Extraction of Nickel Nanoparticles from Electroplating Waste and Their Application in Production of Bio-diesel from Biowaste

Abhishek Kumar Sharma, Sameerah Desnavi, Charu Dixit, Utkarshaa Varshney, and Ankur Sharma

***Abstract*—Electroplating waste samples were collected from various nearby industries in Aligarh, Uttar Pradesh (India), a prominent place for these industries and it was found that the concentrations of Cr^{+6}, Ni^{+2}, Cu^{+2} and Zn^{+2} ions were much more than the permissible norms of discharge which causes serious damage to the environment. To cater this issue, these heavy metal ions were extracted from the sample and then converted to their respective oxide nanoparticles by chemical precipitation and sol-gel methods respectively. And then, these nanoparticles were characterized by FTIR and XRD techniques. Also one of the major wastes produced in India is the butchery waste which causes severe health problems and is aesthetically unpleasant. This paper mainly focuses on the production of biodiesel from butchery waste by a new pathway utilizing heterogeneous nano-catalysts of Nickel(Ni^{+2}) (extracted from electroplating waste) for the process of trans-esterification, which produces biodiesel which are mono-alkyl esters of long chain fatty acids (FAME-Fatty Acid Methyl Esters).**

***Index Terms*—Electroplating waste, nanoparticles, chemical precipitation, sol-gel, XRD, FTIR, butchery waste, trans-esterification , biodiesel.**

I. Introduction

Due to rapid industrialization, urbanization and rise of living standards, there is a serious increase in environmental pollution. Apart from this, economic and industrial development and growth in Nation’s economy, there is a serious need of management and safe disposal of this waste. In cities like Aligarh in Uttar Pradesh (India), where these electroplating, lock, brass-hardware, leather, steel industries are flourishing day by day, the waste produced by them is a problem of global concern. This waste largely contains the heavy metal ions like Cu (II), Zn (II), Cr (VI) and Ni (II) etc. Till now this heavy metal waste is dumped directly into the environment without any significant scientific treatments [1]. So, it’s a very serious issue.

In India, Butchery waste is produced in large quantities especially during the festival of Eid-ul-zuha which causes environmental problems as well as diseases [2]. This waste contains a large amount of triglycerides which can be converted into biodiesel. Biodiesel is technically competitive with conventional, petroleum-derived diesel fuel and requires virtually no changes in the fuel distribution infrastructure. Other advantages of biodiesel as compared to petro-diesel include reduction of most exhaust emissions, biodegradability, higher flash point, inherent lubricity [2]. Moreover, Production of biodiesel from animal fats is less expensive than traditional methods like extraction of biodiesel from trans-esterification of soya-bean oil [3], [4], jatropha, vegetable oils, waste cooking oils [5], [6] etc.

In order to meet these challenges, we had made an attempt for utilizing the electroplating waste for extracting the nanoparticles (heterogenous catalysts) by chemical precipitation and sol-gel method and then using these nanoparticles in production of bio-diesel from the butchery waste [7], [8].

II. Experimental

Few samples were collected by us from the nearby industries (names can’t be disclosed). These industries generally produce two types of waste:

- The waste produced after Chrome plating,
- The waste produced after Ni plating.

The pH of chrome plating waste was found to be 0.7 and the pH of Ni plating waste was found to be 1.5.

After testing these samples in atomic adsorption spectrophotometer in the Department of Applied Chemistry, AMU, Aligarh, the observation result is shown in Table I. We got very drastic and unbelievable results. The concentration of the heavy metals was found to be thousands times more than the permissible limit set by the Bureau of Indian Standards (BIS).

TABLE I: Concentration of Heavy Metal Ions in Waste Samples

	Ni^{+2} (ppm)	Cr^{+6} (ppm)	Cu^{+2} (ppm)	Zn^{+2} (ppm)
Nickel plating waste	30000-40000	20-40	5-10	5-8
Chrome Plating Waste	70-100	80000-120000	300-350	150-200

A. Extraction of Ni^{+2} Nanoparticles

200 ml of the Nickel plating waste sample was treated with 10 M NaOH solution (prepared by adding 10 g NaOH pellets to 100 ml distilled water) till the pH becomes 8 at about 40 ℃ on the heater with magnetic stirrer. Cu^{+2}, Zn^{+2} and Ni^{+2} ions get precipitated. Then to separate out this precipitate from the mixture, the mixture was allowed to

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centrifuge. Then we get the filtrate, which contains Cr^{+6}.
The precipitate that remains after centrifugation is now dissolved in water. Since this mixture is free from Chromium, Nickel can be easily extracted from it. 100 ml of this solution was taken and allowed to react with Dimethyl Glyoxime (prepared by adding 0.2g of DMG powder dissolved in 20ml of Ethanol) (Ethanol taken was 99.9% pure of the company CHONG YU HI-TECH)). The mixture was continuously stirred at room temperature and DMG is added drop-wise to the mixture to form red precipitate of Ni $(DMG)_2$. The precipitate so obtained is separated by centrifugation and washed. The paste thus obtained is again washed with ethanol and kept in oven at 110 ℃ for about 12 hours, red hard mass was obtained.

The red hard mass was grinded mechanically and was kept for calcination in furnace for 4 hours at 450 ℃. Greyish white mass now obtained was grinded for about 45 minutes and a fine greyish white powder was obtained. This obtained fine powder was characterized by XRD and FTIR spectroscopy.

B. Preparation of Oil from Butchery Waste

Samples of butchery waste were obtained from local slaughter houses in Aligarh and were analyzed it was found that when 3 kg of the solid waste sample was taken in a container in water and kept under constant mechanical stirring at 110 ℃ for about 1-2 hours. 0.5 kg of oil was obtained after centrifugation, floating at the top. The oil sample was then separated using decantation. The density of oil obtained was 0.75g/cm (by performing simple mathematical calculations)

The characteristics of oil so obtained are:

TABLE II: CHARACTERISTICS OF OBTAINED OIL

FFA Content	2.5gm
Flash Point	206 ℃
Cloud Point	37 ℃
Pour Point	33 ℃
Refractive Index	1.47158(At 16.96^0c)

C. Trans-Esterification/Production of Biodiesel

Biodiesel was produced using base catalyzed Trans-esterification process [4]-[6]. Sample of 100 ml oil was taken in a beaker and is kept on hot plate magnetic stirrer at a temperature maintained at 55 ℃. 16% v/v methanol i.e. 6.25 ml was added along with 0.25 g of NaOH (obtained from MERCK) and 0.056g (0.75w/w %) of nickel nanoparticles were added in the mixture [9]. The mixture was maintained at pH of 8.5 and allowed to stir for 70 minutes till two separate layers of biodiesel (FAME) and glycerol were observed.

The obtained sample was kept in separating funnel and about 20 mL of chloroform was added in the separating funnel to obtain distinct layers of bio-diesel and mixture of nanoparticles with glycerol. Proceeding further, it was washed with water 3 times to remove glycerol, remaining nano-catalysts and other un-reacted chemicals settling the bio-diesel at the bottom of the funnel. Bio-diesel was collected by pouring the bottom layer in beaker. It was heated to remove excess water from the bio-diesel.

III. RESULTS AND DISCUSSIONS

A. Characterization of Nanoparticles

1) XRD pattern of nickel oxide nanoparticles

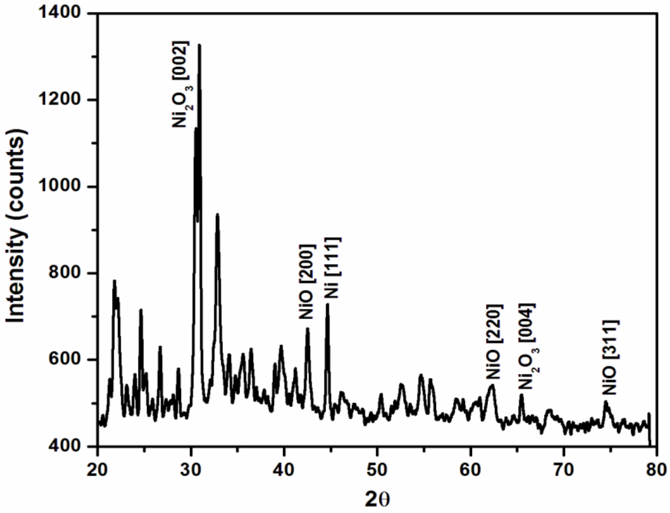

Fig. 1. XRD pattern of Nickel Oxide nanoparticles

The crystalline phase, structure and particle size of Nickel Oxide nanoparticles were obtained by X-ray diffraction (Rigaku-Miniflex) using Cu-K_α radiations (λ= 1.5406 Å) in 2θ range from 20° to 80°. The average size of the particles was calculated by the Scherrer's formula:

$$D = \frac{0.9\lambda}{\beta\ cos\theta}$$

where λ is the wavelength of X-ray radiation, β is the full width at half maximum (FWHM) of the peaks at the diffracting angle θ. The X-Ray diffraction peaks at 2θ of 42.52, 62.14, 74.5 were identified as peaks of NiO cubic phase crystallites with various diffraction planes [200], [220], [311]. The other peaks found at an angle (2θ) of 30.92, 65.48 were identified as Ni_2O_3 which corresponds to [002], [004]. A peak observed at (2θ) of 44.66 was identified for Ni [111] [10]. The average size was found to be around 25 nanometer (nm). Hence this result confirmed the formation of Nickel Oxide nanoparticles and some extra peaks shows there is some impurity.

2) FTIR pattern of nickel oxide nanoparticles

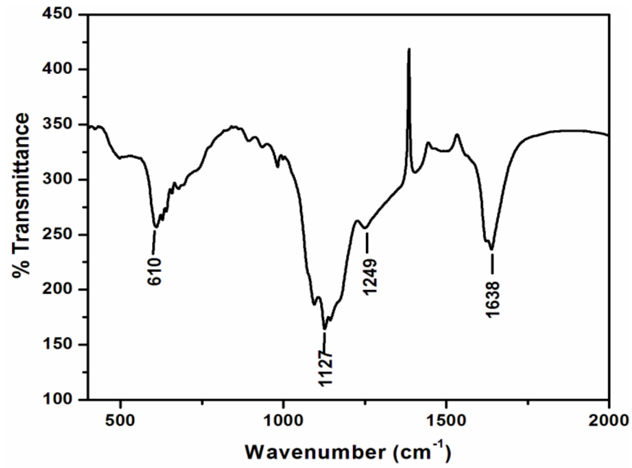

Fig. 2. FTIR pattern of Nickel Oxide nanoparticles.

FTIR spectra were recorded in solid phase using KBr pellet technique in the region 2000–400 cm^{-1}. FTIR spectra of Nickel Oxide nanoparticles are shown in Fig. 2. The band observed at 1638 cm^{-1} is due to the OH bending of water. A strong band at 610 cm^{-1} is assigned to the Ni–O stretching band which is consistent with that reported elsewhere confirm the formation of NiO nanoparticles [11]. Due to adsorption of CO band at 1127 cm^{-1} (C-O) and a symmetric stretching vibration at 1249 cm^{-1}(COO^{-1}) are appeared.

The Ni^{+2} nanoparticles of size 25 nm are obtained from the collected electroplating wastes by means of precipitation method followed by sol–gel technique. The extracted Ni^{+2} nanoparticles are now used as heterogeneous catalysts to increase the available reaction sites for the reactants and decrease the temperature requirement for the process of trans-esterification [5]-[12] for the conversion of pyrolytic oil to get FAME (fatty acid methyl esters) known as Bio-diesel [5] .

3) FTIR pattern of bio-diesel

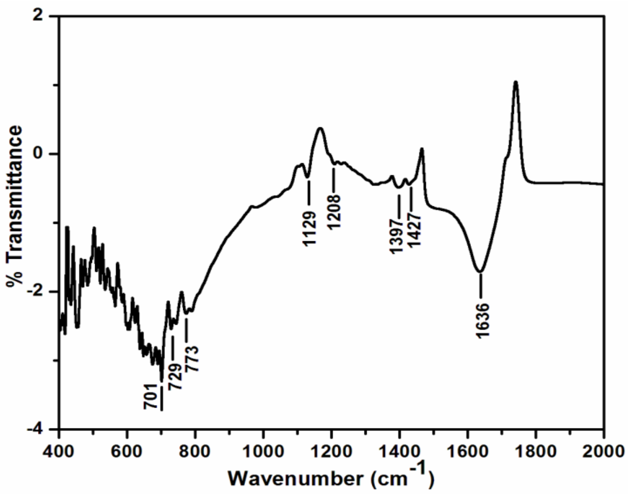

Fig. 3. FTIR pattern of obtained bio-diesel.

FTIR spectra were recorded in liquid phase by mounting the sample in liquid sample holder in the region 2000–400 cm^{-1}. FTIR spectroscopy is very fast and precise method for analyzing bio-diesel. Since, the bio-diesel is mono-alkyl ester, the characteristic peaks of ester in FTIR spectrum due to the presence of C=O bond and C-O bond were found to be around 1636 cm^{-1} and 1208 cm^{-1}. Some other peaks were noticed at 701, 729, 773, 1129, 1397, 1427 cm^{-1} which indicated the conversion of oil into bio-diesel [12].

Initiation of trans-esterification involves abstraction of proton by methanol by the nano-catalysts to form methoxide ion [7]-[15]. The methoxide ion thus created, attacks on carbonyl carbon present in the triglycerides, forming alkoxy carbonyl.

The electroplating waste was successfully converted into nanoparticles of Ni^{+2} thus one major type of waste that earlier was released into the atmosphere causing severe health problems was utilized to produce very effective nanoparticles that have many applications in various areas.

The another major waste-butchery waste was again converted into very useful and less toxic biodiesel which has many advantages over conventional petroleum fuel [9] and that by a new and more effective method using nanoparticles as catalysts.

Biodiesel produced also has many advantages as it is a renewable source of energy [2]-[8].

Feasibility of this work lies in the idea that it caters to 2 major types of wastes and converts them into biodiesel which is a very useful renewable source of energy and is less toxic.

IV. CONCLUSION

As per our study, Ni^{+2} nanoparticles can be extracted easily by means of precipitation followed by sol-gel process from the electroplating waste. These nanoparticles can be used as a catalyst for carrying out trans-esterification reaction using butchery waste [14] in a more efficient and less time consuming manner. It yields high quality biodiesel that has many applications and also is very eco-friendly. This work is solely oriented towards the effective utilization of waste and serves as an example for the "utilization of waste to utilize the waste".

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