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RECLAIMING NATURAL RUBBER LATEX FROM DISPOSABLE GLOVE WASTE AND CHARACTERIZING ITS STRUCTURE

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Abstract. The widely used disposable gloves are primarily made from natural polymers that can be reclaimed rather than disposed of in landfills. The latex waste from these disposable gloves was soaked in petroleum ether for 10 days at 50˚C, with occasional stirring. Following the chemical dissolution process, the steeped mixture was refluxed in the presence of the absorbent agent silicon dioxide (SiO_2) for 2 hours at the boiling point of the solvent (100-140˚C). The clear filtrate solution was treated with methanol to precipitate the rubber. The reclaimed rubber was analyzed for its structure using FTIR and 1H NMR spectroscopy, where both techniques revealed the main functional groups and the chemical shifts of the resonance protons corresponding to the natural polymer cis-1,4-polyisoprene. The FESEM images and X-ray diffraction patterns of the reclaimed rubber indicate that it is a refined material with an amorphous texture, elastic morphology and numerous surface folds.

Keywords: *Latex rubber, disposable gloves, reclaim rubber, cis-1,4-polyisoprene, chemical dissolution process.*

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1. Introduction

Rubbers are a major class of industrial materials with a wide range of applications. Consequently, the demand for rubber products continues to increase, resulting in a constant rise in rubber waste, which has become a significant environmental problem worldwide (Nuzaimah *et al*., 2018). Disposable gloves are one type of rubber material that has been widely used in recent years as personal protective equipment (Jędruchniewicz *et al*., 2021). The most common types of disposable gloves are latex, vinyl and nitrile, each made from different materials. Latex gloves are produced from natural latex rubber, while vinyl and nitrile gloves are manufactured from synthetic materials. Vinyl gloves are made from poly(vinyl chloride) and are typically used in low-risk jobs, such as food production and healthcare settings, where hazardous materials are

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not present (Mousavi & Dehestani, 2022). Nitrile gloves, made from nitrile-butadiene rubber, are suitable for use in environments with hazardous contaminants, chemicals, infection risks and exposure to hot oils or extreme temperatures (Preece *et al*., 2021). In comparison, latex gloves, which are made from cis-1,4-polyisoprene natural rubber, are generally more durable than vinyl and nitrile gloves. They offer puncture resistance against mechanical loads and provide a barrier against chemical exposure to bodily fluids, blood and contagious diseases (Guerra *et al*., 2021).

Millions of tons of latex gloves are used worldwide, resulting in significant waste from disposable gloves that pose environmental hazards (Shah *et al*., 2013; Nuzaimah *et al*., 2018). Consequently, various studies are currently being conducted on scrap latex rubber due to the high-quality nature and lightly cross-linked structure of the rubber obtained from waste latex. Therefore, it is considered a promising candidate for recycling (Mathew *et al*., 2001). The abundance of waste disposable gloves, their low cost and their unique properties make them a valuable source of sustainable materials (Ahmad *et al*., 2016). The excellent elastic behavior of disposable gloves can be utilized as thermal and noise insulators (Nuzaimah *et al*., 2018) and they also enhance the mechanical properties of composite materials (Riyajan *et al*., 2012; Ismail *et al*., 2009; Mathew *et al*., 2006). Recycled rubber from disposable gloves can be applied in the construction industry, where it can improve the mechanical properties of concrete (Mousavi & Dehestani, 2022).

In the present study, disposable latex gloves were collected after a single use and recycled using organic solvents through a chemical dissolving method.

The ground powder of disposable gloves was dissolved in petroleum ether to reclaim rubber. Silicon dioxide (SiO_2) was added to adsorb colors and other contaminants. The precipitated rubber was characterized for its structure using FTIR and ^1H NMR, its crystallinity through XRD and its morphology via FESEM analysis.

2. Experimental

2.1. Materials

The rubber disposable gloves used in this study are natural latex gloves from Mastools Company, China. Silicon dioxide (SiO_2) was obtained from AIDRICH and the organic solvent petroleum ether was sourced from ROMIL Company. All chemicals were utilized as received, without any further purification.

2.2. Chemical treatment of consumed gloves

The organic solvent petroleum ether was utilized to reclaim rubber from waste gloves. In 250 ml conical flasks with stoppers, 100 ml of the solvent was added to 20 g of ground gloves, followed by 10.0 g of SiO_2 as an absorbent agent. The flasks were sealed and placed in a water bath maintained at 50˚C for 10 days. At the conclusion of the soaking period, the contents of the flasks were transferred to a reflux flask and heated for 2 hours at the boiling point of the solvent (100-140)˚C. Subsequently, the contents of the flask were cooled and filtered and the collected clear solution was heated at 50˚C in a water bath with 40% (v/v) methanol, which served as a precipitating agent. A pale brown precipitate formed, which was then filtered and dried at 50˚C in a vacuum oven.

3. Results and Discussion

Rubber waste, particularly from daily and disposable gloves used for hygienic purposes, is accumulating in significant quantities, leading to various forms of pollution. Consequently, reclaiming rubber from these gloves has become an urgent necessity. The scope of this study is to reclaim rubber from disposable gloves and characterize its structure and properties.

3.1. Characterization of reclaimed rubber

The reclaimed rubber from disposable gloves, obtained through a chemical dissolution method using petroleum ether as a solvent, was characterized for its chemical and crystalline structure, as well as its morphological surface, using the following technical analyses.

3.1.1. FTIR spectroscopy

The FTIR measurement was conducted using a JASCO V-630 FTIR spectrometer from the USA. The FTIR spectrum, shown in Figure 1, displays the main peaks along with their corresponding absorption frequencies. The peak at 3359 cm^{-1} is attributed to the -OH group of H_2O, which is present as humidity in the sample. The peaks at 2918 cm^{-1} and 2852 cm^{-1} represent the stretching vibrations of the (C-H) bonds in alkane groups. The band at 1698 cm^{-1}, as illustrated in Figure 1, corresponds to the stretching vibrations of the (C=C) bonds in alkene groups, while the peak at 1424 cm^{-1} is associated with the bending vibrations of (C-H) bonds in alkane groups. Finally, the peaks at 1083 cm^{-1}, 875 cm^{-1} and 711 cm^{-1}, as shown in Figure 1, are attributed to the bending vibrations of (C=C) bonds in alkene groups (Rahmah *et al*., 2019).

The FTIR data indicate that the reclaimed rubber is a hydrocarbon polymer, characterized by its structure, which contains unsaturated double bonds as well as methyl and methylene groups.

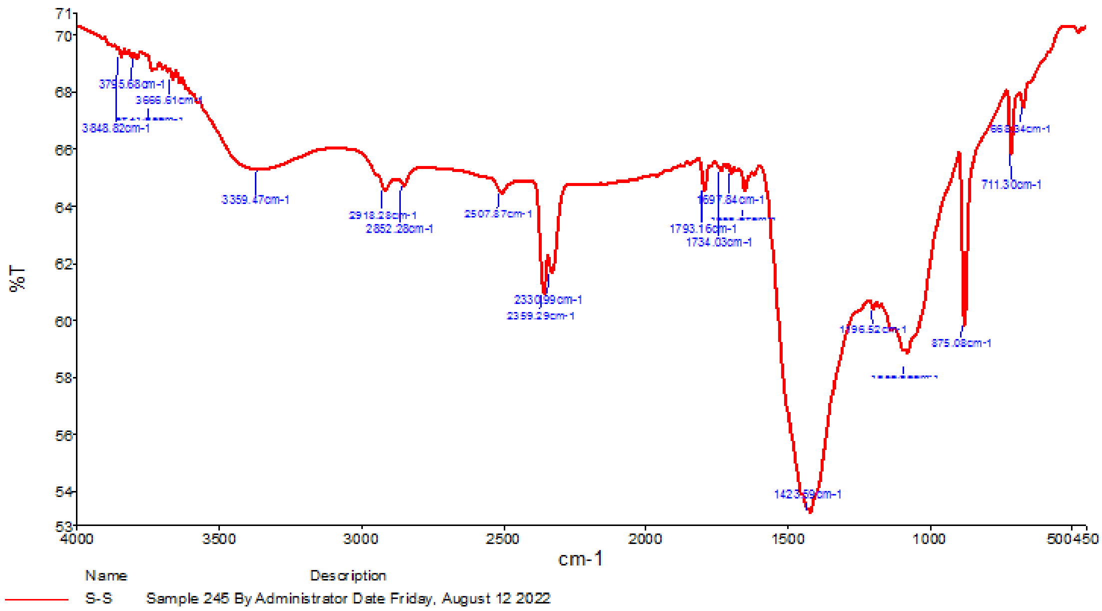
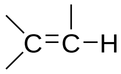


Figure 1. FTIR spectrum of reclaimed rubber from disposable gloves

3.1.2. ¹H NMR spectroscopy

The ¹H NMR spectroscopy of the reclaimed rubber was conducted using a Bruker AVANCE NEO 400 instrument with a PROBHD Z163739 - 0420 probe, utilizing $CDCl_3$ as the solvent. The ^1H NMR analysis of the rubber, which was reclaimed from disposable gloves through a dissolution process using petroleum ether, is presented in Figure 2. This figure illustrates the chemical shifts of the rubber protons, which are detailed in Table 1. The proton resonance (singlet, H) at δ = 1.45 ppm corresponds to the methylene groups in the rubber. Additionally, the proton resonance (singlet, H) at δ = 1.85 ppm is attributed to the methine (=CH-) group, while the proton resonance (singlet, H) at δ = 2.35 ppm is associated with the methyl group. Finally, the proton resonance (singlet, 1H) at δ = 3.60-5.04 ppm represents the alkene group (Silva *et al*., 2017; Lee *et al*., 2010).

Table 1. ¹H NMR chemical shifts and description of protons in reclaimed rubber

Sample	Chemical Shift σ / ppm	Description of Protons
Reclaimed Rubber from Gloves	**1.45**	**Methylene (-CH_2-) group**
	1.85	**Methine (=CH-) group**
	2.35	**Methyl (-CH_3) group**
	3.60- 5.04	**Alkene group** 

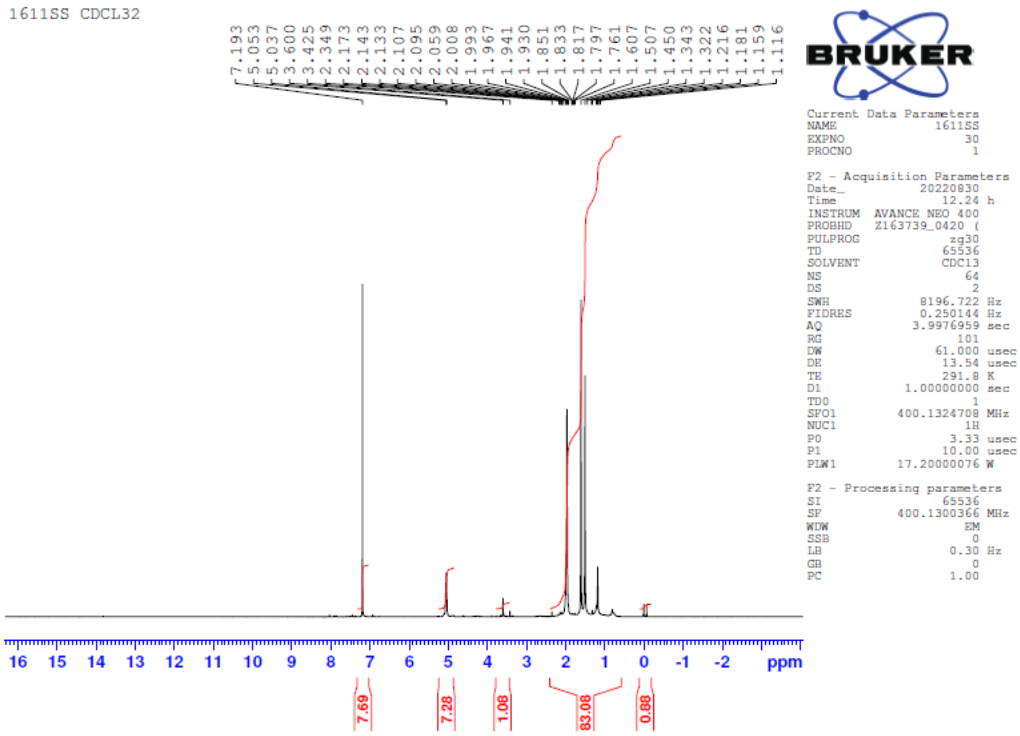
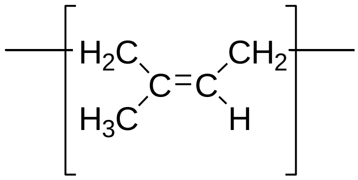


Figure 2. ¹H NMR spectrum of reclaimed rubber from disposable gloves



Scheme 1. Chemical structure of Cis-1,4-Polyisoprene

The ^{1}H NMR data (Figure 2, Table 1) indicate that the reclaimed rubber is cis-1,4-polyisoprene (Scheme 1), as determined by the functional groups identified through both FTIR and ^{1}H NMR spectroscopy.

3.1.3. X - ray diffraction

The X-ray diffraction (XRD) analysis of reclaimed rubber was performed utilizing a Philips X-ray Diffractometer (PW1730) equipped with Cu-Kα radiation (40 kV, 30 mA). The resulting XRD pattern, illustrated in Figure 3, reveals that the reclaimed rubber is predominantly amorphous, characterized by a broad plateau with a pronounced maximum at 18.5° on the 2θ axis. Research conducted by Johns and Rao (2008) indicates that pure cis-1,4-polyisoprene exhibits a distinctive peak at approximately 19° on the 2θ axis. Furthermore, Chen et al. (2019) have identified that natural rubber (NR) displays four characteristic diffraction plateaus at 11.5°, 14.3°, 16.9° and 19.0° on the 2θ axis. The X-ray pattern presented in Figure 3 reveals that small peaks corresponding to the locations identified by Chen et al. (2019) are subtly embedded within the broad plateau. Additionally, Figure 3 depicts another moderate peak with a lower maximum at 38.5° on the 2θ axis, which is indicative of silicon dioxide residue (Szymanski *et al.*, 2024).

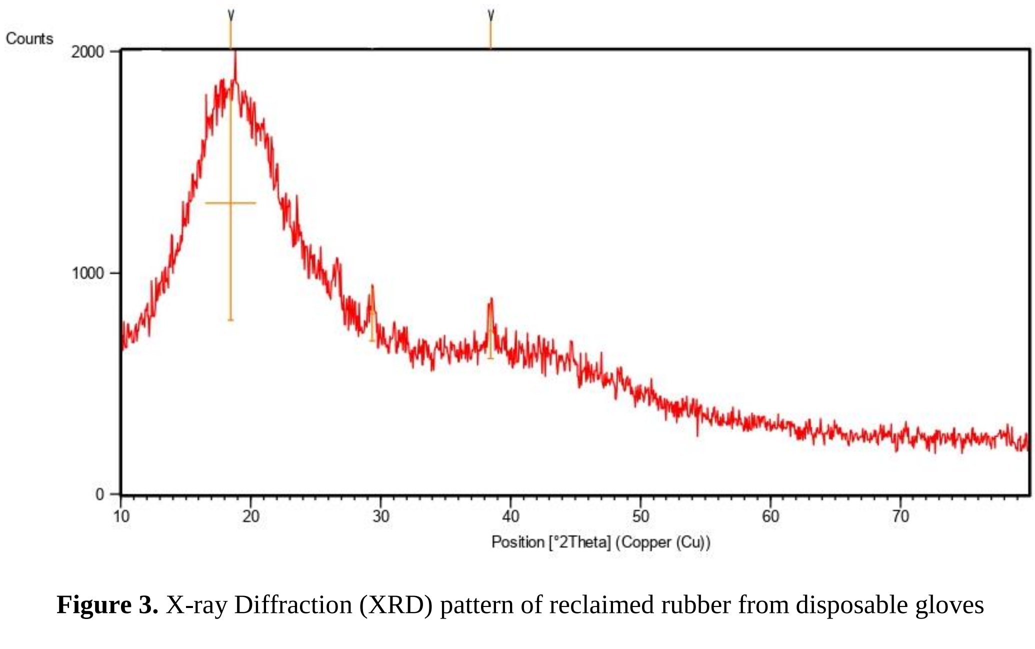


Figure 3. X-ray Diffraction (XRD) pattern of reclaimed rubber from disposable gloves

3.1.4. FESEM measurement

The FESEM images were obtained using a TESCAN MIRA FESEM from the Czech Republic. Figure 4 (a, b) displays the surface morphologies of the reclaimed rubber sample at different magnifications. The FESEM image in Figure 4 (a) reveals that the sample has a resilient surface and contains folds with elastic properties. In contrast, the FESEM image in Figure 4 (b), taken at a higher magnification, shows that the test sample resembles rubber paste, featuring numerous folds and exhibiting an amorphous nature (Zheng *et al*., 2019; Soundararaj *et al*., 2021).

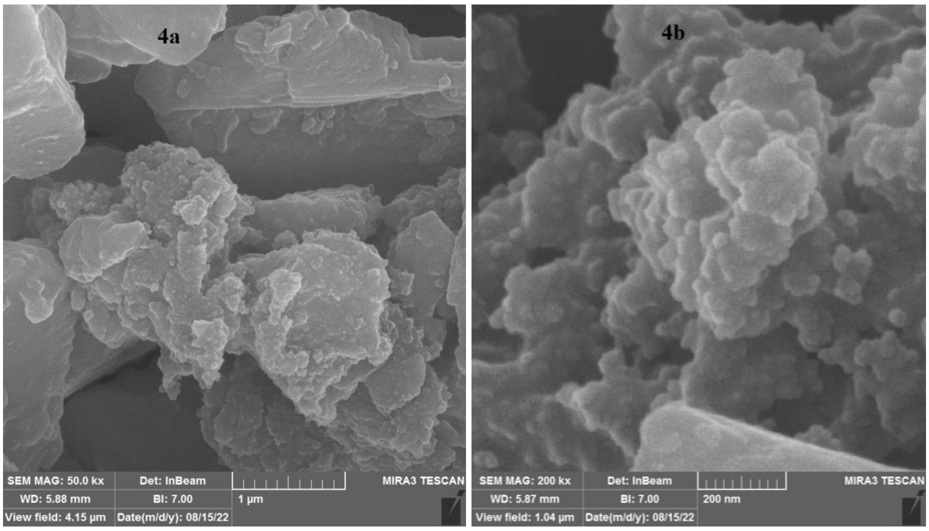


Figure 4. FESEM images of reclaimed rubber from disposable gloves a - 50,000x magnification and b - 200,000x magnifications

4. Conclusions

The waste from medical disposable gloves was recycled and the reclaimed latex rubber was analyzed. The powder from the waste gloves was soaked in petroleum ether solvent for 10 days at 50°C, in the presence of a SiO_2 absorbent agent. The resulting black solution was then refluxed for 2 hours at the boiling point of petroleum ether (100-140°C). Finally, the clear filtrate was treated with methanol to precipitate the rubber. The reclaimed rubber was characterized using FTIR and ^1H NMR spectroscopy, which indicated that the functional groups of the studied material are consistent with those of natural rubber. The XRD analysis revealed that the rubber is amorphous and of high purity. Additionally, the FESEM images of the reclaimed rubber show that the material possesses an elastic morphology with a non-crystalline structure.

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