STUDIES ON CLEANING EFFICIENCY OF VARIOUS NATURAL RUBBER LATEX CLEANING COMPOUNDS

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by

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LIST OF ABBREVIATIONS

ASTM	American Standard for Testing Materials
℃	Degree Celcius
$CaCO_3$	Calcium carbonate
$CaNO_3$	Calcium nitrate
cm^3	Centimeter cubic
DEG	Diethylene glycol
EB	Elongation at break
g	gram
HA	High Ammonia
hrs	hours
HZW	Hazardous waste
ILW	Industrial latex waste
ISO	International Organization for Standardazation
KOH	Potassium hydroxide
LA	Low Ammonia
m/m	mass per mass

M100	Modulus at 100% elongation
M300	Modulus at 300% elongation
M500	Modulus at 500% elongation
MEA	Monoethanolamine
min	minutes
ml	milliter
mm	milimeter
MST	Mechanical Stability Time
NBR	Acrylonitrile Butadiene Rubber
NH3	Ammonia
NR	Natural rubber
phr	Part per hundred rubber
rpm	revolutions per minute
s	second
SBR	Styrene Butadiene Rubber
TMTD	Tetra Methyl Thiuram Disulphate
TSC	Total Solid Content

WLP	Waste latex paint
wt/wt	weight over weight
ZDEC	Zinc diethyl carbamate
ZnO	Zinc oxide

KAJIAN TENTANG KECEKAPAN PEMBERSIHAN OLEH PELBAGAI SEBATIAN PEMBERSIH LATEKS GETAH ASLI

ABSTRAK

Sebatian pembersihan lateks getah asli (GA) telah disediakan menggunakan tiga jenis lateks GA; lateks GA beramonia tinggi (HA), sebatian sisa industri (ILC) dan sisa lateks mentah (RWL). Setiap lateks kemudiannya di campurkan dengan dua jenis agen pembersih iaitu monoethanolamin (MEA) dan dietilina glicol (DEG) pada kadar yang berbeza; 1 phr, 3 phr dan 5 phr. Ujian mekanikal dan keberkesanan pembersihan sebatian pembersih lateks GA telah disiasat. Kemudian, sebatian pembersih lateks GA HA pada 3 phr agen pembersih MEA dicampurkan dengan kalsium karbonat ($CaCO_3$) untuk diuji sifat-sifat mekanikal dan keberkesanan pembersihan sebatian pembersih lateks GA HA. Sebatian pembersih lateks GA HA dengan 30 phr $CaCO_3$ pada 3 phr MEA kemudian digunakan untuk menentukan teknik aplikasi yang sesuai iaitu teknik aplikasi berus, semburan dan semburan koagulan. Secara keseluruhannya, agen pembersih yang sesuai ditambah pada sebatian pembersih lateks GA ialah MEA pada 3 phr dan ILC didapati mempunyai keberkesanan pembersihan yang terbaik. Sifat-sifat mekanikal sebatian latex HA yang ditambah $CaCO_3$ menurun dengan peningkatan $CaCO_3$. Tetapi, keberkesanan pembersihan dilihat meningkat dengan peningkatan $CaCO_3$ dan 30 phr $CaCO_3$ dianggap sebagai kadar yang optimum. Antara tiga jenis teknik aplikasi berbeza, teknik aplikasi semburan dipilih sebagai teknik aplikasi terbaik disebabkan memberi pengeringan yang paling cepat dan keberkesanan pembersihan yang terbaik.

STUDIES ON CLEANING EFFICIENCY OF VARIOUS NATURAL RUBBER LATEX CLEANING COMPOUNDS

ABSTRACT

Natural rubber latex cleaning compound was prepared by using three types of natural rubber (NR) latex; high ammonia (HA) NR latex, industrial latex compound (ILC) and raw waste latex (RWL). Each of latex types was compounded with two types of cleaning agent which were monoethanolamine (MEA) and diethylene glycol (DEG) at various loadings; 1 per hundred rubber (phr), 3 phr and 5 phr. The mechanical and cleaning effectiveness properties of the NR latex cleaning compound were investigated. Next, HA NR latex cleaning compound at 3 phr of MEA cleaning agent was compounded with calcium carbonate ($CaCO_3$) to investigate the mechanical properties and the cleaning effectiveness of the HA NR latex cleaning compound. The HA NR latex cleaning compound with 30 phr of $CaCO_3$ at 3 phr of MEA was used to determine the suitable application technique which are brush, spray and coagulant spray application technique. Overall, the suitable cleaning agent to be added to the NR latex cleaning compound is MEA at 3 phr and ILC was found to have the best cleaning effectiveness. The mechanical properties of the HA NR latex added with $CaCO_3$ cleaning compound was found to be reduced with the increased of $CaCO_3$. However, the cleaning effectiveness of the HA NR latex cleaning compound was found to be improved with increased loading of $CaCO_3$ and 30 phr of $CaCO_3$ was considered as the optimum loading. Among three different types of application techniques, spray method is found as the best application technique since it gives fastest drying time and better cleaning effectiveness.

CHAPTER ONE

INTRODUCTION

1.1. Overview

Natural rubber (NR) latex is the colloidal dispersion of cis 1,4- polyisoprene obtained from Hevea brasiliensis tree. Figure 1.1 shows the overview of latex classification where latex can be classified into two types which are NR latex and dry rubber. The world consumption of rubber keeps on increasing over the years. According to International Rubber Study Group (2016), the world rubber consumption on 2010 was around 24 million and after 5 years the rubber consumption was increased to nearly 27 million on 2015. Based on this statistic, there were increments of rubber consumption around 12.5% in 5 years.

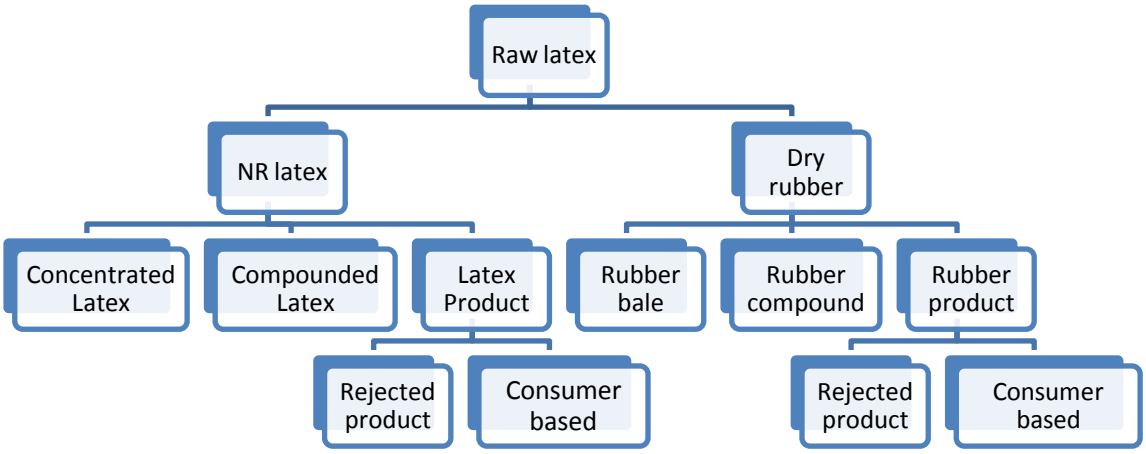

Figure 1.1: Overview of the latex classifications.

In Malaysia, the NR latex consumption increased from 400 000 tonnes from 2010 to 410 000 in 2015 (NR Rubber Statistic, 2016). As referred in Figure 1.2, latex products contribute up to 80% in Malaysia's export of rubber product. Then it was followed by tyres and inner tubes by 7%, general rubber goods 6%, industrial rubber goods by 4% and footwear by 3%. According to Figure 1.3, Malaysia's NR consumption was already increased around 50, 000 tonnes within 5 years from year 2010 to year 2015. The increased in the NR latex production indirectly producing the large mass consumption of latex waste and thus contribute to the accumulation of solid waste disposal.

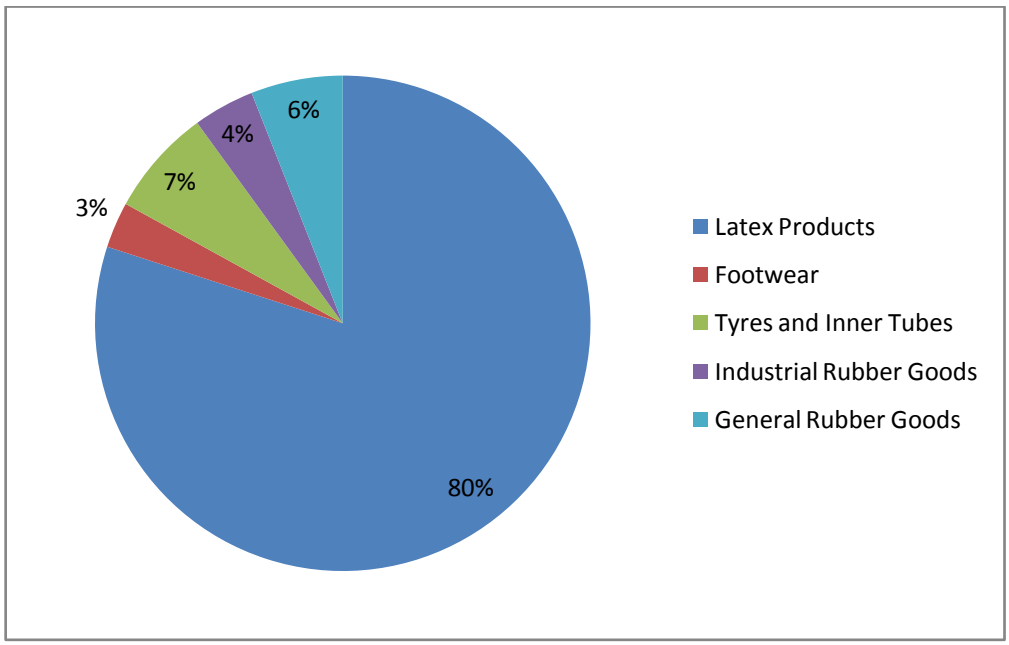

Figure 1.2: Malaysian's Export of NR Products by Product Sector (NR Rubber Statistic, 2016)

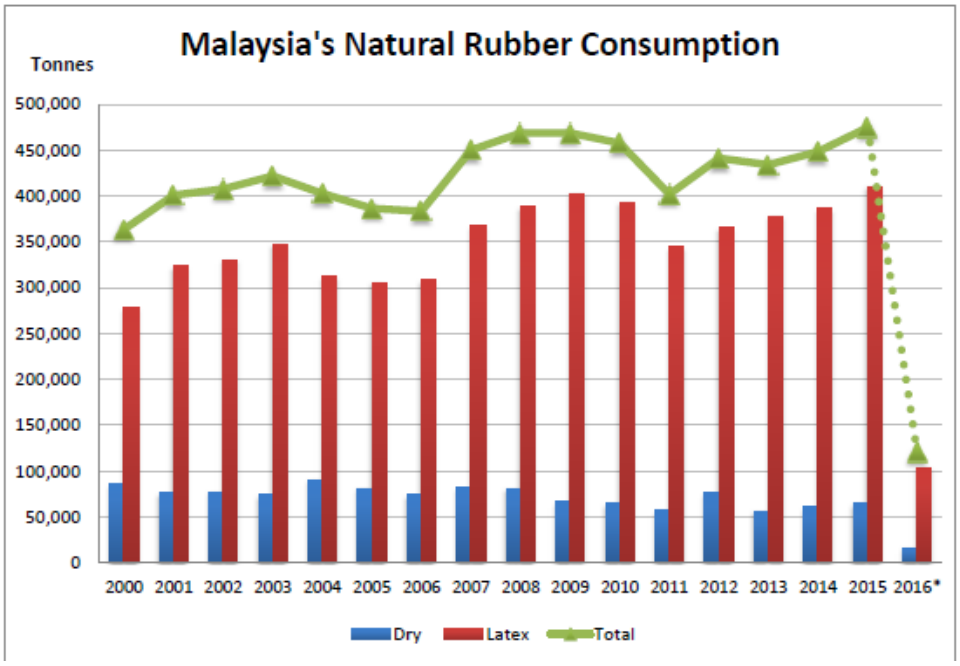

Figure 1.3: The Statistic of Malaysia's Natural Rubber Consumption (NR Rubber Statistic, 2016)

Basically, latex waste can be divided into two categories which are solid waste and liquid waste. The solid waste of the latex contributed from the rejected and used products, while liquid waste was from excess latex in the production of latex products either compounded or raw latex. In order to solve the disposal problem, most of the current research of the NR latex is focusing on producing more biodegradable latex by replacing common filler into biodegradable filler such as starch (Afiq *et al.*, 2015 and Afiq and Azura, 2013). The incorporation of starch in the carboxylated acrylonitrile butadiene rubber (XNBR) latex was found to be aged faster compared to the control XNBR films due to the thermo-oxidative ageing in the XNBR latex macromolecules and the pyrodectrination process of the starch chain (Afiq *et al.*, 2015). In the other research of starch incorporated into NR latex, with increasing of sago starch loading, the NR latex were more susceptible to decompose due to the formation starch hydrolysis

cleavage and the microbial colonies on the surface of the films (Afiq and Azura, 2013). However, there are still few research was conducted to solve the disposal problem of liquid waste. Mufidah *et al.*, (2014) conducted a research to turn liquid waste latex into mould cleaning compound. In their research, the NR latex films were laminated with waste latex films as the core layer and compressed using compression moulding. The cleaning effectiveness of the mould cleaning compound is measured by visual inspection on the dirty surfaces. It was found that the cleaning effectiveness of the laminated NR latex films were comparable with the current rubber cleaning compounds.

This project aims to re-use the liquid waste latex from the industry as latex cleaning compounds. The cleaning agents were added into the latex compound in order to improve the ability of the latex to clean dirty surfaces. This project focuses on the outdoor applications such as monuments and historical buildings. The current method of cleaning monuments and historical buildings are through sandblasting and water based cleaning methods. These methods have a drawback where it can damage the monuments and historical building instead of preserving the special character of the monuments and historical buildings (Siegesmund and Snethlage, 2011).

The latex cleaning compounds can be use based on the concept similar to the beauty mask where the dirt will stick on the latex films after the cleaning process. The latex cleaning compound is applied on the dirty surfaces where the dirt from the surfaces will attach to the film when the film is dried and stripped off from the surface. The advantages of using latex cleaning compound include easy handling of the waste by converting the waste into new product, easy handling of the waste by turning it from

liquid to solid waste which reduced the disposal cost and protect the surface of the monuments or historical buildings during cleaning process.

1.2. Problem Statement

The excellent properties of elasticity and flexibility of the NR latex made the NR latex a versatile material. NR latex usually used to make a dipped product such as gloves and condoms (Pendle, 1995), latex extruded thread (Doyle *et al.*, 2011) and blood transfusing tubing catheters (Lawrence and Turner, 2005).

Waste latex can be divided into two categories which were solid and liquid waste. Solid waste is the rejected and used product from consumers. While, liquid waste is from the production in the factory. The production of waste latex rubber is due to the unstable nature of the latex compound and the strict specification in the quality of latex products (Mathew *et al.*, 2001). Solid wastes usually send to the landfills for disposal. In contrast with solid waste, liquid waste is more complicated to be disposed. According to ISO 14000, any hazardous materials either in solid, gas, liquid or slurry form is prohibited to be disposed without treatment. The authorities also have restricted that liquid waste latex cannot be drain off to the environment without purification. The waste latex needs to be coagulated with acid and neutralized first before it can be disposed. Hence, latex manufactures faced a major challenge to manage the economic and environmental issues for waste latex treatment.

Water treatment is needed as the discharge of waste water from latex processing industry to the environment may caused serious and prolong consequences. Therefore, suitable technologies must be used for treating this waste water (Yassin, 2008). Latex industries

in Malaysia have implemented treatment facilities that consistent with the regulations. Biological methods, especially aerobic, anaerobic and facultative ponds are widely used for treatment of rubber waste water in Malaysia (USA, 2007). These systems are inexpensive and have a high efficiency for organic load reduction with appropriate available land. Disposal of liquid waste latex is more complicated since it needs to be treated with acid which may affect the ecology system. Thus, the idea of recycling the liquid waste latex into another product is more practical in term of cost and safe to the environment.

Recently, there are a lot of efforts from various researchers (Nevatia *et al*., 2002; Ismail and Awang, 2008; Jose *et al*., 2010; Noriman *et al*., 2010, Bazhenov *et al*., 2006) which have addressed the usage of waste or recycle materials including waste latex due to environmental awareness and the requirement for better cost efficiency. Most of the researchers are commonly focused on the used of solid waste latex as fillers in rubber compound. Boondamneon *et al*. (2013) used the solution blending method to recycle waste NR (WNR) latex which was in liquid form and studied the effect of blend ratio and compatibilizer on solution casted treated waste natural rubber latex/polystyrene blends for thermoplastic elastomer application.

Meanwhile, sand blasting and water based cleaning methods are the most used practice to clean the dirty surfaces. Even though sand blasting and water based cleaning methods provide fast cleaning method, but they give bad effect to the monuments and historical building. Sandblasting methods not only clean the surface of the historical building and monuments but also sacrificed the character of the historical building by eroding the surface of the building and hence damage the surfaces (https://www.nps.gov/tps/how-to-

preserve/briefs/6-dangers-abrasive-cleaning.htm#abrasive). While, the disadvantages of water based cleaning method is the water moisten the monuments and able to penetrate the monuments and damage the interior of the monuments (Siegesmund and Snethlage, 2011). The other cleaning method that can be used is the lamination of the NR latex. In the research done by Mufidah *et al.* (2014), they were investigating the effect of laminating NR latex with waste latex for mould cleaning application. It was the compound that can be beneficial as new substitute for mould cleaning application since it can attract dirt from the mould. They investigated the effect of different cleaning agents, monoethanolamine (MEA) and diethylene glycol (DEG) on the properties of the mould cleaning compound.

Currently in Europe, latex cleaning compound has been used as indoor cleaning. This latex cleaning compound is known as DriKlean which used to clean masonry, such as marble, limestone, terracotta, sandstone, concrete and plaster. This type of cleaning method is mostly used when traditional cleaner cannot be used safely. Driklean ables to removes dust, soot, oils and other surface soiling by absorb the dirt into latex film and contained (www.buildsite.com/pdf/prosoco/Enviro-Klean-DriKlean-Product-Data-900745.pdf). The idea of using latex cleaning compound for outdoor cleaning is focusing on the cleaning the historical building and monuments. This is because a gentle handling is needed to clean historical building and monument in order to prevent them from deteriorations (https://www.nps.gov/tps/how-to-preserve/briefs/6-dangers-abrasive-cleaning.htm#abrasive).

1.3. Objective

The objectives of this research include:

1. To determine the effect of different types and loadings of cleaning agent on the mechanical properties of different types of NR latex; High ammonia (HA) NR latex, industrial latex compound (ILC) and raw waste latex (RWL).
2. To investigate the effect of calcium carbonate loading on the mechanical properties and the cleaning effectiveness of the HA latex cleaning compound.
3. To study the effect of different application techniques on cleaning effectiveness of NR latex cleaning compounds.

1.4. Thesis outline

This thesis pays attention to recycle waste natural rubber latex by using the waste latex as cleaning compounds. In order to improve the cleaning effectiveness of the latex cleaning compounds, calcium carbonate was added. Three different application techniques were used to apply the latex cleaning compounds. This thesis is divided into five chapters:

Chapter one gives brief introduction on the waste natural rubber latex, including the research background, problem statement and objectives of this research.

Chapter two involves the background theories and literature review; natural rubber latex, latex compounding, latex processing, recycling of the latex, cleaning agent and cleaning application method.