin Soe, principal scientist, and other technical staff members at the Division of Atomic Energy, Yangon for the permission and help for gamma chamber application.

REFERENCES

[1] A. Masoumi and M. Ghaemy, “Adsorption of heavy metal ions and azo dyes by crosslinked nanochelating resins based on poly (methylmethacrylate-co-maleic anhydride),” *eXPRESS Polymer Letters*, vol. 8, no. 3, pp. 187–196, 2014.

[2] Md. Tamez Uddin, Md. Arifur Rahman, Md. Rukanuzzaman, and Md. Akhtarul Islam, ‘’A potential low cost adsorbent for the removal of cationic dyes from aqueous solutions,” *Appl Water Sci*, vol. 7, pp. 2831–2842, 2017.

[3] Zakariyya Uba Zango and Saifullahi Shehu Imam, “Evaluation of microcrystalline cellulose from groundnut shell for the removal of crystal violet and methylene blue,” *Nanoscience and Nanotechnology*, vol. 8, issue 1, pp. 1-6, 2018.

[4] Gulten Gurdag and Shokat Sarmad, “Cellulose graft copolymers: synthesis, properties, and applications,” *Polysaccharide Based Graft Copolymers*, pp. 15-57, 2013.

[5] N.C. Dafader, N. Rahman, and M. F. Alam, “Study on grafting of acrylic acid onto cotton using gamma radiation and its application as dye adsorbent,” *Nuclear Science And Applications*, vol. 23, no. 1&2, pp. 37-40, 2014.

[6] N. C. Dafader, M. N. Adnan, M. E. Haque, D. Huq, and F. Akhtar, “Study on the properties of copolymer hydrogel obtained from acrylamide/2-hydroxyethyl methacrylate by the application of gamma radiation,” *African Journal of Pure and Applied Chemistry*, vol. 5, issue 5, pp. 111-118, 2011.

[7] Priyamwada Bharthare, Preeti Shrivastava, Pushpendra Singh, and Archana Ttiwari, “Peanut shell as renewable energy source and their utility in production of ethanol,” *International Journal of Advance Research*, Volume 2, Issue 4, pp. 1-12, 2014.

[8] Grandawa, Musa Mohammed, “Characterisation of physico-chemical properties of arachis hypogaea l. shells (groundnut) as environmental remidation,” *Int'l Conference on Chemical, Biological, and Environmental Sciences (ICCBES’14)*, May 12-13, 2014.

[9] Dr. Myo Kywe, Dr. Kyi Toe, “Overview of Myanmar agriculture,” Yezin Agricultural University.

[10] Nabil A. El-Kelesh and Ghada A. Mahmoud, “Synthesis and properties of treated waste cellulose and gma grafted composite to remove different acid dyes from aqueous solutions,” *Cellulose Chem. Technol*., vol. 49 issue 9-10, pp. 881-889, 2015.

[11] S. Sultana, M. R. Islam, N. C. Dafader, and M. E. Haque, “Preparation of carboxymethyl cellulose/acrylamide copoly-mer hydrogel using gamma radiation and investigation of its swelling behavior,” *Journal of Bangladesh Chemical Society*, vol. 25, issue 2, pp. 132-138, 2012.

[12] D. Swantomo, Rochmadi, K. T. Basuki, and R. Sudiyo, “Synthesis and characterization of graft copolymer rice straw cellulose-acrylamide hydrogels using gamma irradiation,” *Atom Indonesia*, vol. 39, no. 2, pp. 57–64, 2013.

[13] A. M. Abdel Ghaffar, M. B. El-Arnaouty, A. A. Abdel Baky, and S. A. Shama, “Radiation-induced grafting of acrylamide and methacrylic acid individually onto carboxymethyl cellulose for removal of hazardous water pollutants,” *Designed Monomers and Polymers*, vol. 19, issue 8, pp. 706-718, 2016.