Treatment Of Waste Water By Using Nanosilica From Rice Straw

Su Su Aung [1], Myat Myat Thaw [2]

Abstract

Rice is the most important food crop of the developing world and the staple food of more than half of the world's population. Generally, rice is grown and planted twice a year where a lot of rice by-products have been produced after harvesting the matured paddy. Rice straw is one of turning waste products into the valuable resources and to manage the environmental issues. This research work deals with finding an appropriate treatment process to enhance the utilization of rice by-products as precursors for producing efficient nanosilica. Novel nanosilica was synthesized from rice straw by sol-gel method. Physiochemical properties such as pH value, bulk density and moisture content of synthesized nanosilica were measured by AOAC method. The extracted nanosilica was characterized by EDXRF, SEM, XRD and FTIR spectroscopy. And then, the adsorptive properties of nanosilica was applied to reduce the turbidity of water sample due to effect of dosage and effect of contact time. Their efficiency, limitations, and advantages were compared and discussed.

Keywords – nanosilica, sol-gel method, turbidity, rice straw, physiochemical properties

Introduction

Nowadays, nanomaterials have also provided a promising approach to removing heavy metals from wastewater. In general, nanosilica are materials whose external dimensions are in the nanoscale (usually 1–100 nm) or nanoscale internal surface. These properties contribute to their extraordinary adsorption capacity and reactivity, both of which are favorable for the removal of heavy metal ions. So far, tremendous studies on nanosilica have been carried out to investigate their applications on heavy metal water treatment and they have exhibited great potential as a promising alternative to adsorbing heavy metals and turbidity from waste water (Cui and. Liu, *et al*., 2017). Rice straw and rice straw ash (RSA) are interesting sources of considerable levels of high quality silica, which has several applications. The production of nanosilica at industrial scale is based on mechanical, physical, chemical, and energy intensive thermal operations at high temperatures using large amounts of acids, generating significant volumes of effluents. Rice straw has exclusive nonporous silica layers. Silica is a basic raw material widely used in the semiconductors, ceramics, polymers, and materials industries and this silica is usually produced from quartz fused at high temperatures, which affords to obtain ultrapure polycrystalline silicon and silicon hydride (Egorova and Revina., 2000).[1]

In addition to environmental and economic advantages, low-energy, simpler methods to obtain pure nanosilica create opportunities for the development of new industrial applications of removal of heavy metals from wastewater (Kamath and Proctor,1998). Various methods are used to produce larger amounts or pure or ultrapure nanosilica from rice straw Figure 1.

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Botanical Description

Common name = Rice straw or paddy straw

Botanical name = *Oryza sativa* L.

Family name = Poaceae

Myanmar name = Kaukyoe

Plant part used = Stem

Figure: 1 Photograph of rice straw (Banmaw Township)

Materials and Methods

All chemicals and reagents used in this research were analytical and reagent grade obtain from Banmaw University. In all the investigations, the recommended and standard procedures of both conventional and modern techniques were employed. Instruments employed in this work consist of lab wares, glass wares and other supporting facilities. The experiments were carried out in the Laboratory of the Department of Chemistry, Banmaw University and the spectroscopic analyses were studied at the University Research Centre from University of Yangon, Magway University and Monywa University.

Preparation of Nanosilica from Rice Straw

Rice straw was collected from Shwekyina village, Banmaw Township, Kachin State. Silica nanoparticles production from agricultural waste (rice straw) were synthesized by sol-gel method (Le , 2017). The obtained rice straw was washed with distilled water to neutralize the pH in order to remove the sand, dust, light empty grains and fine dirt. Hence, the repeated washing of rice straw (RS) neutralizes the pH and removes the adhered impurities on the surface of silica. Rice straw (RS), an inexpensive waste material, was used to produce nanosilica. The silica was obtained by using sol-gel method, which involves extraction of silica using alkalis solution and gelation of the silica using acid solution. To evaluate the effect of purification parameter and to confirm the presence of silica, XRD analysis was carried out on silica nanoparticles for 2.5 M KOH treatments Figure 2. Moreover, the synthesized silica nanoparticles from rice straw were characterized by SEM, FTIR and XRD (Egorova and Revina., 2000).

Collection of Water Sample

The waste water sample was collected from Shwegu Township, Kachin State near agricultural side. Figure 3. Sample collection and testing of water qualities were continuously made within 24 hours.

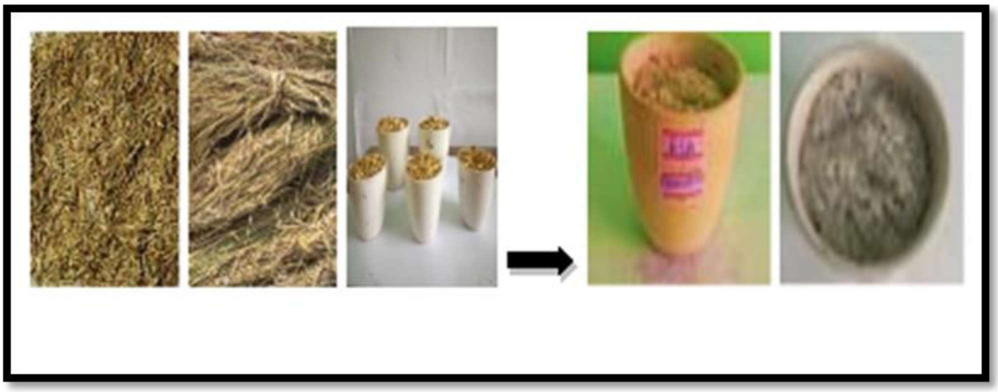


Figure 2. Rice straw to nanosilica

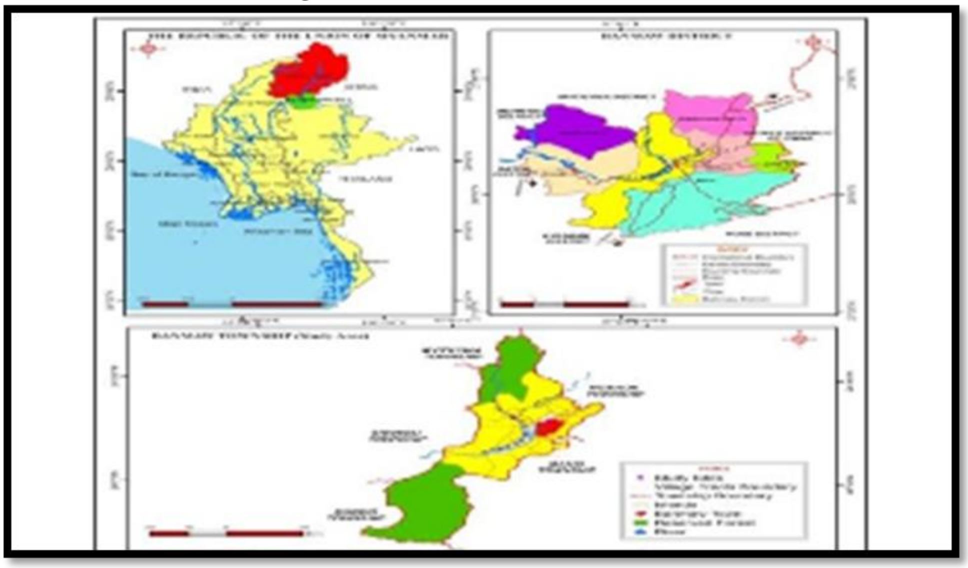


Figure 3. Sampling sites for rice straw and waste water

Physicochemical Properties of Synthesize Nanosilica

Determination of Bulk Density

The cylinder was filled with the ash up to 10 cm^3 and weighed. It was tapped gently until there is no more reducing in volume. The volume was recorded and the bulk density was calculated by the following equation (AOAC, 1990). (European Pharmacopeia, 2010).

$$\text{Bulk density} = \frac{\text{weight of ash (g)}}{\text{final volume of ash}(cm^3)}$$

Determination of Moisture Content

Moisture content of nanosilica was determined by the oven method. Accurately weighed sample 1.0 g was added to porcelain basin and then heated for 1 hour in drying oven at 100 ± 5 °C. After heating, the porcelain basin was removed from the oven and placed in desiccator for cooling and then weighing was repeated until a constant weight was obtained (AOAC, 1990).

Determination of pH

1.0 g of the nanosilica was placed in a beaker and then 100 mL of distilled water was added and stirred by magnetic stirrer for 30 minutes. The resulting solution was filtered and pH of the filtrate was measured by using pH meter.

Determination of Physicochemical Properties of Water Sample

The physicochemical parameters of collected water sample were investigated within 1hour . The turbidity of water was determined by turbidity meter water testing in Figure 4. The results were shown in Table 4.

Treatment of Water Sample with Synthesize Nanosilica

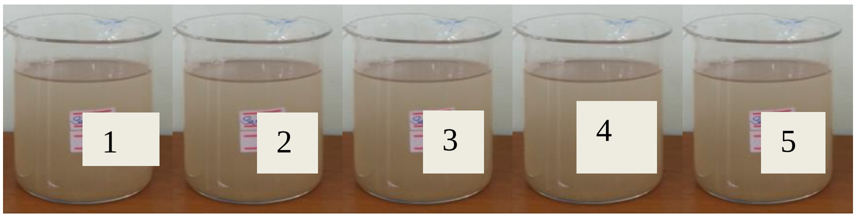
Effect of dosage on turbidity of waste water sample

Accurately weighed of nanosilica sample varying from 0.01 g to 0.05 g were thoroughly mixed with 50 mL of waste water sample. Then they were shaken on electric shaker for 1 h with 150 rpm of rotation speed. After shaking, the water sample were filtered. The turbidity of water was determined by turbidity meter water testing. The result was shown in Table 5 and Figure 4.

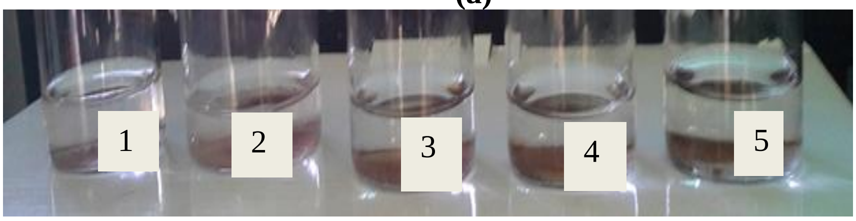
Figure 4. Instruments used for water quality

Effect of contact time on turbidity of waste water sample

In the contact time experiment 0.01g nanosilica of known particle size were brought into contact with a fixed volume of (50 mL) water sample. Then they were shaken on electric shaker for (10 min to 60 min) with 150 rpm of rotation speed. After shaking, the water sample were filtered. The contact time measurements were made at ambient temperature. The turbidity of water was determined by turbidity meter and water testing. The result was shown in Table 6 and Figure 5 (a)(b).



(a)



(b)

Figure 5 (a) Water sample before treated with synthesize nanosilica
(b) Water sample after treated with synthesize nanosilica

Results and Discussion

Physicochemical Properties of Nanosilica

The bulk density, moisture and pH of synthesized nanosilica was shown in Table 1. It was shown that the bulk density and pH value of nanosilica are 0.6 gcm^{-3} and 9.1. The higher the bulk density of the nanosilica, the more porosity on the surface of nanosilica can exist. The moisture % of nanosilica is absolutely zero. According to the experimental result, it can be found that the synthesized nanosilica has adsorptive nature to be used as an adsorbent for colour removal (WHO, 2008).

Table 1. Physicochemical Properties of Nanosilica

No	Parameters	Value
1	Moisture (%)	0.001
2	Bulk density (gcm^{-3})	0.602
3	pH	9.101

Characterization of Silica Nanoparticles from Rice Straw Ash

EDXRF analysis

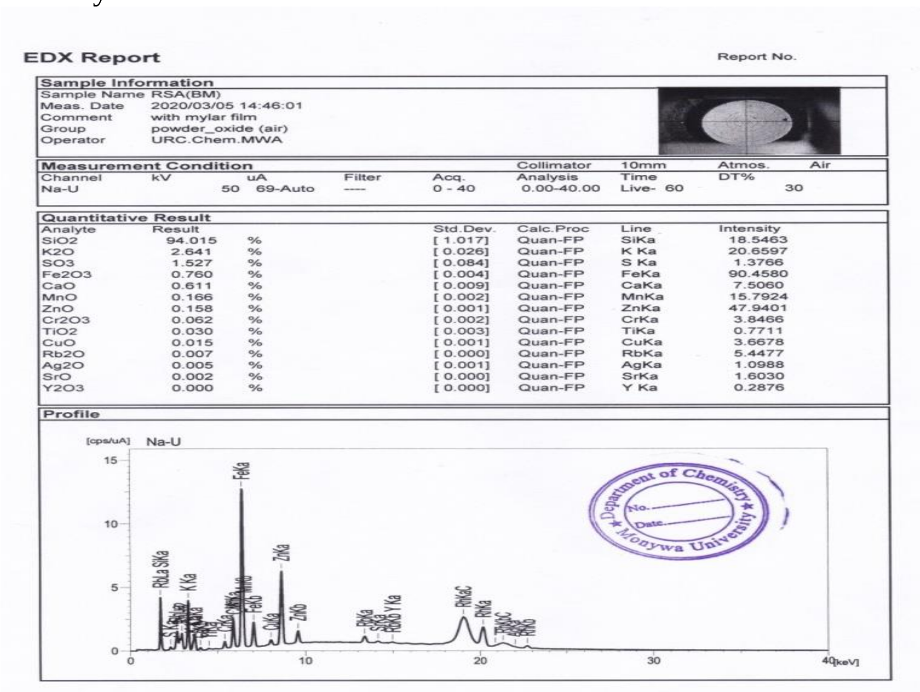


Figure 6 Energy Dispersive X-ray Fluorescence (EDXRF) spectra of synthesize nanosilica

Mineral contents in extracted silica were measured by using Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer at Department of Chemistry, Monywa University. According to the EDXRF results, the content of silica (98.871%) was observed in nanosilica and absent of toxic heavy metals (such as Hg, Pb, Cd and As). The result was shown in Table 2.

Table 2 Relative Abundance of Nanosilica from Rice Straw by EDXRF Analysis

Oxide Forms	*Relative Abundance (%) from Nanosilica*
SiO_2	98.871
K_2O	0.277
SO_3	0.443
CaO	0.121
MnO	0.040
Fe_2O_3	0.094
CuO	0.010
ZnO	0.119

SEM analysis

To extract the amorphous silica nanoparticles from rice straw the following procedure was utilized. First, the rice straw was washed with distilled water to remove any impurities that can contaminate the final silica product as well as washing can dissolute some soluble substances, including metal salts, allowing a preliminary chemical purification (Kamath and Proctor,1998). Second, the hydrothermal process at sub-critical water conditions was carried out at high-temperature, high-pressure, and acidic media with strong oxidation activities (using nitric acid). At those conditions the organic compounds can be decomposed, and the trace metals can be turned into soluble ions; then, silica can be obtained. The morphology of SiO_2-based nanoparticle is illustrated in Figure 7. As shown in the figure, the diameter of each nanoparticle NP ranges from 10 to 30 nm indicating that the NP is nanosized (Cui and. Liu, *et al*., 2017).

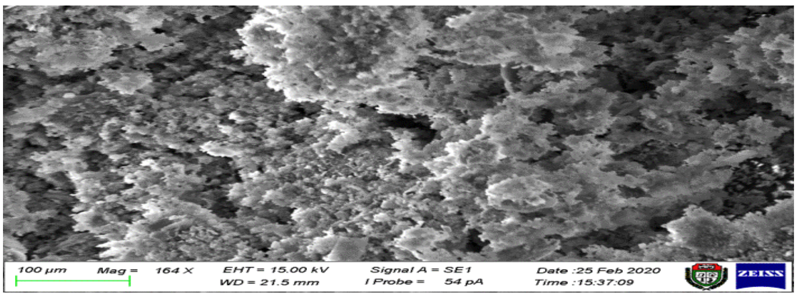


Figure 7 . SEM image for synthesize nanosilica

FTIR analysis

Silica was synthesized from rice straw with extraction, were analyzed with FTIR and Figure 8 had shown the spectrum. Main peak at wave number 1073.15 cm^{-1} was showed the typical for stretching vibration for –OH (Hydroxyl group).

Therefore, silica was used as sample, had hydroxyl group. It showed Si-OH bond or silanol. Although the vibration was not only silanol bond but also –OH from water which could not be ignored. Second peak at 791.56 cm^{-1} showed silica group. It showed siloxane group Si-O-Si. Siloxane group were made sure with peak at 619.96 cm^{-1} and deformation of Si-O bond for SiO_4. Other peak with high intensity was shown at 465.67 cm^{-1}. It showed carbonyl vibrational stretch from hemicellulose. It might be dissolved when extraction process and adsorbed by silica also H-O-H bond and silinol to metal. The results are described in Table 3.

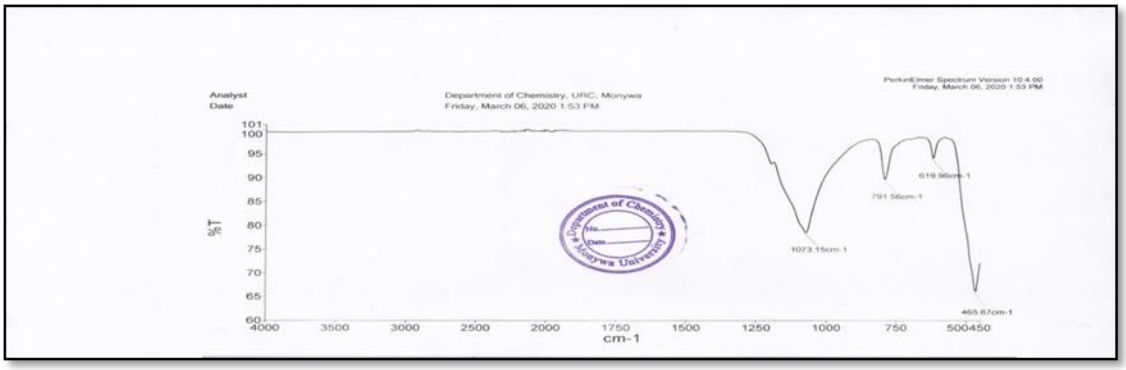


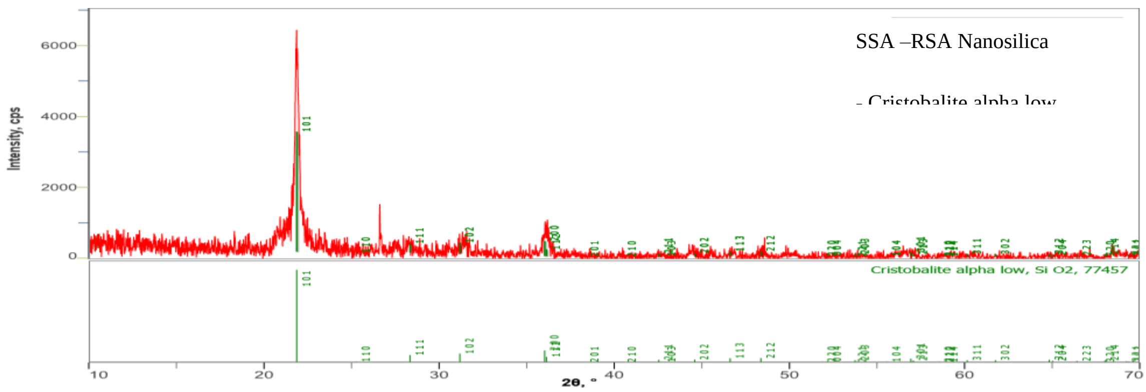
Figure 8. FTIR spectrum for nanosilica

Table 3. FT-IR spectral data of nanosilica

Frequency (cm^{-1})	Position assignment
1073.15	–OH (Hydroxyl group)
791.56	Si-O-Si bending (silanol)
619.96	deformation of Si-O
465.67	Si-O and metal

XRD analysis

XRD patterns of the obtained silica powder were recorded using a powder X-ray diffractometer (X' Pert Pro, PAN atypical, The Netherlands) with Cu-K (wavelength 1.5406 as a radiation source. The average crystallite size of the nanosilica powder was calculated from XRD pattern by using the Scherrer's equation:



where D p is the size of the particle, ʎ the wavelength of X-ray, β ½ the wavelength of full width half maximum and θ the peak position. The resulting pattern showed amorphous silica, with additional phase at 2θ=31.46 and 50.16. There was no phase that appeared at 2θ=22. Based on the table, main peak from the cristobalite difractogram and quartz polymorphy appeared as companion phase and polymorph tridimit did not appear (Liou and Yang, 2011). This result was similar with previous research. Standard nanosilica was shown in Figure 9 .

Table 4. Physicochemical Properties of Waste Water Sample

No	Parameters	Value
1	pH	7.6
2	EC(mS/cm)	0.82
3	TDS(g/L)	9.101
4	DO(ppm)	8.2
5	Salinity	0.4
6	Turbidity(NTU)	59.8

Effect of dosage on turbidity of waste water sample

In order to find out the minimum amount of nanosilica required for the removal of turbidity on waste water sample, the experiments of dosages were calculated. It was evident that for the quantitative removal of 0.01g of nanosilica in 50 mL was required. It was observed that by increasing the dose from 0.01 g to 0.03 g the removal efficiency increases and attain to constant. The results are described in Table 5.

Table 5. Effect of dosage on turbidity of waste water sample

Dosage (g) of nanosilica	Removal (%)
0.01	85.5
0.02	87.3
0.03	89.2
0.04	89.5
0.05	89.5

Effect of contact time on turbidity of waste water sample

The effect of contact time for the removal of turbidity on waste water sample (10 min to 60 min). The minimum dosage 0.01g was used to attain equilibrium. Table 6 show effect of contact time on the removal of turbidity on water sample. It was observed that, the percent of removal increases with time and attain the equilibrium at 40 min. After 40 min the removal percent become independent of contact time, the experiments of dosages were calculated.

Table 6. Effect of contact time on turbidity of waste water sample

Contact Time (min)	Removal (%)
10	30.4
20	52.2
30	75.1
40	85.5
50	85.5
60	85.5

Conclusion

Nanosilica has been extensively exploited to remove turbidity of waste water owing to their exceptional properties. Nanosilica was summarized in table at the end of this review. Nanosilica exhibit great advantages as adsorbents towards turbidity of waste water. Nevertheless, there are still some bottlenecks that needed to be overcome to make better use of these nanomaterials in waste water treatment. First, most nanosilica was unstable and tend to aggregate, thus reducing their removal capacity. The nanosilica seems to be a promising approach to solving these problems. Second, the commercial nanosilica used for heavy metals removal on an industry scales are rare and more efforts are needed to develop market-available nanomaterials. The synthesis, as well as operating costs of nanomaterials should be optimized for the sake of the economy and the production of these nanomaterials should meet the requirements of green chemistry. Last but not least, with the increasing use of nanomaterials in waste water treatment, their impacts and toxicities towards both the environment and human beings should be taken into consideration.

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