Reduction of Magnesium Content in Fresh Natural Rubber by Ion Exchange Resin

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ชื่อวิทยานิพนธ์ การลดลงของปริมาณแมกนีเซียมในน้ำยางสดธรรมชาติด้วยเรซิน
ชนิดแลกเปลี่ยนประจุ
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บทคัดย่อ

งานวิจัยนี้เป็นการศึกษากระบวนการลดปริมาณแมกนีเซียมในน้ำยางสดธรรมชาติด้วยเรซินชนิดแลกเปลี่ยนประจุ ซึ่งใช้หลักการแยกประจุแมกนีเซียมออกจากน้ำยางสดธรรมชาติ วิธีการดังกล่าวสามารถลดปริมาณแมกนีเซียมได้ต่ำกว่า 100 ppm ภายหลังจากการแช่เรซิน การแช่เรซินร่วมกับการกวน การส่งผ่านน้ำยางสดธรรมชาติผ่านเรซินด้วยเครื่องเพิ่มแรงดัน และการส่งผ่านเรซินด้วยแรงโน้มถ่วงภายในคอลัมน์กรองและถังกรอง นอกจากนี้ยังพบว่า ลักษณะทางกายภาพของขนาดอนุภาคน้ำยางสดธรรมชาติและเรซินไม่เปลี่ยนแปลงภายหลังการใช้งาน ถึงแม้จะมียางปกคลุมที่ผิวของเรซิน โดยในระหว่างกระบวนการแยกประจุแมกนีเซียมไม่พบการเกิดตะกอนกากขี้แป้งหรือกากของเสีย นอกจากนี้ วิธีการนี้ยังสามารถลดปริมาณกากขี้แป้งได้ดีกว่าวิธีการตกตะกอนเคมีด้วยสารไดแอมโมเนียมฟอสเฟต (DAP) โดยเฉพาะอย่างยิ่งการลดลงของปริมาณการเกิดกากของเสียจากเครื่องปั่นแยก วิธีการนี้ยังสามารถลดระยะเวลา จำนวนคนงานและปริมาณการใช้น้ำในการทำความสะอาดเครื่องปั่นแยก รวมไปถึงลดการใช้พื้นที่ในการฝังกลบกากขี้แป้งได้อีกด้วย ยิ่งไปกว่านั้นยังพบว่า ความสามารถในการทำงานของเรซินเพิ่มขึ้น เมื่อถูกฟื้นฟูสภาพด้วยกรดไฮโดรคลอริก (HCl) และสารโซเดียมไฮดรอกไซด์ (NaOH) ส่งผลทำให้สามารถนำเรซินกลับไปใช้งานซ้ำได้อีกถึง 6 ครั้ง ในการลดประจุแมกนีเซียมในน้ำยางสดธรรมชาติ ในส่วนของเสียเรซินจากวิธีการนี้ สามารถนำไปใช้เป็นวัตถุดิบตั้งต้นใหม่ในการเผาร่วมในเตาเผาปูนซีเมนต์ในกระบวนการผลิตปูนซีเมนต์ได้อีกด้วย

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ABSTRACT

This paper presents reduction of magnesium content in fresh natural rubber by ion exchange resin. This research used an ion exchange resin to separate magnesium ions (Mg^{2+}) from fresh natural rubber latex (F-NRL). This method reduced the level of Mg^{2+} ions in F-NRL to less than 100 ppm after immersion, immersion with stirring, or passing through a syringe pump, gravity column, or gravity flow filter tank. In addition, the physical size of the particles of F-NRL and resins did not change after treatment although rubber covered the surface of the resins. During the separation process, there was no concentrated latex sludge or waste. In addition, this method could reduce the quantity of concentrated latex sludge effectively compared with chemical precipitation with DAP and especially minimize the volume of waste from the centrifuge machine. Moreover, this method reduced operation time, the number of laborers and water quantity to clean the centrifuge machine, and also reduced the size of land area used for waste dumping or sanitary landfill. In addition, the performance of the resin increased following regeneration using HCl and NaOH that allowed the resin to be reused 6 times to reduce the concentration of Mg^{2+} ions in F-NRL. Moreover, the waste resin from this method disposed as a new raw material in a co-incineration cement kiln in the cement production process.

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CHAPTER 1

Introduction

1.1 Background

Magnesium is an important component in fresh natural rubber latex (F-NRL) which is the cause of concentrated latex sludge or waste in the concentrated latex process. The waste is a product of the concentrated latex process that is the main problem for disposal. The amount of waste through the operation is approximately 1% of the F-NRL. In other words, the amount of waste produced at each factory is around 0.39–1.58 tons per day which depends on the production scale (Tekprasit, 2000).

This waste comes from the precipitation of magnesium contained in the F-NRL using diammonium phosphate (DAP) before transfer to the centrifuges for concentration in the latex process. After this process, the F-NRL is separated into two fractions that include the concentrated latex and skim latex. But the waste in the F-NRL occurs throughout the process. Normally, it begins at collection in the field and the preservation of the F-NRL using an ammonia solution until transport to the factory. In ammonia-preserved F-NRL, proteins react on the surface of the rubber particle and there are also reactions with multivalent metal ions such as Mg^{2+} ions. In addition, the reactions affect the stability of the rubber particles and the latex remains as stable F-NRL until transfer to the factory.

Before centrifugation at the factory, DAP is added to the F-NRL to precipitate the magnesium. The required quantity of DAP depends on the remaining magnesium in the F-NRL. The ratio of magnesium to DAP is usually 1:1.5 (Nithi-Uthai et al., n. d.). Generally, a factory will add between 1.35–2.22 kilograms of DAP per ton of concentrated latex and the amount of waste is about 12 kilograms per ton of the F-NRL (Taweepreda et al., 2011 refer to Pollution Control Department, 2005). In addition, the time required for precipitation is around 8–12 hours. The sources of waste can be found at several points in a factory that include the reception tank where chemicals are added for preservation of the F-NRL and DAP is added before centrifuging.

In addition, waste can be found in the centrifuging process at the separator bowl disc area due to clogging of the machine by the waste. Cleaning of the disc is performed every 2–3 hours

(Nithi- Uthai et al., n. d.) and requires 8–20 minutes per cleaning time. Furthermore, the waste is found in the skim latex tank, preservative concentrated latex storage tank, and in the waste disposal area of the factory. The waste or concentrated latex sludge from all sources is collected and transferred to disposal areas at the factory such as a dumping site, landfill, and outdoor burning.

The concentrated latex sludge or waste is classified as a waste or unusable material according to the Notification of the Ministry of Industry. The criteria require that the waste not be allowed to be transported out of the factory premises unless permission is granted from the director general of the Department of Industrial Works or from an authorized person to manage waste with the proper method and location according to the criteria and procedures. The waste generator is allowed to have the waste in possession within the factory premises for no longer than 90 days. If the time for the procedure is longer than that, a waste generator will ask for permission from the Department of Industrial Works. When waste treatment or disposal is performed at the factory premises, it must be done in accordance with certain regulations (Notification of the Ministry of Industry, 2006).

The criteria affect the management of the waste at a factory due to the difficulty controlling and managing the waste from the process. Thus, this problem is ignored by the factory or the waste is not managed efficiency. Generally, the waste is disposed by several methods such as a dumping site, landfill, or outdoor burning but these methods are malodorous and cause air pollution. Moreover, the waste components leach from the waste into the soil or water sources. Although the leachate is nontoxic, it continues to increase in concentration. When the rain leaches the waste components from the waste into the natural water sources, it has an impact on the environment (Suksaroj et al., 2011).

Nowadays, researchers try to reduce the concentrated latex sludge or waste from all concentrated latex processes. For example, they separate the rubber content from the waste with sulfuric acid. The waste is then used in agriculture and in making concrete. For example, the waste can be used to make fertilizer and can be used as an admixture for construction materials. However, the research is mainly in prototype stages and further development is needed with field installations in the industry. Therefore, the amount of waste cannot be reduced. Although the industry tries to minimize the volume of waste, the amount of waste just increases every year.

The cause of concentrated latex sludge or waste in the concentrated latex process is the magnesium in the F-NRL and the volume of waste depends on the quantity of magnesium and other factors in the F-NRL which is collected from different sources of rubber plantations that include normal tapping and ethylene gas tapping.

Nowadays, many rubber plantations use a new tapping technology known as ethylene gas tapping to increase the latex productivity. The ethylene is a stimulant for latex production that has several techniques for use in the tapping procedure such as RRIMFLOW, Double TEX and LET. These techniques are called ethylene gas tapping. This tapping is used in mature rubber trees when they are around 20 years old or before destruction of the rubber trees to increase the duration of latex flow and activate the latex cell metabolism (Traoré et al., 2011 refer to Lustinec et al., 1965; Buttery and Boatman, 1967; Pakianathan et al., 1976; Jacob et al., 1989; D'Auzac et al., 1997) which increases the volume of latex from the rubber trees.

So, the amounts of F-NRL that is received at the factories from different rubber plantations and tapings are in various qualities. The properties of the F-NRL must be tested, especially when the F-NRL is used in the concentrated latex process. The amount of magnesium content is measured before processing of the F-NRL because the magnesium in the F-NRL creates the concentrated latex sludge or waste when it reacts with ammonia and phosphate. This waste is a cause of pollution such as waste water (leachate) and malodors when it is disposed by incorrect methods by a dumping site or outdoor burning.

Generally, minor purchasers evaluate the latex quality from the dry rubber content before transfer to a factory to produce the concentrated latex. But in the concentrated latex process, especially in the latex centrifugation procedure, if the F-NRL has a high magnesium content, the manufacturer needs to purchase and add DAP for precipitation of the magnesium in the F-NRL before transfer to the centrifugation process.

So, if the stakeholders at each stage of the concentrated latex process can reduce the quantity of magnesium in the F-NRL before the centrifugation process in concentrated latex, the factory can then dispose of the concentrated latex sludge more easily, reduce the residual waste in the environment, save costs of production, and the costs of waste management and disposal.

Therefore, the aims of the research are to develop adsorption technology (ion exchange resin) to reduce the magnesium content in F-NRL in concentrated latex process and to study the effects of the technologies to increase latex productivity (ethylene gas tapping; RRIMFLOW, Double Tex, and LET technique) that affect the magnesium content in the F-NRL. Further, to study the environmental impact and economic costs using magnesium reduction technology by comparison of chemical precipitation using DAP with adsorption technology (ion exchange resin).

1.2 Review of literature

1.2.1 Introduction to fresh natural rubber latex (F-NRL)

Fresh natural rubber latex (F-NRL) that is tapped from rubber trees (*Hevea brasiliensis*) consists essentially of a colloidal emulsion of rubber globules or particles which show Brownian movement that is more rapid in the F-NRL than in preserved latex (Verhaar, 1973). Fresh latex is a fluid; it has a density in the range of 0.975–0.980 Mgm^{-3} and a pH of 6.0–7.0. The particle size of the F-NRL varies over a wide range. A range of 20–5,000 nm is common. In addition, the viscosity of latex is variable (Blackley, 1997) which depends on the clone of rubber tree, age, and season of tapping. The constituents are given in Table 1.1.

Table 1.1 Constituents of F-NRL

Constituent	**wt% of whole latex**
Total solids	36
Dry rubber	33
Proteinaceous substances	1 – 1.5
Resinous substances	1 – 1.25
Ash	up to 1
Sugars	1
Water	add to 100

Source: Blackley, 1997.

The F-NRL is classified into 3 principal phases: (1) Rubber phase 35% (2) Aqueous phase 55%, and (3) Lutoids and other phases 10%.

1. Rubber phase

1.1. Rubber particle

The rubber particles in the F-NRL have a spherical shape. They are comprised mainly of the rubber hydrocarbon that is surrounded by a shell of phospholipids and an outside shell of protein. The rubber particle is shown in Figure1.1. The rubber particle has a density of around 0.920 Mgm^{-3}.

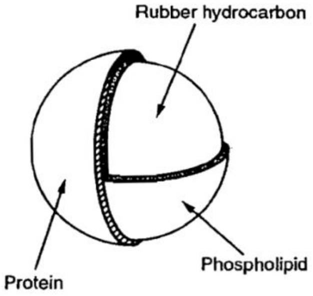

Figure 1.1 Rubber particle

Source: Blackley, 1997

The rubber hydrocarbon is predominantly linear *cis*-1,4 polyisoprene, C_5H_8 (Blackley, 1997). The constituents of rubber particles are shown in Table 1.2.

Table 1.2 Constituents of rubber particles

Constituent	**wt% of rubber particles**
Rubber hydrocarbon	86
Water (possibly dispersed in the rubber hydrocarbon)	10
Proteinaceous substances	1
Lipid substances	3

Source: Blackley, 1997.

1.2 Proteins

The surface of the rubber particles of the F-NRL is believed to be a proteinaceous adsorbed layer. The adsorbed layer defines the electrical charge carried by the particles, the electrophoretic action of the particles, and the latex when it is colloidally destabilized (Blackley, 1997). In addition, the protein layer is found to have negative radicals of carboxylate ($RCOO^-$). The carboxylates are attached to the outside of the protein layer and these negative radicals maintain the liquid stability of the rubber latex (Khajornchaikul, 2006).

The surface of the rubber particles includes 5% cysteine disulphide linkage by weight. When the rubber latex loses stability, the protein will putrefy. This part is digested and releases hydrogen sulphide and mercaptans with bad odours.

1.3 Lipids

The lipids in the F-NRL consist of fats, sterols and sterol esters, and waxes such as phospholipids, and eicosyl alcohol. They are dissolved in the rubber hydrocarbon that is predominantly inside the bulk of the particles. In addition, phospholipids are strongly adsorbed to the surface of the rubber particles (Blackley, 1997).

2. Aqueous phase

2.1 Carbohydrates

The aqueous phase of the F-NRL is a dilute solution which has a density of around 1.020 Mgm^{-3}. This phase has many chemicals that are proteins, electrolytes, amino acids, and carbohydrates. The carbohydrate that is in this phase is known as l-methyl inositol or quebrachitol. Also in this phase, the carbohydrates that are present in small volumes include sucrose, glucose, galactose, fructose, and other inositols. These carbohydrates, including quebrachitol, affect the latex properties when the latex does not have adequate preservation. The carbohydrates become microbiologically oxidized and are known as volatile fatty acids (VFAs), which are comprised of propionic acid, formic acid, and acetic acid (Blackley, 1997).

2.2 Proteins and amino acids

The aqueous phase of the F-NRL is comprised of many proteins. They are known as hevein and α-globulin. Hevein is soluble in water at all pH values and does not precipitate from water by boiling. α-globulin is soluble in acid solutions, alkaline solutions, and neutral salt solutions, but is not soluble in distilled water (Blackley, 1997).

2.3 Other substances

The other substances in this phase of the F-NRL consist of free nitrogenous bases such as methylamine and choline, organic acids (amino acids), inorganic anions (phosphate and carbonate), and other metal ions that include magnesium, potassium, sodium, iron, and copper. Moreover, the F-NRL contains a small quantity of cyanide (free hydrocyanic acid) (Blackley, 1997).

2.4 Lutoids and other particulate phases

When F-NRL is centrifuged undiluted at a low speed the latex separates into two parts: a white (rubber particles) part and a bottom yellow part. At the frontier between the two parts is a thin vivid yellow layer. In the bottom yellow part are ill-defined aggregates called lutoids. The lutoids are mainly water. They contain a small volume of phospholipids that are insoluble proteins and soluble proteins. Moreover, after tapping they can quickly decompose at tropical temperatures. In addition, lutoids are broken down by high temperature and the effect of the liquid in lutoids is to cause swelling and eruption. Then in the suspended liquid, the positive ions and metal ions such as calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) in the lutoids spread out and contaminate the serum. The rubber particles then coagulate and affect the latex vessels by clogging and stopping the latex flow after tapping. After the lutoid layer is broken and coagulation occurs, the lutoids catch onto the surface of the rubber particles which make them larger and they move slowly. In this case, the rubber latex loses stability. If ammonia is added to the rubber latex, the lutoids, Mg^{2+} ions, and other metal ions will mix with the ammonia and change to brown and violet colored sediments. Then, they precipitate and separate out of the rubber (Blackley, 1997).

Frey-Wyssling particles are the yellow bodies in the vivid yellow layer that separates the bottom and top fractions when the F-NRL is centrifuged. They are non-rubber particles and are often bright yellow spheres. Their color is caused by carotenoid pigments. The particles are major lipids that are larger and slightly denser than the rubber particles.

Under low and high speed centrifuge conditions, the F-NRL is separated into two fractions. The top fraction is the white fraction, or rubber cream, and the next fraction is the bright yellow layer. The last is regarded as the bottom fraction. Most of the magnesium content of the F-NRL is associated with this bottom fraction (Blackley, 1997).

1.2.2 Concentrated latex and process

1.2.2.1 Concentrated latex

Thailand is the biggest producer and exporter of concentrated latex in the world and is the third in the world for the export of block rubber and ribbed smoked sheets (Pruksachart, 2009). The products of concentrated latex have many commercial uses such as gloves for surgery and household purposes, and condoms. Other commercial products that include the use of concentrated latex are rubberized floor mats, foam products, latex thread, adhesives, and leather products.

Due to the spread of the AIDS virus, dipped products make up more than 60% of concentrated latex consumption. More than 90% of the concentrated latex is produced by the centrifugation process. Other forms of concentrations include creaming, evaporation and electro decantation. In Thailand, three types of latex are produced: high ammonia (HA), medium ammonia (MA) and low ammonia (LA) preserved with TMTD/ZnO (LA-TZ) (Thungsong Sisawad, 2008).

Concentrated latex is made from the F-NRL. The F-NRL that exudes from rubber trees (*Hevea brasiliensis*) (Blacklay, 1997) usually contains 30–40 wt% of rubber (Verhaar, 1973) with an average of 33 wt%. The remainder of the F-NRL is mainly water.

The concentrated latex is produced by centrifugation. The normal practice is to concentrate the F-NRL to a dry rubber content of around 60 wt% (Blackley, 1997). The centrifuged concentrate is known as cream and the dilute latex is known as skim. Normally, concentrated latex is preserved with ammonia to prevent spontaneous coagulation and putrefaction. The concentrated latex includes two main types: HA concentrated latex which uses 0.7% ammonia per weight of rubber and LA concentrated latex which uses 0.2% ammonia per weight of latex. Other chemicals are added to produce a suitable quality of rubber latex.

In Thailand, the concentrated latex is produced under quality control standards of the Thai Industrial Standards Institute (TIST). The TIST 2533 (1990) standard followed ISO 1997 (E). This standard was improved from TIST 2533 (1990) to the current TIST 980–2552 (2009) (Notification of Ministry of Industry, 2009) which added new concentration standards of magnesium in the concentrated latex. In addition, the Thai Latex Association (TLA) determined new property standards for the concentration of magnesium which are higher than the

ISO standard to improve the quality of concentrated latex from Thailand. This standard is guaranteed by the Rubber Research Institute of Thailand that the data in the standard refers to TIST 980–2552 (2009) (Natural rubber latex concentrate) (Pruksachart, 2009). The standard is shown in Table 1.3.

Table 1.3 Physical and chemical properties of concentrated latex

Specification	**High Ammonia**
Total Solids Content (%TSC)	62.00 (Max)
Dry Rubber Content (%DRC)	60.00 (Min)
Non-Rubber Content (%NRC)	1.70 (Max)
Ammonia Content	0.60 (Min)
Volatile Fatty Acid Number (VFA No.)	0.03 (Max)
Magnesium Content, ppm	40.00 (Max)
Mechanical Stability Time @55% TS, sec	650 (Min)
pH	9.50–10.50
KOH Number (KOH No.)	0.65 (Max)
Specific Gravity at 25°C	0.94 (Min)

Source: Notification of Ministry of Industry, 2009.

The TIST 980–2552 (2009) standard added a new value for the concentration of magnesium content because in the concentrated latex process by centrifugation there is a problem with clogging in the centrifuge machine by concentrated latex sludge during centrifugation.

So, the factories need to clean the machine every 2–3 hours which leads to downtime of 8–20 minutes per cleaning time. Although magnesium in F-NRL has precipitated before this stage, in fact, the concentrated latex can continuously produce magnesium starting from the collection time at the plantation until delivery to the factory because the F-NRL is preserved by ammonia.

In addition, in ammonia-preserved F-NRL, the Mg^{2+} ions which may be present in the aqueous phase will react with the ammonia and phosphate anions to precipitate as the very sparingly-soluble $MgNH_4PO_4$. In addition to the precipitated magnesium, other contaminants are sand, dirt, and soil (Blackley, 1997). The precipitates and sediments from the F-NRL form a concentrated latex sludge. The ammonia affects the stability of the rubber particles and the F-NRL until transfer to the factory. At the factory, preservatives and DAP are added to the F-NRL in a storage tank before centrifugation. The concentrated latex sludge precipitates in this tank. Moreover, the sludge is found in the centrifuge machine at the disc area, skim latex tank, preservative storage tank before transport to customers, and at the disposal areas in the factory.

1.2.2.2 Process

When the F-NRL arrives at the factory the method of operation is as follows:

1. Receive the F-NRL

A sample is drawn from the lorry tank and quick tests for the approximate %DRC and ammonia content are done. If the test shows the %DRC to be unsatisfactory (because of rain or for other reasons) the F-NRL should not be centrifuged (Verhaar, 1973). In addition, the F-NRL needs to be clean and have good quality. Normally, the concentration of the VFA is less than 0.04% and the %DRC is more than 30% by weight with low magnesium content. Generally, the magnesium content is around 200–300 ppm (Chaiprapat et al., 2009 refer to Nithi-Uthai et al., 1996). Then TMTD/ZnO (TZ) and ammonia solution are added to preserve the quality of the F-NRL.

The factory will receive the F-NRL from customers who have registered with the factory. Then they collect 10–20% of the F-NRL from the tank for quality tests (Chaiprapat et al., 2009), such as VFA value and a calculated %DRC for payment to the suppliers. If the properties pass the standard, they will filter the F-NRL by sieve and transfer the material to a fresh latex tank. If the properties do not pass the standard the material is rejected. If the customer needs to sell the F-NRL, the factory will reduce the price depending on the quality of the F-NRL (Songkhla Provincial Industry Office, 2009). Then the latex is transferred to the skim latex tank or is held for mixing with other latex (Chaiprapat et al., 2009).

2. Chemical Adjustments

Normally, the F-NRL is preserved with 0.2% wt% of ammonia on the whole latex which is sufficient for short-term preservation. For long-term preservation, 0.7% wt% is required in the absence of ancillary preservatives.

Ammonia can deactivate some multivalent metal ions by the formation of ammine complexes. In addition, other multivalent metal ions are effectively deactivated through removal from the latex aqueous phase by precipitation as sparingly-soluble compounds. Some metal ions may precipitate as hydroxides. More important for the colloid stability of ammonia-preserved F-NRL is the interaction of magnesium ions (Mg^{2+}) with ammonia and phosphate anions which may be present in the aqueous phase to precipitate the very sparingly-soluble $MgNH_4PO_4$ according to the following reaction:

$$Mg^{2+} + NH_3 + HPO^{2-}_4 \longrightarrow MgNH_4PO_4 \downarrow$$

Source: Blackley, 1997.

Before centrifugation, the F-NRL is collected in a tank to precipitate the magnesium ions using DAP. The quantity of DAP added depends on the amount of magnesium in the F-NRL. The ratio of DAP to magnesium in the F-NRL is about 1 : 5.5. After the addition of DAP to the F-NRL, it is mixed and kept in a tank for around 8–12 hours to precipitate the magnesium (Chaiprapat et al., 2009 refer to Khajornchaikul, 2006). Magnesium is separated from the F-NRL together with any sand, dirt, and soil (Blackley, 1997). The amount of magnesium should decrease to 100 ppm of total solids (Chaiprapat et al., 2009 refer to Khajornchaikul, 2006).

When the F-NRL and DAP are mixed and kept in a tank, the latex needs to be preserved with some chemicals such as ammonia and tetramethylthiuram disulphide (TMTD) to prevent putrefaction. The preservative chemicals used in the concentrated latex process should destroy latex microorganisms, repress their activity and growth in the latex, and increase the colloid stability. In addition, they should deactivate the multivalent metal ions, by sequestration or precipitation as insoluble salts; especially the magnesium ions (Mg^{2+}) that can minimize the colloid stability of the latex. The principal culprit in the F-NRL in this respect is the magnesium ions (Blackley, 1997).

3. Centrifugation

Concentrated latex manufacture by centrifugation is an important method because it is continuous in high volume applications. Ninety percent of the concentrated latex used in industries is produced by centrifugation (Blackley, 1997).

The concept of this process consists of the latex passing though the centrifuge machine at high speeds which separates the latex into a concentrated latex fraction containing 60% DRC or greater and a 3–7% DRC in the skim latex fraction. The ammonia in the rubber latex will dissolve into the serum and its effect is to decrease the concentration of the rubber latex. So, in concentrated latex preservation 0.7% ammonia is added to increase the ammonia volume by direct ammonia gas into the rubber latex.

Generally, the bowl of the centrifuge machine rotates at about 6,800–7,600 rounds per minute and discharges around 300–500 liters/hour of the F-NRL. In addition, he efficiency of the centrifuge machine depends upon the type and brand of the machine. Moreover, they have different characteristics, quantity of discs, and motor sizes.

In the centrifugation process, there are other solid components in the F-NRL that are not rubber. They are centrifuged into the bowl and caught on the inside of the bowl and disc. In the event of dirty F-NRL together with magnesium, the machine plugs rapidly. So, the machine needs to be shut down frequently for cleaning. In the case of highly pure F-NRL with low amounts of sediment, the factory can use the centrifuge for a longer time. Normally, the factory shuts down the centrifuge machine for cleaning every 2–3 hours to dispose of the sediments at the disc area and the cleaning time is 10–15 minutes per machine. The sediments are referred to as rubber bowl or concentrated latex sludge (Chaiprapat et al., 2009).

4. Improved concentrated latex

Concentrated latex is improved after centrifugation and before transport to customers. The factory will take a sampling for analysis for some parameters such as %DRC and add NH_3 into the concentrated latex which follows the standard for concentrated latex for either HA or LA; for example, 0.7% by weight of NH_3 is added into the concentrated latex to produce HA concentrated latex. Most of the factories produce this type. On the other hand, LA concentrated latex is produced when 0.2% by weight of NH_3 is mixed with other preservatives such as TZ. In addition, other chemicals may be added; for example, to produce low ammonium-boric acid (LA-BA) (Chaiprapat et al., 2009 refer to Kovuttikulrangsie, 1980). Furthermore, lauric acid may be added to improve the mechanical stability time (MST) (Songkhla Provincial Industry Office, 2009). For LA concentrated latex, the MST is low and laurate soap is added to increase the MST. The molecules of laurate soap can easily catch onto the rubber particle surface.

Laurate soap also helps to treat the stability of rubber latex. Generally, the factory will maintain the quality and treat if necessary (Chaiprapat et al., 2009).

5. Storage and transportation

When the concentrated latex has an improved quality according to customer specifications the latex is contained in closed 200 liter drums and labeled with the name of the company, date, and other information. Then the drums are transferred to a storage area. Before transport to the customer, they are sampled to test the quality again. Next, they will move the drums into a shipping container with a crane until the container is full.

A diagram of the concentrated latex process is shown in Figure 1.2. From the concentrated latex diagram, the concentrated latex is separated into two fractions that consist of concentrated latex and a skim latex fraction. There is also waste material from this process. The waste material is the concentrated latex sludge. Concentrated latex sludge can be found in many points such as the reception fresh latex tank, storage tank for adding chemicals, centrifuge machine, skim latex tank, and concentrated latex tank.

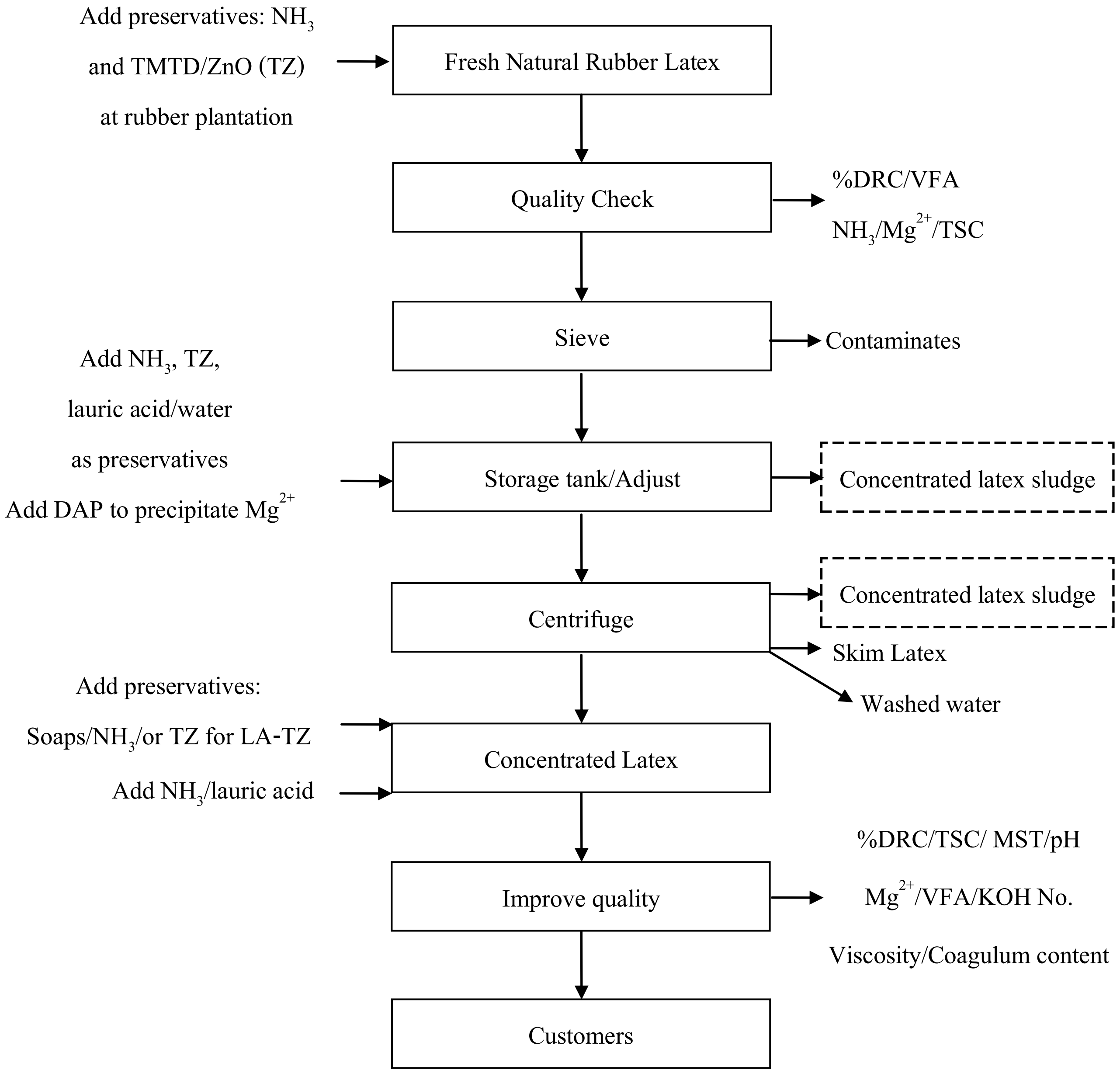

Figure 1.2 Concentrated latex process

Source: Chaiprapat et al., 2009, Rubber Industry, n. d., and Thungsong Sisawad, 2008.

1.2.3 Concentrated latex sludge

1.2.3.1 Source of concentrated latex sludge

In the concentrated latex industry with the centrifugation method, chemical preservatives are added to the F-NRL to prevent spoilage and bad odors before centrifugation. The chemicals include ammonia, tetramethylthiuram disulfide (TMTD), and zinc oxide (ZnO) for preservation and diammonium phosphate (DAP) to precipitate the magnesium before transfer to the concentrated latex process. The sediment in this process is called $MgNH_4PO_4$ or concentrated latex sludge (sludge or waste) that is poorly soluble in water. The interaction of magnesium ions (Mg^{2+}) with ammonia and phosphate anions which may be present in the aqueous phase results in precipitation of the very sparingly-soluble $MgNH_4PO_4$ according to the following reaction:

$$Mg^{2+} + NH_3 + HPO^{2-}_4 \longrightarrow MgNH_4PO_4 \downarrow$$

Source: Blackley, 1997.

Normally, the magnesium in the F-NRL can find various uses such as an additive to fertilizer which is composed of magnesium. Magnesium is a micronutrient in the soil and > 0.3 cmol/kg(1) is a medium nutrient level and < 0.3 cmol/kg is a low nutrient level with reference to soil nutrients for rubber (Siriratpiriya et al., 2009 refer to Thainugil, 1986). Magnesium affects the growth of rubber trees and the latex yield (latex quality) since magnesium is a component of chlorophyll that accelerates enzyme action and the use of carbon dioxide.

In addition, adding fertilizer with magnesium decreases the potassium in rubber leaves and the rubber tree can increase the volume of latex. On the other hand, if the rubber trees do not receive enough magnesium, the growth of the rubber trees pauses and the amount of latex drops. The sources of magnesium consist of kieserite, magnesia, and dolomite (Sungwatin, 2008).

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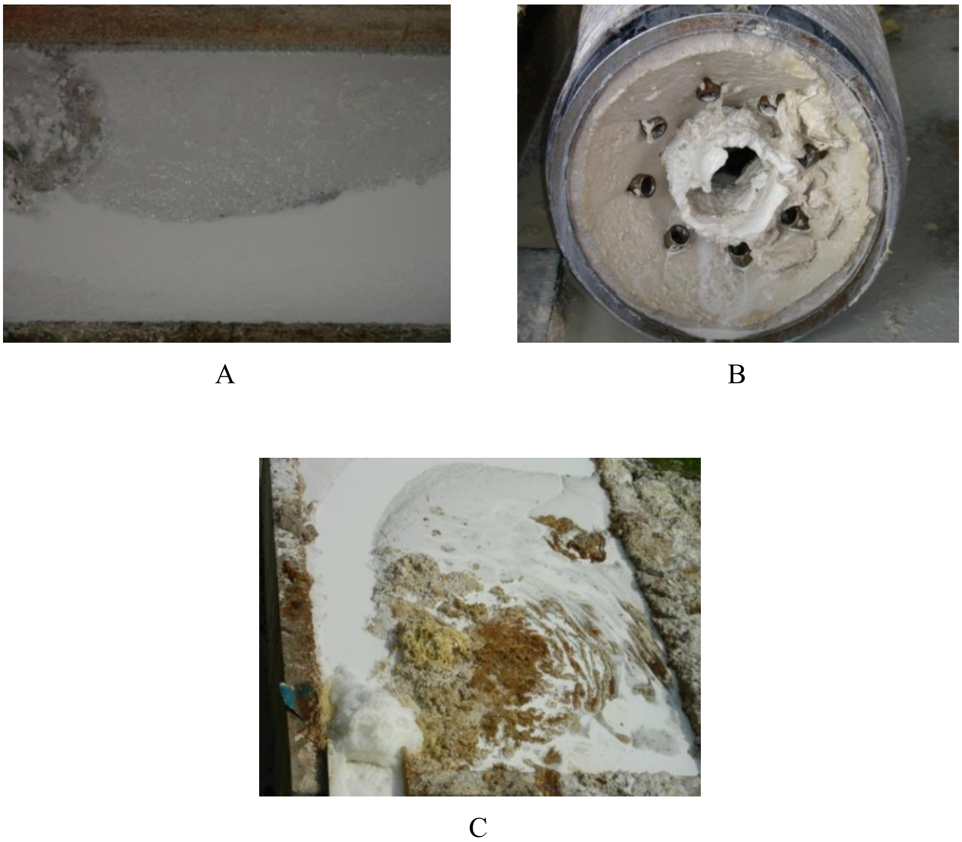
(1) cmol/kg = milli equivalent of cation per weight of soil 100 gram which refers to the magnesium cation.

Moreover, the magnesium concentration in the F-NRL affects the quality of the latex. The F-NRL, which is high in magnesium, can precoagulate and become unstable which causes low dry rubber content (Siriratpiriya et al., 2009 refer to Kangpisadarn, 1986). The magnesium content in the F-NRL will vary which depends on the clone of rubber, landscape, and weather (Khajornchaikul, 2006).

When the F-NRL is collected from rubber plantations for the concentrated latex process, the latex is examined for quality. Since the magnesium value should be lower than 100 ppm of total solids, DAP is added to precipitate the magnesium ions. DAP will interact with magnesium and ammonia to produce a sediment which is called magnesium ammonium phosphate ($MgNH_4PO_4$) in the concentrated latex sludge.

In the factory this concentrated latex sludge can be found in the storage tanks, centrifugation process (Niyomdecah, 2009 refer to Yodkaew, 1997), and in the skim latex sediment tank in the concentrated latex process (Figures 1.3 A-C).

The concentrated latex sludge from the precipitation with DAP also contains sand, dirt, soil (Blackley, 1997), bark, and leaves. All of these constituents produce white or soft yellow solids because the sludge contains magnesium and phosphorus (Niyomdecha, 2009 refer to Danteravanich, 2002). When the sludge is centrifuged and accumulates in the bowl body and disc in the concentrated latex process, the machine plugs rapidly. Therefore, the machine needs to be shut down for cleaning every 2–3 hours to clean the sludge out of the disc area (Chaiprapat et al., 2009). The concentrated latex sludge is sent for disposal by dumping on the ground or outdoor burning (Tekprasit, 2000).



A

B

C

Figure 1.3 Fresh concentrated latex sludge (sludge) from concentrated latex process

A) Sludge from storage tank, B) Sludge from centrifuge machine,

C) Sludge from skim latex sediment tank

Source: Wintex Rubber Industry Co., LTD., 2011.

1.2.3.2 Composition of concentrated latex sludge

Physical characteristic

The fresh concentrated latex sludge is a fine grain, white-gray or bright yellow color mud (Figure 1.4 A-B). The main composition consists of phosphorus, magnesium, and ash and it has a neutral condition. In the process, ammonia is added to the F-NRL and moved to the centrifuge machine. When the F-NRL is centrifuged, the F-NRL is separated into three fractions which are the concentrated latex, skim latex, and sludge. During the process the amount of ammonia in the sludge is low and the pH of the sludge is nearly neutral (Klangtin and Sukkasem, 2009 refer to Kovuttikulrangsie, 2000). However, the pH of the sludge can be different in various factories due to differences in the process. The factories have different collection times and the amount of ammonia to preserve the F-NRL can be different which results in different pH values. If the sludge is collected within 48 hours, the sludge is basic due to the presence of the ammonia. However, sludge that is collected after 48 hours has a neutral pH due to the loss of ammonia (Ubon, 2007).


A B

Figure 1.4 A-B Fresh concentrated latex sludge

Source: Wintex Rubber Industry Co., LTD., 2011 and Nam Hua Rubber Company Limited, 2014.

Density

The sludge is a highly contaminated substance with a high density that contains more contaminates than the F-NRL material. Normally, the F-NRL has a density in the range of 0.975–0.980 g/ml and the density of a rubber particle is around 0.92 g/ml (Klangtin and Sukkasem, 2009 refer to Kovuttikulrangsie, 2003). When the F-NRL is centrifuged at 20,000 rounds per minute, it separates the rubber particles, serum, and sludge. The density of the sludge is around 1.16–1.63 g/ml and the contaminants in the F-NRL include resins, heavy metals, proteins, lipids, rubber hydrocarbons, and some chemicals for preservation which are NH_3, TMTD, and ZnO and DAP to precipitate the magnesium. Therefore, the sludge has a high density because the components of the sludge include magnesium, phosphorus, and ash that affect the physical properties and appears as bright yellow or white gray clay. The density of the sludge is about 18.97–66.33% greater than the fresh natural rubber latex (Klangtin and Sukkasem, 2009).

Total solids content (TSC) and moisture (MC)

The total solids content (TSC) includes phosphorus and magnesium due to the addition of DAP to precipitate magnesium from the F-NRL. The DAP interacts with the magnesium to become $MgNH_4PO_4$ sediment. This sediment is separated from the F-NRL at the rubber tank or storage tank before transfer to the centrifuge. When the F-NRL is centrifuged, the sediment will mix with the proteins, carbohydrates, sugars, and other components in the sludge (Klangtin and Sukkasem, 2009 refer to Kovuttikulrangsie, 2003). In addition, when the lutoids burst, the solution inside the lutoids releases suspended solids that are cation and anion metals such as calcium and magnesium ions and they spread into the F-NRL. The debris of lutoid membranes after bursting will coagulate and attach to the surface of the rubber particles which causes the rubber to be unstable. These particles then separate from the rubber and mix with the sludge.

Frey-Wyssling particles are spherical, non-rubber particles that are often bright yellow and they are larger and slightly denser than rubber particles. When they mix with ammonia they separate into the serum. After centrifugation they move and mix with the sludge. The total TSC values are around 58.05–62.96% by weight. The moisture in the sludge consists of the remaining water and ammonia in the sludge after centrifugation. The moisture content is around 37.05–41.95% by weight (Klangtin and Sukkasem, 2009).

Fixed solids (FS) and volatile solids

Fixed solids (FS) consist of carbon and heavy metals that remain after burning at 550 ± 50°C. Other organics in the sludge that are volatile and go into the gas phase are volatile solids. The sludge has fixed solids in the range of 24–28% by weight and volatile solids in the range of 72–76% by weight (Klangtin and Sukkasem, 2009 refer to Kovuttikulrangsie, 2004).

Chemical characteristics

The components and characteristics of the sludge are various due to the various sources of sludge and each factor can vary due to many reasons. So, the property of the sludge is unstable. A report by Tekprasit (2000) found that the production of sludge through the operations is approximately 1% of the F-NRL that is processed.

The properties of the sludge that are profitable nutrients for plants include nitrogen (N), phosphorus (P) in the form of P_2O_5, potassium (K) in the form of K_2O, magnesium (Mg), and zinc (Zn) that are present at average values of 2.06, 19.6, 1.8, 5.31, and 1.01% dry weight, respectively. A report by Danteravnich (n. d.) found that the sludge consists of nitrogen (N), phosphorous (P) in the form of P_2O_5, potassium (K) in the form of K_2O, magnesium (Mg), and zinc (Zn) that were present at average values of 2.31, 19.41, 1.51, 5.31, and 1.05% dry weight, respectively. When the results are compared with Tekprasit (2000), the values are similar.

From a report by Klangtin and Sukkasem (2009), the sludge was dried at 70°C for 24–48 hours to separate the serum and ammonia from the sludge. The solids were crushed into fine grains and analyzed for the nutrients that included nitrogen, phosphorus, potassium, calcium, and zinc (Figure 1.5).

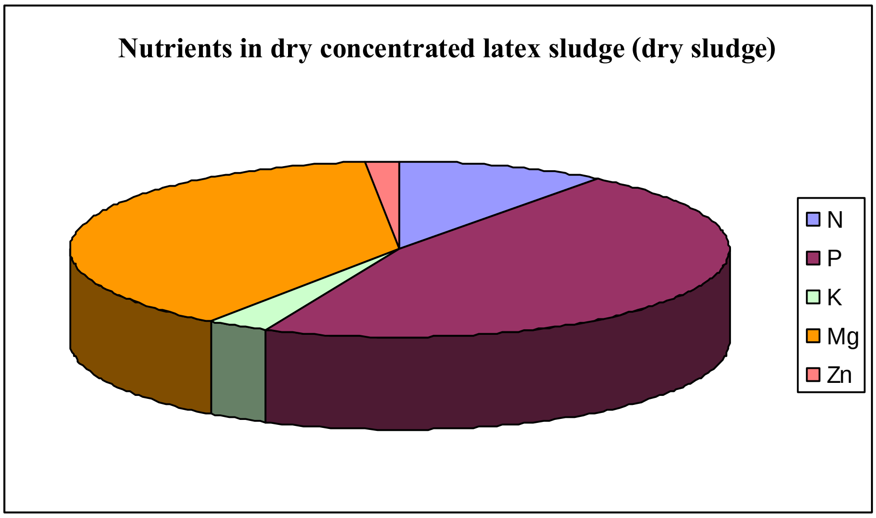


Figure 1.5 Nutrients in dry concentrated latex sludge (dry sludge)

Source: Klangtin and Sukkasem, 2009 refer to Kovuttikulrangsie, 2004.

Total Nitrogen

The total nitrogen in the dry sludge came from the proteins on the rubber particles and the lutoid membranes that were attached to the rubber particles that mixed with the sludge during the centrifugation. Therefore, there is a variation of total nitrogen in the sludge. The ammonia added to preserve the fresh natural rubber latex vaporized during the drying of the sludge at 70°C. The total nitrogen in the dry sludge was around 3.07–3.65% by weight (Table 1.4).

Table 1.4 The nutrients in dry concentrated latex sludge (dry sludge)

Nutrients	**Quantity (% by weight)**
1. Nitrogen (N)	3.07–3.65
2. Phosphorus (P)	14.22–15.17
3. Potassium (K)	0.79–1.20
4. Heavy metals	
4.1 Magnesium (Mg)	11.69–12.86
4.2 Zinc (Zn)	0.37–0.98
4.3 Calcium (Ca)	0.01–0.06

Source: Klangtin and Sukkasem, 2009 refer to Kovuttikulrangsie, 2004.

Total Phosphorus

Most of the phosphorus comes from the addition of DAP to precipitate the magnesium metal in the F-NRL. The amount of phosphorus in the dry sludge was around 14.22–15.17% by weight (Table 1.4).

Total Potassium

The potassium in the sludge comes from the rubber particles and serum that remain from centrifugation which was taken up from the soil by the rubber trees as a nutrient. The amount of potassium in the dry sludge was around 0.79–1.20% by weight (Table 1.4).

Other metals

Before the F-NRL is transferred to the centrifugation process, DAP is added into the F-NRL to precipitate the magnesium as $MgNH_4PO_4$. This substance is separated from the latex at centrifugation. The amount of magnesium in the sludge was in a range of 11.69–12.86% by weight (Table 1.4).

In addition, the sludge also includes zinc and calcium at around 0.37–0.98 and 0.01–0.06% by weight, respectively. The source of zinc is from the addition of zinc to accelerate and preserve the F-NRL in the concentrated latex process. The source of calcium is from the bursting of the lutoids at the high temperature conditions of the F-NRL. When the lutoids split, they allow suspended solids to spread into the serum. After centrifugation the suspended solids that consist of cations and anions of metals such as calcium and magnesium ions will separate and become part of the sludge. The quantity of calcium is very low when compared with other elements.

The quantities of phosphorus, potassium, and heavy metals in the sludge are different due to the differences of the concentrated latex process and the amounts of chemicals used, especially the amount of DAP added into the F-NRL (Klangtin and Sukkasem, 2009 refer to Kovuttikulrangsie, 2004). The results of the analysed sludge by X–Ray Fluorescence (XRF) by Tekprasit (2000) are shown in Table 1.5.

Table 1.5 Compound substances in the sludge from X–Ray Fluorescence (XRF)

Substances	**(%) Concentration**	
	Sludge code 00192/41CA	**Sludge code 00192/41CB**
Mg (as MgO)	8.974	12.871
Al (as Al_2O_3)	0.074	0.029
Si (as SiO_2)	0.369	0.089
P (as P_2O_5)	14.224	18.259
S (as SO_3)	0.182	0.091
K (as K_2O)	2.09	2.516
Ca (as CaO)	0.22	0.336
Ti (as TiO_2)	0.021	-
Mn (as MnO_2)	0.034	0.282
Fe (as Fe_2O_3)	0.3	0.07
Zn (as ZnO)	1.335	0.573
Rb (as Rb)	0.064	0.052
Ni (as NiO)	-	0.01
Cu (as CuO)	-	0

Source: Tekprasit, 2000.

The amount of phosphorus in the form of P_2O_5 is the highest followed by magnesium as MgO, potassium as K_2O, and zinc as ZnO. Dantheravanich (n. d.) found that the average values of P, K, Mg, and Zn were 23.27%, 13.22%, 15.59%, and 0.79%, respectively, and Al, Si, S, Ca, and Rb had average values of 0.35%, 0.61%, 0.85%, 1.88, and 0.26%, respectively. Much smaller amounts of other elements found were Fe, Ni, Mn, Cu, Pb, Cr, and Ti. Other elements in the forms of compounds included MgO, Al_2O_3, SiO_2, P_2O_5, SO_3, K_2O, CaO, MnO_2, Fe_2O_3, NiO, and CuO. These data show the wide variety of metals in the sludge. Therefore, before processing the sludge, the impact of contamination on the environment from the metals should be considered and the concentration of the metals should be studied for safe utilization and good management of the sludge.

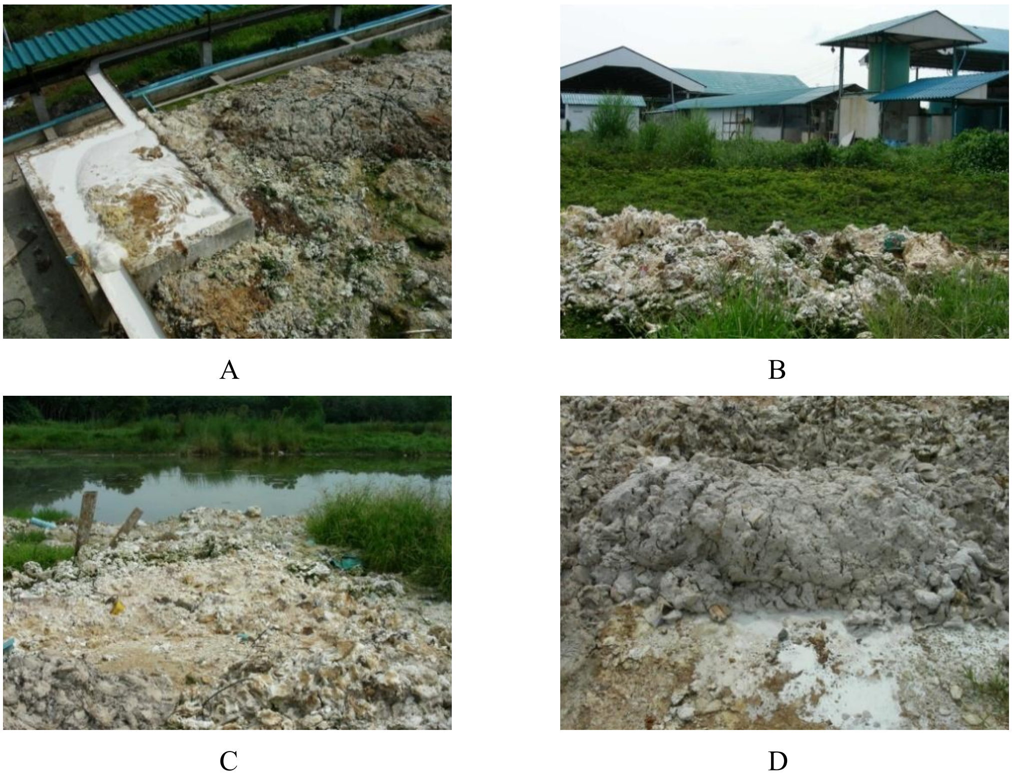
Biology characteristics

In addition, the sludge is unstable and leaches easily and some components are soluble. When the sludge is extracted with distilled water, potassium (K) was found to leach in a maximum range of 69-88%, nitrogen (N) 11–12% and phosphorus (P), magnesium (Mg), and zinc (Zn) at least 1%.

The BOD and COD values from sludge extraction found that the ratios of BOD and COD were more than 0.5. Moreover, the water extracted from the sludge contained biodegradable substances (Tekprasit, 2000). In addition, the substances in the sludge were biodegradable in a 50–60% moisture condition, especially the organic matter. From the experiment by Danteravanich (n. d.) the sludge was put in a 50–60% moisture condition. At 30 days the values that changed were pH, volatile solids (VSs), ash, N, P, and K. The VS values decreased rapidly from 60% to 40% (decreased 27%) which was rapid during the first 5 days. On the other hand, the ash values increased, but the pH value dropped to a neutral value and the trends of the N, P, and K values were to rise a little bit.

1.2.3.3 Environmental impact from concentrated latex sludge

Most of the concentrated latex sludge or waste is collected and disposed at a dumping site, landfill, or outdoor burning within the property of the factory (Figure 1.6). That is a cause of pollution such as waste water (leachate) and malodors. Nowadays, the researches try to reduce this waste by many methods such as the biogas production process (Kharemdebeh et al., 2015), making concrete, and as an admixture for construction materials (Pongkan, 2008).



A B

C D

Figure 1.6 Concentrated latex sludge disposal

A) Concentrated latex sludge residue in process

B-C) Concentrated latex sludge dumping site within factory

D) Leachate from concentrated latex sludge heap

Source: Wintex Rubber industry Co., LTD., 2011.

Moreover, this waste is used to produce fertilizers and/or conditioners for soil treatment at rubber plantations, oil palm plantations, and mainly at the nursery stage of palm oil (http://www.nstda.or.th/pub/2012/20121203-63-GRASS-3-v2.pdf, 2012 and Chinnawong et al., 2014), or other products used in agriculture.

This waste is nontoxic as a fertilizer when only the heavy metal composition is considered since the total zinc, total lead, total arsenic, and total copper are lower than the standards in the Fertilizer Act (Volume 2) B.E 2550 (2007) (Triyong, n. d.). In addition, the waste has a high quantity of other inorganic substances which includes $MgNH_4PO_4$ (http://www.nstda.or.th/pub/2012/20121203-63-GRASS-3-v2.pdf, 2012).

However, this waste also has a high quantity of rubber content. Normally, the rubber is not separated from this waste before it is used to produce fertilizer and/or soil conditioners. The rubber content in the waste can change the properties of the soil because the rubber content in the waste does not biodegrade easily. In the long term it can plug the soil, reduce water adsorption and gas in the soil (Danteravanich et al., 2005), and affect plant growth (death of the plants in the long term) (http://www.nstda.or.th/pub/2012/20121203-63-GRASS-3-v2.pdf, 2012).

Although, the quantity of minerals and some heavy metals in the leachate from this waste are lower than the soluble threshold limit detected from the waste or unusable material according to the Notification of the Ministry of Industry B.E. 2548 (2005), it continues to increase in concentration, and contaminate the soil and water (Suksaroj et al., 2011).

1.2.3.4 Solving the problem and management

Recently, management of the concentrated latex sludge (waste) in the factories is not efficient. Most of the waste products in many factories are disposed by dumping in areas that surround the factory in a landfill, making a ridge and piling the waste, outdoor burning, and mixing with other garbage. These management problems are related to the Notification of the Ministry of Industry. For example, the waste products cannot be taken to disposal sites outside the area of the factory because the waste cannot be classified specifically between hazardous waste or non–hazardous waste in order to follow the law although some studies report that the chemical composition of this waste is low in heavy metals in the leachate and in solid waste form. Moreover, this waste does not have a specific area for disposal which means this waste should go only to a sanitary landfill.

In addition, the waste is not allowed to be transported out of the factory premises unless permission is granted from the director general of the Department of Industrial Works or from an authorized person to manage waste with the proper method and location according to the criteria and procedures. The waste generator is allowed to have the waste in possession within the factory premises for no longer than 90 days. If the time for the procedure is longer than that, a waste generator will ask for permission from the Department of Industrial Works. When waste treatment or disposal is performed at the factory premises, it must be done in accordance with certain regulations (Notification of the Ministry of Industry, 2006).

Although they try to follow the rules in the notification, which are controlled by the Department of Industrial Works for disposal of the waste products, they are not successful in proper management of the waste products. Since the properties and characteristics of the waste products are not clear, the waste management systems need to be distinct and the properties of the waste products need to be defined. In the meantime there are no new specific rules for disposal and control of the waste products and the waste generators have to follow these rules to manage the waste although some rules in the notification are in conflict with each other.

The Department of Industrial Works prepared a handbook to regulate the industry sector to control pollution prevention, safety, protection of workers and reduce accidents, and address occupational health safety in the rubber industry. This handbook refers to pollution, waste, and environmental management. The groups of pollution are classified into 3 parts which are water pollution, air pollution, and waste or unusable material. The waste or unusable material from the rubber industry refers to the concentrated latex industry and it is means the concentrated waste latex sludge (Rubber Industry, n. d.). Table 1.6 shows the classification of the waste or unusable material.

Table 1.6 Quantity of concentrated latex sludge from the concentrated latex process

Pollution and waste	**Source**	**Characteristic**	**Volume**	**Sludge production rate Ton/production**	**Treatment and disposal**	**Source solution**
3. Waste or unusable material	1. Rubber tank	Concentrated waste latex sludge	320 kg	5.2 kg	Sanitary landfill	Separate concentrated waste latex sludge from wash water
	2. Centrifuge machine		150 kg	2.4 kg		Separate rubber from bowl before rinsing
	3. Sludge from treatment system	Bad odor				

Source: Rubber Industry, n. d.

Table 1.6 shows two sources of concentrated waste latex sludge.

1. Rubber tank: This waste is produced from mixing preservative chemicals into the latex and some chemicals to precipitate the magnesium from the latex before centrifugation.

2. Centrifuge machine: In the concentrated latex process, rubber is separated by a centrifuge machine and the rubber is split into 2 parts that consist of rubber and non–rubber solids. The solids are centrifuged in the centrifuge machine and the discs inside the machine clog up.

In addition, it can be found this waste precipitates in the skim latex tank before transfer of the skim latex to produce skim block. Table 1.7 shows the status and methods for treatment and disposal of these waste products. The concentrated latex sludge refers to waste or unusable material according to the Notification of the Ministry of Industry in the criteria for waste or unusable material B. E. 2548 (2005). The waste treatment and disposal methods of the rubber factories follow the guideline as indicated in Table 1.7.

Table 1.7 Guideline for the waste or unusable material management

Type and category of waste or unusable material		**Management method**	
Code	**Name**	**Code**	**Name**
16 05 09	Concentrated latex sludge	071	Sanitary landfill
19 12 04	Rubber scrap	011	Sorting
19 12 12	Soil scrap, bark	071	Sanitary landfill
19 08 14	Sludge from treatment system	071	Sanitary landfill
10 01 01	Ash from fuel	071	Sanitary landfill

Source: Rubber Industry, n. d.

In reference to Table 1.7, the Notification of the Ministry of Industry has the criteria of the waste or unusable material B.E. 2548 (2005) classification and assigns the definitions as follows:

Waste or unusable material means material unused or all waste that is produced from factory activity and involves waste from materials, waste from the production process, waste that worsens a product, and waste water that has hazardous components.

Waste or unusable material management means treatment, disposal, stabilization discard, distributed, exchange or reuse, and storage for waste management.

The codes of the kinds of waste or unusable material is classified into 19 sections and specific codes of waste or unusable materials with 6 digit codes and separated into 3 pairs of digits with the following meanings:

The first two digits refer to the kind of activity or type of waste or unusable material. In this case, the concentrated waste latex sludge or sludge is classified in section 16 (**16** 05 09) which refers to waste or unusable material that is not classified in other sections.

The middle pair of digits refers to a special process in the activity that produces the waste or unusable material or type of waste or unusable material. In this case, the concentrated latex sludge is classified in section 16 (**16 05** 09) that refers to gas in a container that is tolerant to pressure and unused chemicals.

The last pair of digits refers to the special characteristic of waste or unusable material. The concentrated latex sludge is classified in section 16 05 (16 05 **09**) which means unused chemicals not part of 16 05 06 (HM) or 16 05 08 (HM) which refer to chemicals used in a laboratory and are hazardous substances, mixtures of chemicals, and unused inorganic and organic hazardous substances, respectively (Notification of the Ministry of Industry, 2006).

From the meanings of the code, the classification of types and codes of the concentrated waste latex sludge is not correct because the concentrated latex process uses many chemicals such as NH_3, TMTD, ZnO, and DAP which are classified as hazardous substances in the Hazardous Substance Act B.E. 2535 (1992), Notification of the Ministry of Interior in safety in the work environment (chemical) B.E. 2520 (1977), Notification of the Ministry of Interior in safety in the use of chemicals B.E. 2534 (1991), and Notification of the Ministry of Industry in list of hazardous materials B.E. 2546 (2003).

Currently, concentrated latex sludge cannot be classified as either hazardous or non–hazardous. When the chemicals in concentrated latex process are considered from all notifications, this sludge is a hazardous waste because it contains hazardous chemicals. But if this sludge is classified as a waste that is produced at a factory which follows the Ministry of Industry criteria for waste or unusable material B. E. 2548 (2005), the sludge is a non–hazardous waste. Therefore, this sludge cannot be clearly identified and classified as to the type of sludge.

Nowadays, the legal definition for the method of concentrated latex disposal in a sanitary landfill is regulated by the criteria and methods for waste or unusable material with the code 071 as follows:

The three digit code that is used for waste or unusable material management (Treatment and disposal codes) in form SG 3 shows the details of the waste or unusable material and the permission to take the waste or unusable material to an outside site and is classified into 8 types. In the case of concentrated sludge, the type is 07 that is disposal and the three digit code is 071 which means sanitary landfill, especially for waste or unusable material that is non–hazardous waste only according to Notification of the Ministry of Industry B.E. 2548 (2005).

Table 1.8 shows the guideline for the rubber industry to control the waste or unusable material disposal.

Table 1.8 Environmental management in a rubber factory

Pollution and waste	**Source**	**Treatment and management**
Concentrated latex industry		
3. Waste or unusable material	Fresh latex tank	Sanitary landfill
	Centrifuge machine	
	Water treatment pond	

Source: Rubber industry, n. d.

The sanitary landfill method is used for disposal of concentrated latex sludge in the factory, but in fact, most of the factories that dump or landfill use incorrect methods at the factory site because there is no sanitary landfill within the factory premises for disposal of concentrated latex sludge. In addition, management of the concentrated latex sludge inside the factory is not clear for disposal because some sludge remains within the factory premises.

Moreover, the law specifies that they may not move the waste or unusable material outside of the factory area except when the factory receives permission from the director of Department of Industrial Works or the person that the director of Department of Industrial Works assigns for management of the methods and location sites that follow the standards and criteria for control in appendix 4 at the end of the announcement. In case the method for treatment or disposal of waste or unusable material is within the factory area, they must follow the relevant parts of the Factory Act, Section 4, Subsections 17 and 21-24. But when the waste or unusable materials are not moved to an area outside factory area, the factory cannot keep the waste or unusable material inside the factory for more than 90 days. If they go over the limit of 90 days, they will get a permit from the Department of Industrial Works using the SG 1 form for permission which is at the end of the announcement. And in case the factory needs to keep the hazardous waste inside factory premises, they have to follow the Notification of the Ministry of Industry in topic manifest system B.E. 2547 (2004) (Notification of the Ministry of Industry, 2006).

From a legal point of view, there are difficulties in the management of the concentrated latex sludge in a factory. So, the factory will solve the problem by utilizing the sludge to make a ridge, make a road bed, or open/lowland dumping on the ground. In addition, researchers have tried to develop methods to utilize the sludge. But, the use of sludge has concerns about the toxic residue that has only a small amount of data to answer questions concerning health and environmental issues. So, questions regarding the proper utilization of the sludge have not been successfully answered.

1.2.4 Magnesium

Magnesium (Mg) is an element in the second column (group 2A) of the periodic table that is an alkaline earth metal, atomic number 12, atomic mass 24.31 and has a 2+ oxidation state. It is a gray–white lightweight metal. The earth is composed of about 2.1% magnesium and in the soil it is around 0.03–0.84%, in water 4 mg/L, and in ground water >5 mg/L (Eaton et al., 2005). In ground water, magnesium salt causes hardness of water (Laegreid et al., 1999).

In addition, elemental magnesium reacts quickly and can mix with other elements to readily become compounds (Udchanon, 1997).

Moreover, magnesium is an important element and in compound substances it is used in many functions in humans, animals, and plants and in the environment and is utilized in the manufacturing industry. In industry, magnesium is used to produce alloys, pyrotechnics, flash photography, drying agents, fertilizer, pharmaceuticals, and in foods (Eaton et al., 2005).

This research is interested in the effect of magnesium in plants, especially the rubber tree (*Hevea brasiliensis*) that produces the F-NRL for use in the concentrated latex process industry.

1.2.4.1 Effect of magnesium in the fresh natural rubber latex and concentrated latex process

Normally, magnesium is an essential constituent in rubber trees that is found as magnesium ions (Mg^{2+}). In rubber trees, magnesium is an important component of chlorophyll in the leaves that performs the process of photosynthesis which affects the growth and improves the volume of latex (Sungwatin, 2008). The rubber trees take up Mg^{2+} ions that are dissolved in the soil solution (Magnesium in plants and soil, n. d.). In addition, the sources of magnesium in rubber trees are from many factors such as the clone of the rubber tree, water, fertilizers, nutrients in the soil, soil type, tapping system (tapping system with stimulant) (Webster and Baulkwill, 1989), and the season (Khajornchaikul, 2006) all of which affect the level of Mg^{2+} in the F-NRL. The range of the magnesium content in the F-NRL is between 100–1,000 ppm (Rubber Research Institute of Thailand, 1989).

The high or low levels of the magnesium content may be explained by other factors such as the discharge of Mg^{2+} ions from lutoid swelling and bursting when in contact with oxygen in the air outside the rubber tress. When a lutoid is ruptured by tapping and preservation, the lutoid particle releases Mg^{2+} ions into the serum (Alam et al., 2014). The lutoid membrane bursts by the mechanical force during tapping. The magnesium ions in the lutoids can be distributed to the outside and attach with anions that surround rubber particles which causes the rubber particles to coagulate. The coagulation can be fast or slow and depends on the cultivar, tapping system, temperature, and some chemicals (Chantuma, 2001 and Doungmusik, 2013).

Moreover, if the F-NRL has a high quantity of magnesium, the rubber has a low quality (Siriratpiriya et al., 2009 refer to Kungpisadan, 2004). The latex with a high magnesium level becomes unstable latex (Karunanayake and Perera, 2006 and Webster and Baulkwill, 1989) and precoagulates before use in the next process (RRIM, 1997).

A high magnesium level in latex will decrease the MST (Webster and Baulkwill, 1989 and Rubber Research Institute of Thailand, 1989) which reduces centrifuge efficiency, increases the sludge content of concentrated latex process, and increases the volatile fatty acid number (VFA No.) in concentrated latex (Rubber Research Institute of Thailand, 1989). If the levels of magnesium are high, the F-NRL from each area should be tested and the excess magnesium needs to be precipitated out of solution by adding DAP to form $MgNH_4PO_4$ (Webster and Baulkwill, 1989), and becomes a constituent of the concentrated latex sludge.

The addition of the phosphate ions (PO_4^{3-}) in the DAP to the F-NRL to precipitate Mg^{2+} ions should be added in the lowest volume because any excess PO_4^{3-} ions affect the physical properties of dipped products that are made of the F-NRL. Therefore, the level of magnesium in the latex cannot be reduced to zero (ppm). So, the addition of phosphate ions should be at a concentration of 30 ppm for the best quality latex for dipped products (Karunanayake and Perera, 2006). Moreover, if too much DAP is added it causes an increased potassium hydroxide number (KOH No.) and low MST (Rubber Research Institute of Thailand, 1989).

Generally, the magnesium level is satisfactory at around 20–30 ppm in concentrated latex (Webster and Baulkwill, 1989). For concentrated latex the Thai Industrial Standards Institute defines a value of 40 ppm in TIST 980–2552 (2009) (Notification of Ministry of Industry Thailand, 2009).

1.2.4.2 Technology for magnesium separation from fresh natural rubber latex

Generally, magnesium ions (Mg^{2+}) are found in many sources such as the human body, plants, animals, soil, fresh water, and sea water. Normally, the ions in solution are removed or separated by ion exchange methods. For example, calcium and magnesium ions (Ca^{2+} and Mg^{2+}) in hard water are separated from the water by using ion exchange principles to remove high concentrations of Ca^{2+} and Mg^{2+} ions and the hard water becomes soft water that contains low concentrations of Ca^{2+} and Mg^{2+} ions.

This principle of an ion exchanger (ion exchange material) is a media material to exchange or remove ions in solution. The media material is an insoluble solid material that can take up charged ions from a solution and release an equivalent amount of other ions into the solution (Inglezakis and Poulopoulos, 2006). There are many kinds of ion exchangers such as resin (ion exchange resin) and membrane (ion exchange membrane). The ion exchange membrane or membrane process is based on the principles of dialysis, electrodialysis, reverse osmosis, nanofiltration, micro, and ultrafiltration (Strathmann et al., 2006).

Ion exchange membranes are used in the separation processes and the most important process is electrodialysis. Electrodialysis is used largely to desalt brackish water (Baker, 2000) to produce drinking water from brackish water or sea water (Jiraratananon, 1998) and is used in other industries such as wastewater purification and in the food and drug industries (Strathmann et al., 2006), and medical supplies (Sata, 2002).

Electrodialysis works on the principle of anion and cation membranes that are constructed into a set of multicells that are built of many plates and frames in a stack. They are prepared in a pattern between anode and cathode electrodes. Each set of anion and cation membranes forms a cell pair (Baker, 2000). In the case of desalination of brackish water or sea water, the salt solution is pumped and passed through the cells while an electric potential is maintained across the electrodes. The cations in the solution move to the cathode, and the anions move to the anode. The cations pass through the negatively charged cation exchange membrane but are retained by the positively charged anion exchange membrane. Likewise, anions pass through the anion exchange membrane but are retained by the cation exchange membrane (Jiraratananon, 1998 and Baker, 2000).

The membrane application was applied and used to remove or separate magnesium ions from the F-NRL in the research of Meesupre (2010) that studied the topic of sludge formation and removal in the concentrated rubber latex industry that used the diafiltration process with a rotating membrane filter to separate magnesium from the F-NRL and to investigate the suitable conditions for magnesium reduction in sludge formation. The experiment found that this reduced the energy consumption of the centrifuge in the sludge removal process. In the traditional method, a high-efficiency impeller in both axial and radial mixing was used. The results found that the residual magnesium concentration in fresh rubber decreased at a high impeller speed.

The suitable condition at 50 rpm and 40 minutes gave the lowest residual magnesium concentration (35 ppm) compared to the previous condition of 120 ppm in a non-well-mixed rectangular tank. In addition, it found that the highest sludge concentration was 4,272.16 ppm. The consumption of diammonium hydrogen phosphate (DAHP) could be reduced by half in order to maintain magnesium concentration at 120 ppm (factory specification). Furthermore, the higher speed promoted bigger sludge particle sizes which led to increased centrifuge efficiency. In this novel method, the transmembrane pressure and feed flow rate were fixed at 0.3 bar and 36 L/h, respectively. The suitable condition of rotating speed at 1,200 rpm and one diafiltration volume could reduce the residual magnesium concentration to 121.21 ppm at a rejection rate of 89.04%. So, diafiltration is a promising method to reduce magnesium concentration in fresh natural rubber and use less DAHP.

But, in this case, the use of membrane technology in the F-NRL has the disadvantage of clogging the membrane and electrical energy is needed to supply the needed pressure for the magnesium to pass continuously though the membrane. In addition, the membrane cannot recover for reuse in this process which leads to a disposal problem (http://www.astom-corp.jp/en/en-main2-neosepta.html).

Another method to remove the magnesium is the ion exchange resin principle that is a part of adsorption technology. This method can recover and reuse the resin more than one time.

1.2.5 Ion exchange

The first environmental application of ion exchange was used for the purification of sea (desalination) and impure drinking waters (Inglezakis and Poulopoulos, 2006 refer to Lucy, 2003).

The ion exchangers or ion exchange materials are solid materials or insoluble substances that can take up charged ions from a solution and release an equivalent amount of other ions into the solution (Inglezakis and Poulopoulos, 2006 refer to Helfferich, 1995). In this process, the ions are replaced without physical alteration to the ion exchanger which enables an exchange of positive charged ions (cation exchangers) or negative charged ions (anion exchangers) (Alchin, n. d.). The ability to exchange ions is due to the properties of the structure of the materials. The ion exchange material consists of a matrix that has a positive or negative excess charge. This charge is located in specific locations in the solid structure or in functional groups. The charge of the matrix is compensated by counterions that can move inside the free space of the matrix and can be replaced by other ions of equal charge sign (Inglezakis and Poulopoulos, 2006 refer to Helfferich, 1995).

Generally, ion exchange material has many open areas of variable size and shape that are called pores. Some inorganic exchangers contain uniform pores that show a three-dimensional network of channels with irregular size. When the exchanger is in contact with a liquid phase, the solvent can move through the exchanger and cause a swelling to an extent that depends on the type of counterions. Some electrolytes can infiltrate into the exchanger along with the solvent. As a result, there are additional counterions, the so-called co-ions, which have the same charge sign as the fixed ions (Inglezakis and Poulopoulos, 2006 refer to Helfferich, 1995).

1.2.5.1 Ion exchange resin

- Resins

Resins are a natural or synthetic material. They start in a high viscous state and harden following treatment. The resins are insoluble in water, but they can be soluble in alcohol. They are many different types of resins that depend on the potential uses and chemical composition (Smith and Harris, 2011).

Natural resins come from plants. They have a hydrocarbon base and often contain terpenes that give them a sharp odor. When the resins are fresh, they are gummy, sticky, and soft. After a long time, they harden and can be made into useful products for human use, such as varnishes, paints, sealants, and lacquers.

Synthetic resins are manufactured by using a chemical process. In the process, the resins are made from polymers that are more stable and homogeneous than naturally occurring resins. Synthetic resins are not expensive and they are available in various forms that are used in many products such as paints, plastics, textiles, and varnishes.

The synthetic resins are classified into two types that are thermoplastic synthetic resins and thermosetting synthetic resins.

The thermoplastic resins can be softened and reformed through application of heat and pressure after they are set in a particular shape. This process can be repeated unless the polymeric bonds within the resins are broken. These types of resins consist of polyethylene resin, polypropylene resin, and polyvinyl chlorine (PVC). The applications of these resins include packing films, molded food containers, molded cup holders, and automotive parts. PVC resin is used to produce pipe and conduits.

The thermosetting synthetic resins are softened during the forming stage and set into a final shape. They are cured by curing chemicals or heat treatment. For the final shape, they cannot be melted and reformed into a new shape. The types of products in this group include polyester, epoxy resin, and polyurethane. Polyester is used in the textile industry, epoxy is used in industrial materials and construction, and polyurethane is used in exterior automotive parts (Gilani and Gale, 2011).

- Ion exchange resins

The ion exchange resins (thermoset material) are polymers that can exchange specific ions inside the polymer with ions in a solution that is passed through them (Alchin, n. d.). They consist of a cross-linked polymer matrix with a relatively uniform distribution of ion-active sites throughout the structure (Wheaton and Lefevre, 2000) and it has a function group with a mobile ion that can be exchanged with other ions in the solution to be treated (Ion Exchange Technologies, n. d).

- Ion exchange resin types

The types of resin are cation (positive mobile ion) and anion (negative mobile ion) resins. Both types are produced from similar or basic organic polymers. These ionic groups are added into the matrix that defines the chemical behavior and specific applications of the resin (Inglezakis and Poulopoulos, 2006). So, the ion exchange resins are divided into two types: cation exchangers that have positively charged mobile ions and anion exchangers that have negatively charged ions. Both of them are produced from the same organic polymer base, but they are different in the ionizable group that is attached to the hydrocarbon network. They are called functional groups which determine the chemical behavior of the resin (Resin Types, n. d.).

In addition, the resin can be classified as functional groups. Generally, the resin can be typified into strong and weak acid cation exchanger or strong and weak base anion exchanger. The types and functional group standards are shown in Table 1.9 (Inglezakis and Poulopoulos, 2006).

Table 1.9 Types and standards of the functional groups of ion exchange resins

Type	**Functional group**	**Active group**
Strong acid (cation exchangers)	$-SO_3^-$	Sulfonic
Weak acid (cation exchangers)	$-COO^-$	Carboxylic
Strong base (anion exchangers)	$-[N(CH_3)_3]^+$ $-[N(CH_3)_2C_2H_4OH]^+$	Ammonium
Weak base (anion exchangers)	$-NH_3^+$ $R_1-NH^{2+}-R_2$	Ammonium
Chelating resin	$R-SH$ $R-CN_2N(CH_2COOH)_2$ $R-CN_2NHCH_2CH_2PO_3H$	Chelating

Source: Inglezakis and Poulopoulos, 2006 and Ion Exchange Technologies, n. d.

- Ion exchange resins structure

Most of the synthetic structures of ion exchange resins are cross-linked polystyrene (styrene + divinylbenzene [DVB]), polymethacrylate, and phenol-formaldehyde (Ion Exchange Technologies, n. d.). The chemical structure of the resin matrix and the functional group are produced in two steps which consist of polymerization of the resin matrix and functionalization (i.e., attaching the ion exchange groups to the matrix) (Ion exchange resin structure, n. d.).

Generally, a polystyrene matrix is most commonly used (around 90%). The building block used to make this plastic skeleton is styrene monomer which is an aromatic compound called vinylbenzene (Ion exchange resin structure, n. d.).

- Ion exchange resin matrix

Most of ion exchange resins are produced from a copolymer of styrene (polystyrene) and DVB (Figure 1.7 A-B). The DVB content in the matrix defines the degree of cross-linking. The degree of cross-linking is related to the properties of the resin. For example, low DVB content means low cross-linking and the result is a soft resin prone to swelling in solvents. The ion exchange potential is produced by adding fixed ionic groups into the resin matrix. For instance, in sulfonation, 8-10-SO_3H groups are added into the matrix for every

10 benzene rings. The H^+ ions contained in the $-SO_3H$ groups are the mobile ions or counterions that will be exchanged in a solution with different cations (Inglezakis and Poulopoulos, 2006).

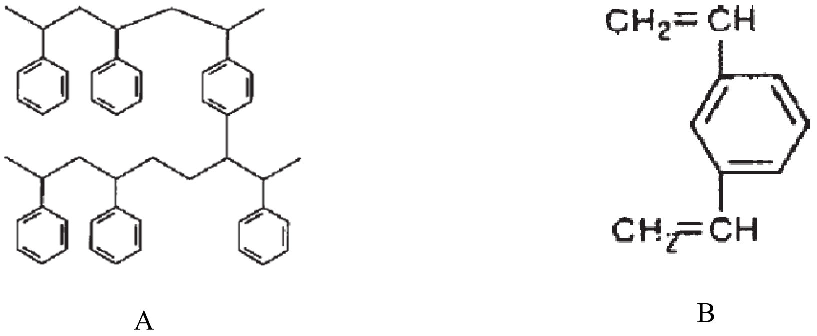


Figure 1.7 Copolymer of styrene (polystyrene) and DVB

A) Cross-linked polystyrene

B) Divinylbenzene (DVB)

Source: Inglezakis and Poulopoulos, 2006.

- Ion exchange resin matrix structure

In the polymerization resin process, the cross-linker is more or less evenly distributed throughout the matrix. The voids or spaces between the chains of polystyrene are called pores. These pores are very small (a few Ångstroms), but the size is relatively constant. The matrix has a pseudo-crystalline structure, similar to glass, and as a result the finished ion exchange resin beads are transparent. The matrix structure can be classified into three types.

First is the gel type. Too much DVB creates a structure with very small pores and large ions cannot move into the resin beads. These highly cross-linked polymers are more difficult to activate.

Second is the macroporous type. This type produces artificial porosity in the tri-dimensional matrix. They have a double porosity: the small pores of the matrix itself and the large macropores produced by the phase extender.

Third is the opaque type. They are very stable due to a matrix that is highly cross-linked and they are very porous; therefore, they can be used to exchange large ions (Ion exchange resin structure, n. d.).

In addition, most of ion exchange resins are polymerized into spherical beads (Ion exchange resin structure, n. d.). The resins are shaped as very small plastic beads. They are porous and contain invisible water within the beads that is measured as moisture or humidity content (Ion Exchange Basics, n. d.).

Most of the resins are often in a moist bead form that are granular or in powdered forms. Sometimes, they are used in a dry form that is available for applications in solvent media. The particle size distribution range is typically 16-50 mesh (0.3-1.2 mm) with a gel or macro porous structure. Presently, the ion exchange resins with a uniform particle size are available resulting in optimum industrial operations (Ion Exchange Technologies, n. d.).

Moreover, the structures of resins that are polymers have permanently fixed ions attached on the structures. These ions cannot be separated or displaced as they are part of the structure. The resin is preserved by electrical neutrality; the fixed ions must be neutralized with counterions. These counterions are mobile ions that can go into and out of the resin beads. This is illustrated in Figure 1.8 (Ion Exchange Basics, n. d.).

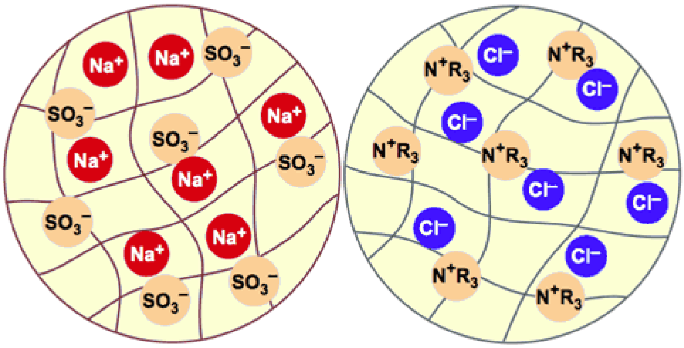


Figure 1.8. Schematic cation and anion resin beads

Source: Ion Exchange Basics, n. d.

Figure 1.8 shows the polymeric skeleton (solid line) of the resin bead (pores that contain water). The sulphonates (SO_3^-) are the fixed ions of this cation exchange resin that are attached to the skeleton. The sodium (Na^+) cations are mobile ions. For example, a cation exchange resin is Amberjet 1200 that is delivered in the sodium form.

The anion exchange resin beads are similar to the cation resin beads. The functional groups are quaternary ammonium cations shown in Figure 1.8 as N^+R_3; (formula form CH_2-N^+-$(CH_3)_3$). The ions move to the bead and are replaced by an ion that moves out of the resin bead. The electrical neutrality is preserved. This process is called ion exchange. Only ions of the same electric sign are exchanged (Ion Exchange Basics, n. d.).

1.2.5.2 Ion exchange resin regeneration

Regeneration is an important process. When the resins are exhausted, they are returned to a fresh state and can restart again. The regeneration of resins is the reversal of the exchange reactions. For example, the softening resins are regenerated by using sodium ions (Na^+) that are supplied by a salt (common salt: NaCl) solution. The reaction is as follows:

$$R_2Ca + 2\ NaCl \longrightarrow 2\ RNa + CaCl_2$$

Source: Rohm and Haas, n. d.

Generally, most of ion exchange resin regeneration is used in columns. The operation is basically discontinuous; a loading phase, called a service run, is followed by regeneration of the exhausted resins. The regeneration process of the exhausted resins can be regenerated by two methods. These methods are 1) co-current regeneration (Wheaton and Lefevre, 2000) or co-flow regeneration (CFR) (Regeneration methods for ion exchange units, 2014) where the fluids flow from the top to the bottom of the column both during the service run as well as during regeneration and 2) counter-current regeneration (Wheaton and Lefevre, 2000), or counter flow regeneration, or reverse flow regeneration (RFR), where the fluids flow alternatively upwards and downwards during service and regeneration (Regeneration methods for ion exchange units, 2014).

1.2.5.3 Ion exchange resin application

The ion exchange resin applications are mainly used in waste water treatment such as in the treatment of mine drainage water, raw water treatment to produce high quality rinse water, chemical recovery from rinse water (Inglezakis and Poulopoulos, 2006), demineralization, water softening (Ion Exchange Basics, n. d.), purification, ultra pure water, dealkalization, nitrate removal, waste treatment, chemical processing, chromatographic separation, and pharmaceuticals and fermentation (Wheaton and Lefevre, 2000).

A cation exchange resin in the sodium form is used for water softening to remove or separate hard metal ions (Ca^{2+} and Mg^{2}) from water (Alchin, n. d.) that cause scale to form in water pipes, domestic cooking utensils, and power plant boilers. Moreover, hard water is a cause of soap precipitation that forms an undesirable gray curd and a waste of soap. Water softening involves the interchange of hardness ions for sodium ions on the resin. The hard water is passed through a sodium cation exchange resin and is softened (Wheaton and Lefevre, 2000). Water softening is an exchange of the Ca^{2+} and Mg^{2} ions (hardness cations) for cations, typically sodium ions (Na^{+}), that cannot form scale because they are much more soluble (Ion Exchange Basics, n. d.).

In the process to soften water, the hardness ions are moved into the resin beads and each divalent cation is replaced by two sodium ions that leave the resin. The reaction is shown in Figure 1.9 and it can be written equation follow as:

$$2\ RNa + Ca^{2+} \longrightarrow R_2Ca + 2\ Na^{+}$$

Source: Ion Exchange Basics, n. d.

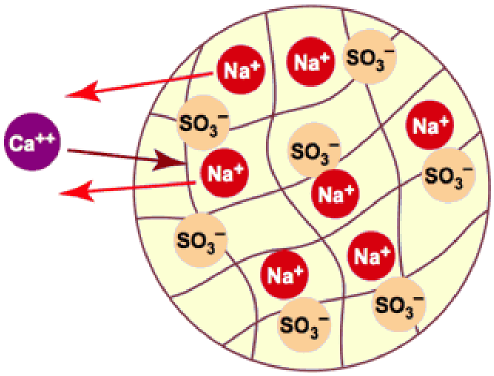


Figure 1.9. The reaction of softening in resin bead

Source: Ion Exchange Basics, n. d.

The resin bead is initially loaded with sodium ions (Na^{+}). Each Ca^{2+} or Mg^{2+} ion that moves into the resin is replaced by two Na^{+} ions that leave the resin bead (Figure 1.9). The anions from the water cannot move into the bead due to the repulsive force of the fixed sulphonate (SO_3^-) anions inside the bead. The cation exchange can take place efficiently because there is a higher affinity for the hardness ions than for the sodium. In this softening process, not all hardness ions are separated from the water, but there is the replacement of these ions by Na^+ ions. The salinity of the water has not changed, but the constituents of the salinity are different in the final process. Finally, when the hardness in the water is removed by the resin, the resin can be regenerated or replaced by a fresh resin (Ion Exchange Basics, n. d).

From the principles and application of ion exchange that are used to separate calcium and magnesium ions from hard water, the researcher is interested in this principle to separate magnesium ions from the F-NRL before transfer to the concentrated latex process. Normally, magnesium ions in this process are separated by adding DAP to precipitate magnesium. This method produces $MgNH_4PO_4$ sediment that is in the concentrated latex sludge, sludge, or waste.

1.3 Objectives

1. To compare the effects of RRIMFLOW, Double Tex, and LET technology on the quantity of magnesium in fresh natural rubber latex and the effects on the concentrated latex process.
2. To study the effects of using magnesium reduction technology to reduce the quantity of magnesium in fresh natural rubber latex with adsorption technology (ion exchange resin) for the concentrated latex process.
3. To study the environmental impact and economic costs using magnesium reduction technology to reduce the quantity of magnesium in fresh natural rubber latex by a comparison of chemical precipitation using diammonium phosphate (DAP) with adsorption technology using ion exchange resin.

1.4 Research scope and conceptual framework

The research scope is classified from each of the objectives.

1. To compare the effects of RRIMFLOW, Double Tex, and LET technology on the quantity of magnesium in fresh natural rubber latex and the effects on the concentrated latex process.

This part analyzes the quantity of magnesium content and total solid content in fresh natural rubber latex from rubber trees that use two tapping methods. The tapping methods consist of the normal tapping system and tapping systems that use a stimulant. In this case, a stimulant refers to ethylene gas stimulation which is available from three techniques; RRIMFLOW, Double Tex, and LET. This stimulant is used to increase the volume of latex in the rubber trees. The rubber trees in this research were mature rubber trees that were grown in the same area. The details are shown in CHAPTER 2.

2. To study the effects of using magnesium reduction technology to reduce the quantity of magnesium in fresh natural rubber latex with adsorption technology (ion exchange resin) for concentrated latex process.

This part studies the reduction of magnesium with adsorption technology (ion exchange resin) that uses macroporous cationic exchange resin in fresh natural rubber latex. The details are shown in CHAPTER 3. The studies include:

2.1 The characteristics of fresh natural rubber latex and resin before and after using macroporous cationic exchange resin.

2.2 The magnesium content of fresh natural rubber latex before and after using three procedures (immersion, pressure pump, and gravity column) that incorporate macroporous cationic exchange resin for magnesium removal in fresh natural rubber latex.

2.3 The properties of fresh natural rubber latex before and after using macroporous and regenerated macroporous cationic exchange resin.

3. To study the environmental impact and economic costs using magnesium reduction technology to reduce the quantity of magnesium in fresh natural rubber latex by a comparison of chemical precipitation using diammonium phosphate (DAP) with adsorption technology using ion exchange resin.

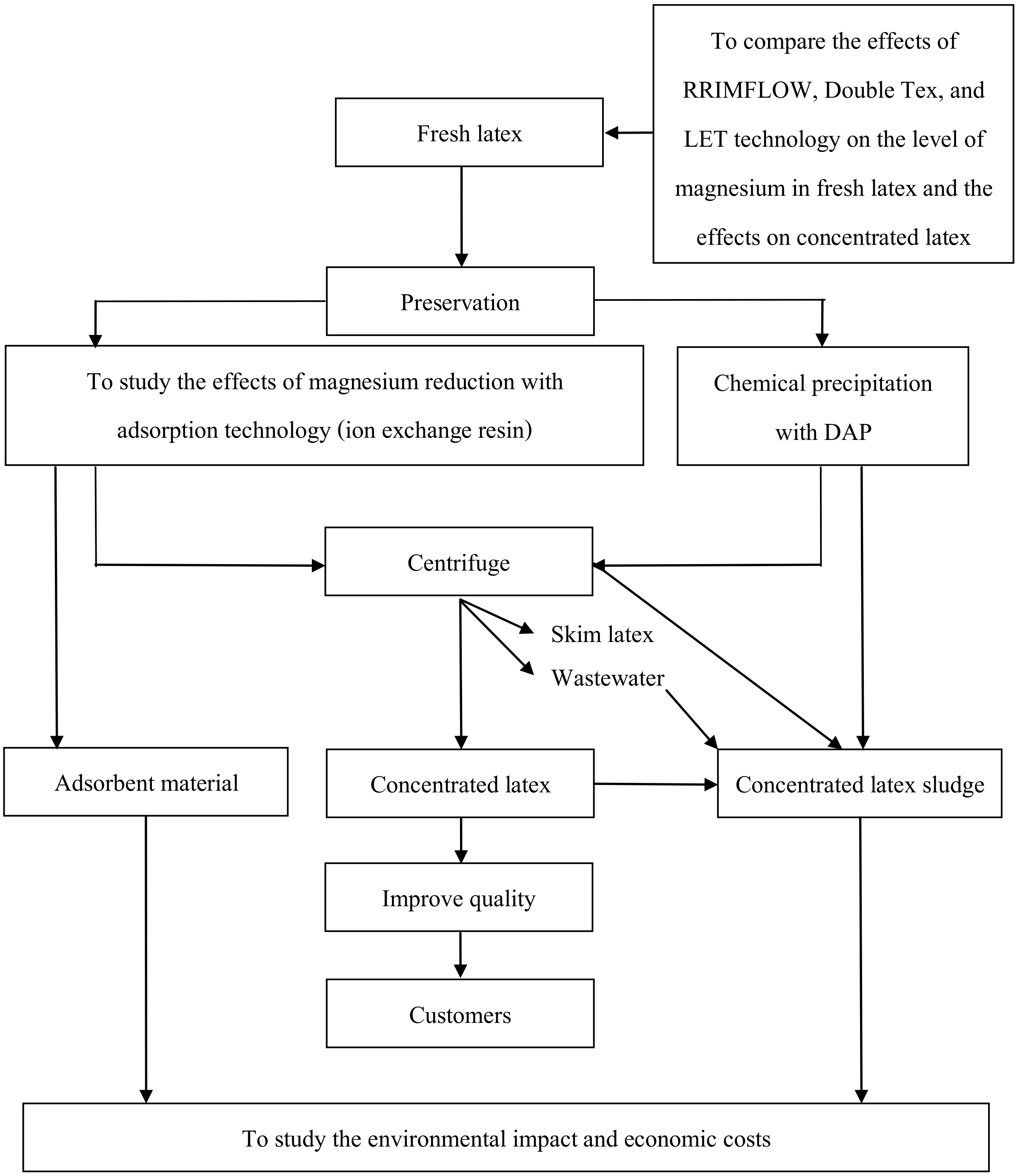
This part is a case study on the primary environmental impact and economic costs in the concentrated latex process as a result of the reduction of magnesium in fresh natural rubber latex from chemical precipitation using DAP compared with adsorption technology (ion exchange resin) that is a new technology for the removal of magnesium ions. The studies include:

3.1 The environmental impact that considered the volume of concentrated latex sludge after the use of the new adsorption technology, the properties of the waste resin, and management of the waste resin.

3.2 The economic costs that considered only the variable costs of the operation which used the materials, energy, and labor to calculate the variable costs of production per unit.

An evaluation of the environmental impact and economic costs of the new adsorption technology cannot cover every issue because the new adsorption technology was in the very early stages in the factory. In addition, there were legal issues for the use of the equipment which is under the protection of petty patent/patent between the owner of the petty patent/patent and the industry. The details are shown in CHAPTER 4.

Conceptual framework



1.5 Output

1. Know the effects of RRIMFLOW, Double Tex, and LET technology on the quantity of magnesium in fresh natural rubber latex and the effects on the concentrated latex process.
2. Know the effects of using magnesium reduction technology to reduce the level of magnesium in fresh natural rubber latex with adsorption technology for the concentrated latex process.
3. Know the environmental impact and economic costs from using magnesium reduction technology to reduce the level of magnesium in fresh natural rubber latex by a comparison with chemical precipitation and adsorption technology.

1.6 Thesis organization

The thesis is classified into three principals.

First, CHAPTER 1 Introduction. This chapter consists of the background of the research problem, review of literature, and the aim of this research.

Second, this part comprises CHAPTER 2, 3, and 4 which are arranged in manuscript style. Each chapter was written with specific methods, results, discussions, conclusions, and references which depend on the title.

CHAPTER 2 Effects of tapping methods on natural rubber latex consistency.

The aims of this research were to investigate the effects of tapping methods on the fresh natural rubber latex, especially the magnesium content and total solids content (%TSC) from rubber trees that used normal tapping and ethylene gas tapping.

CHAPTER 3 Magnesium (II) ion removal from fresh natural rubber latex using macroporous cationic exchange resin.

This chapter examines the removal of magnesium (II) ions from fresh natural rubber latex using macroporous cationic exchange resin. The fresh natural rubber latex was characterized before and after magnesium removal.

CHAPTER 4 Primary studies of environmental impact and economic costs of the new technology for magnesium reduction in fresh natural rubber latex.

This research aimed to study the environmental impact and economic costs using magnesium reduction technology to reduce the quantity of magnesium in fresh natural rubber latex by a comparison of chemical precipitation using DAP with adsorption technology using ion exchange resin.

Third, this part consists of CHAPTER 5 and CHAPTER 6 which are general discussions and general conclusions, respectively, that discuss and conclude all chapters.

CHAPTER 2

Effects of Tapping Methods on Natural Rubber Latex Consistency

Abstract

The quality of latex is important for rubber product, especially, the latex from the tapping process that includes normal tapping and tapping systems that use stimulants. Tapping systems that use stimulants are used to increase the volume of latex from rubber trees. Normally, the latex from the field is tested for many properties before production as a factory product. However, for commercial purposes, the cultivators and shops use only the dry rubber content (%DRC) to calculate the price. At the time of tapping and latex collection the level of magnesium cannot be determined. However, it is the magnesium which has an effect on the environment as it is a cause of concentrated latex sludge or waste in the concentrated latex process. Therefore, the aim of this research is to investigate the magnesium content and total solids content (%TSC) of the latex from normal tapping and ethylene gas tapping methods at the Thepa Research Station in Songkhla Province, Thailand. It was designed as a one-tree plot design with 4 tapping methods; T1 was a control without ethylene stimulation while T2, T3, and T4 ethylene stimulations were applied using the RRIMFLOW, Double Tex, and LET systems, respectively. The results showed that the %TSC in latex from the 4 tapping methods were within the normal criteria. The average %TSC from the control tapping (T1) was the highest, while the %TSC values from the ethylene gas tapping in T2, T3, and T4 were lower. In particular, the average %TSC value of T2 system was the lowest every time. In addition, the quantity of magnesium was high, especially the latex from the ethylene gas tapping in the T2, T3, and T4 methods. Although the T2 method had the highest value, the T3 and T4 methods were also high in magnesium content but varied continuously because the gas leaked out sometimes from the equipment and the injection into the bark was not complete. Although the level of magnesium of the control tapping (T1) was high, it was lower than the ethylene gas tapping systems. The latex from the ethylene gas tapping systems was high in magnesium and it led to increased waste in the factory and affected the environment over the long term.

Key words: tapping method, natural rubber latex, ethylene stimulation

2.1 Introduction

Nowadays, there is an increased demand for natural rubber latex in the rubber industry but the quantity of latex is not enough although the government tries to extend the areas for rubber trees (*Hevea brasiliensis*) plantations. There are also environmental factors such as global warming and seasonal changes that affect latex production and the cultivators are unable to tap rubber or the tapping is less than normal (Editorial Department, 2011). These problems affect the quantity of latex produced in the rubber industry. Generally, natural rubber latex production is produced by tapping and with the use of stimulants. The tapping consists of removing a layer of bark in the form of a spiral on the trunk of the tree. The latex is collected and treated to get the natural rubber. Ethylene is used as a stimulant to generate chemical substances to increase the productivity from the trees (Okoma et al., 2011). Ethylene gas stimulation is an attempt to improve the volume of latex that is susceptible to global warming and seasonal changes. In this research, stimulant refers to ethylene gas stimulation.

Ethylene as a stimulant for latex production of rubber tree has been used widely in commercial latex production. However, the mechanism of the action of ethylene was not completely elucidated, especially at the molecular level (Zhu and Zhang, 2009). In rubber trees, ethylene increased the duration of latex flow after tapping and activated the latex cell metabolism (Traoré et al., 2011 refer to Lustinec et al., 1965; Buttery and Boatman, 1967; Pakianathan et al., 1976; Jacob et al., 1989; D'Auzac et al., 1997), reduced tapping frequency, and increased land and labor productivity (Sainoi and Sdoodee, 2012 refer to Sivakumaran and Chong, 1994; Sivakumaran, 2002; Jetro and Simon, 2007; Lacote et al., 2010; Njukeng et al., 2011; Traoré et al., 2011). In addition, ethylene reacted at the inner bark and increased the pressure. The internal pressure within the system of latex vessels increased and the pressure of the surrounding tissue on the latex cells increased (Coupé and Chrestin, 1989). Also the elasticity of the laticiferous cells was affected and the coagulation of the latex decreased (Sainoi and Sdoodee, 2012 refer to D'Auzac, 1989).

The latex from each tapping needs to be thoroughly analyzed. For example, total solids content (%TSC), sucrose content, inorganic phosphorus, and inorganic phosphorous (Pi) and thiol content (Doungmusik, 2013 refer to Jacob et al., 1989) are measured to determine the quality and suitable tapping methods. After that, the main characteristics of the manufactured product are tested for dry rubber content (%DRC), total solids content (%TSC), volatile fatty acid number (VFA), mechanical stability (MST), and others. Although some properties are not major considerations for initial testing, they do affect the manufacturing and environment after the finished process. Therefore, the aims of this research were to investigate the effects of the tapping methods on the natural rubber latex and especially the magnesium content and %TSC from rubber trees that used normal tapping and ethylene gas tapping.

2.2 Materials and methods

2.2.1 Plant material and study site: The experiment was carried out at the Thepa Research Station in the Thepa District of Songkhla Province, Thailand. The latex samples were collected from rubber trees (RRIM 600 clone) in plan A6. The trees had a mature age of around 20 years old and grew in the same plot with a spacing of 3 × 7 meters in sandy loam soil (pH = 5.5). The site area is shown in Figure 2.1.

2.2.2 Statistical design: This experiment design was a one-tree plot design with 4 random treatments which included 3 repetitions per treatment method (12 repetitions in randomization of all the trees).

2.2.3 Treatment or Tapping systems: The rubber trees were tapped in 4 methods: T1 = Control, 1/3s ↑ 2d/3 (One third spiral upward cut at two days tapped by one day rest); T2 = RRIMFLOW, 1/8s ↑ d/3 (One eight spiral upward cut at one day tapped two days rest; stimulated with ethylene gas [RRIMFLOW system]); T3 = Double Tex, 1/8s ↑ d/3 (One eight spiral upward cut at one day tapped two days rest; stimulated with ethylene gas [Double Tex system]); T4 = LET, 1/8s ↑ d/3 (One eight spiral upward cut at one day tapped two days rest; stimulated with ethylene gas [LET system]). The tapping, treatment systems, and samples are illustrated in Figure 2.2 and Figure 2.3.

2.2.4 Latex analysis: The latex was collected from the rubber trees and the analyses were carried out from January to May 2013. Secondary data from the Pattani Meteorology Station included average rainfall, evaporation, and maximum/minimum temperatures (Figure 2.4). In addition, the testing of the magnesium content (ppm) and the %TSC of the latex used the standards of the Rubber Research Institute of Thailand, 2001. The magnesium content in fresh natural rubber latex was determined by titration with EDTA according to TIST 980-2552 (2009)

(Notification of the Ministry of Industry, 2009) which also carefully examines the quality and quantity control of concentrated latex in the concentrated latex industry.

Determination of magnesium concentration

$$\text{Magnesium content (ppm)} = \frac{24.32 \times B \times 100}{1{,}000 \times A} \times 10{,}000$$

Where

A = Weight of fresh natural rubber latex (g)

B = EDTA factor (volume of EDTA (ml) × concentration of EDTA (mol/L))

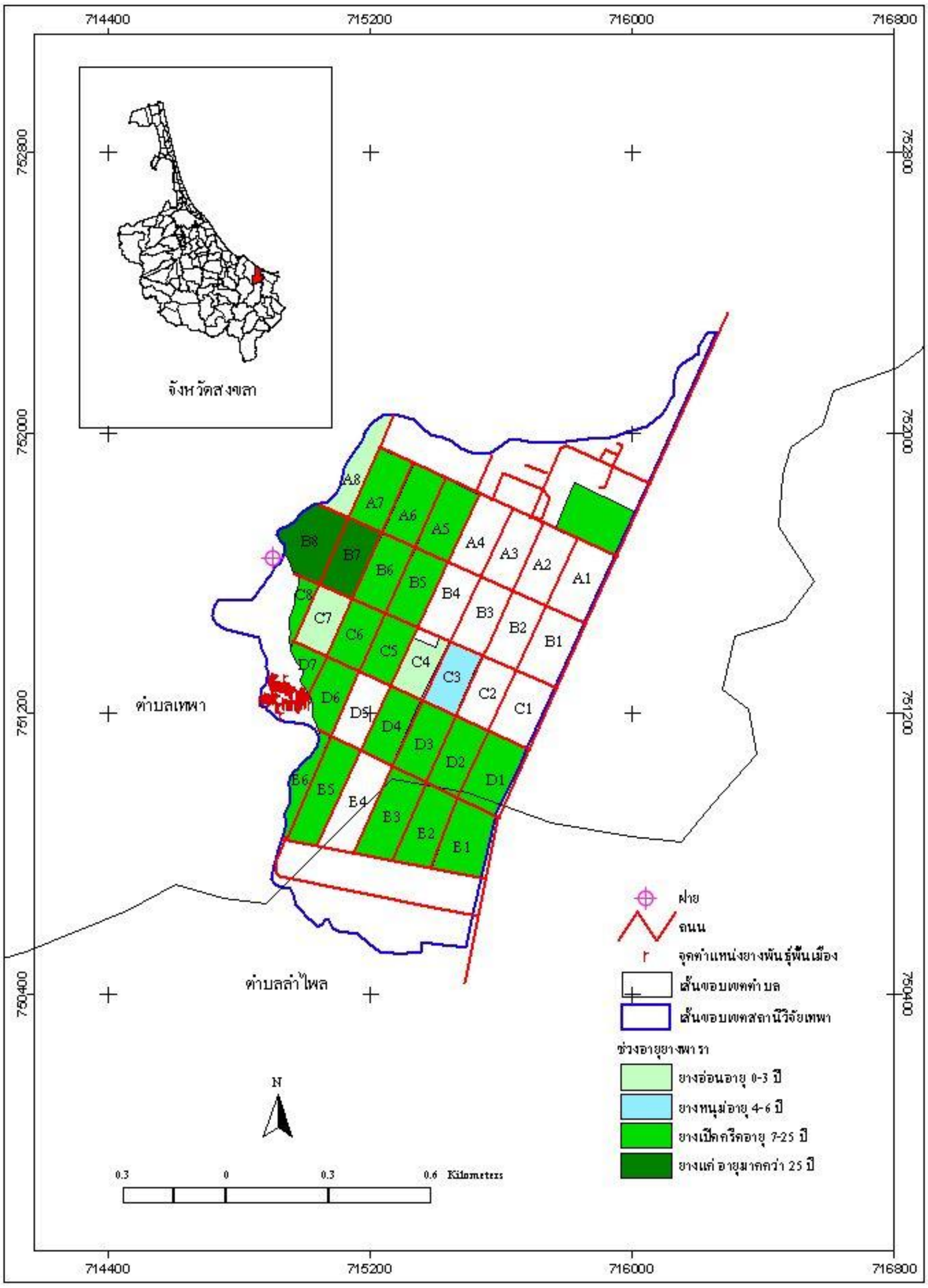


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Figure 2.1 Map of the ages of rubber trees at the Thepa Research Station, Prince of Songkla University, Thepa District of Songkhla Province, Thailand

Note: Rubber trees in Plan A6 were collected for the samples

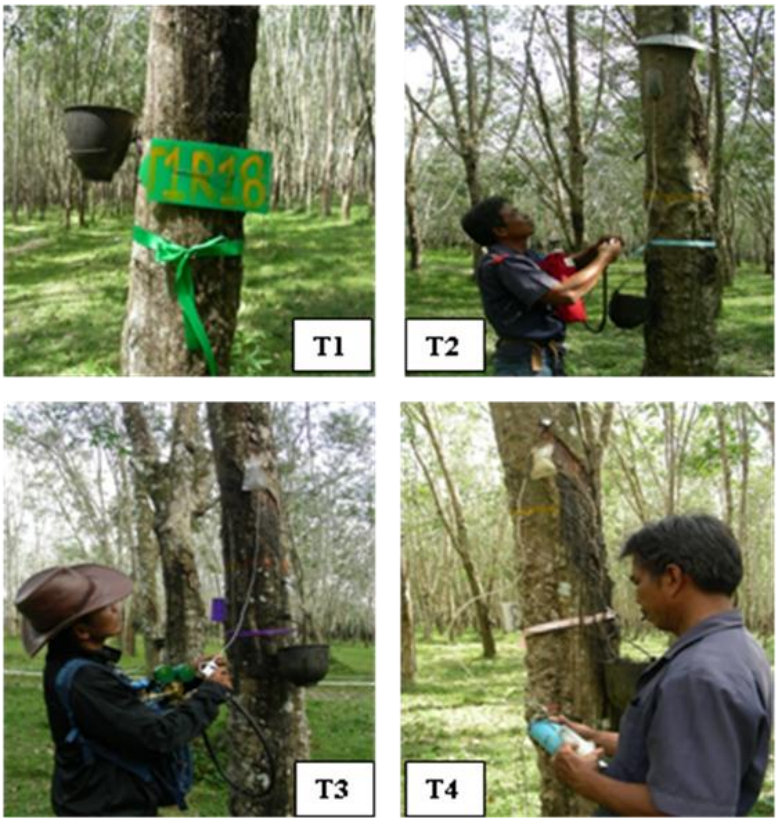

Figure 2.2 Tapping and treatment systems: T1 = Control, 1/3s ↑ 2d/3; T2 = RRIMFLOW, 1/8s ↑ d/3; T3 = Double Tex, 1/8s ↑ d/3; T4 = LET, 1/8s ↑ d/3

A

B

Figure 2.3 A-B Tapping and latex collected from rubber trees

2.3 Results and discussions

2.3.1 Results

2.3.1.1 Weather data

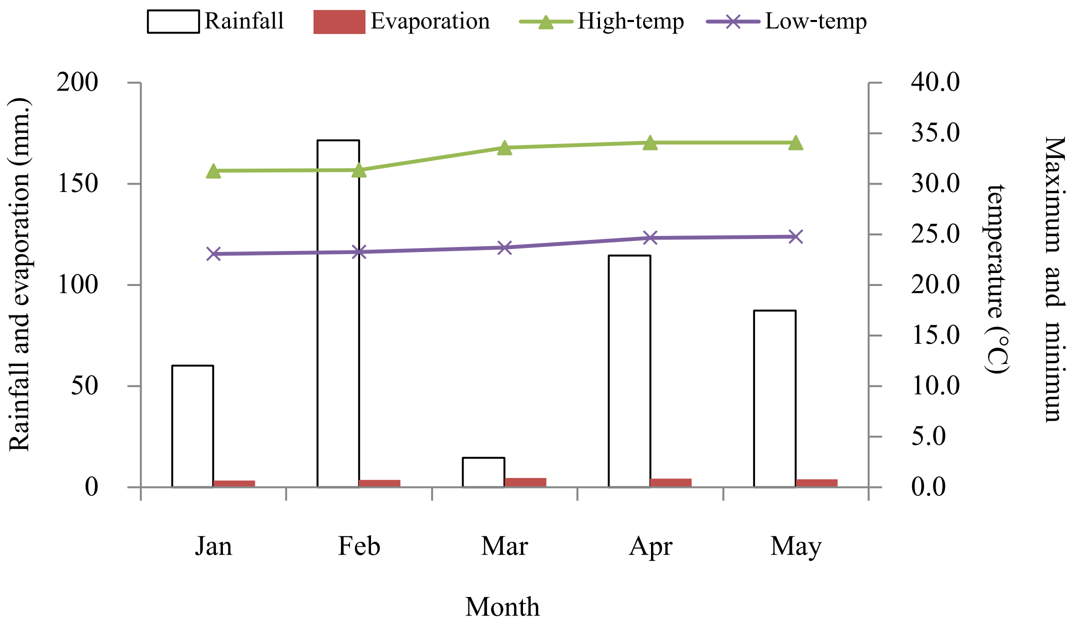

Figure 2.4 Weather data: average rainfall; evaporation; and maximum/minimum temperatures from Pattani Meteorology Station during January – May 2013

The weather data in this experiment were the secondary data that were collected from January to May 2013 from the Thepa Research Station in the Thepa District of Songkhla Province. The data consisted of the average rainfall, evaporation, and maximum/minimum temperatures.

The peak average rainfall of 171.5 mm occurred in February and fell to the lowest point of 14.6 mm in March. On the other hand the average evaporation remained stable at around 4 mm and varied with the rainfall while the average maximum temperature leveled off from March to May at 34.1°C and fell gradually from March to January to around 32.1°C. In contrast, the average minimum temperature remained constant at 23.92°C.

2.3.1.2 Total Solids Content (%TSC)

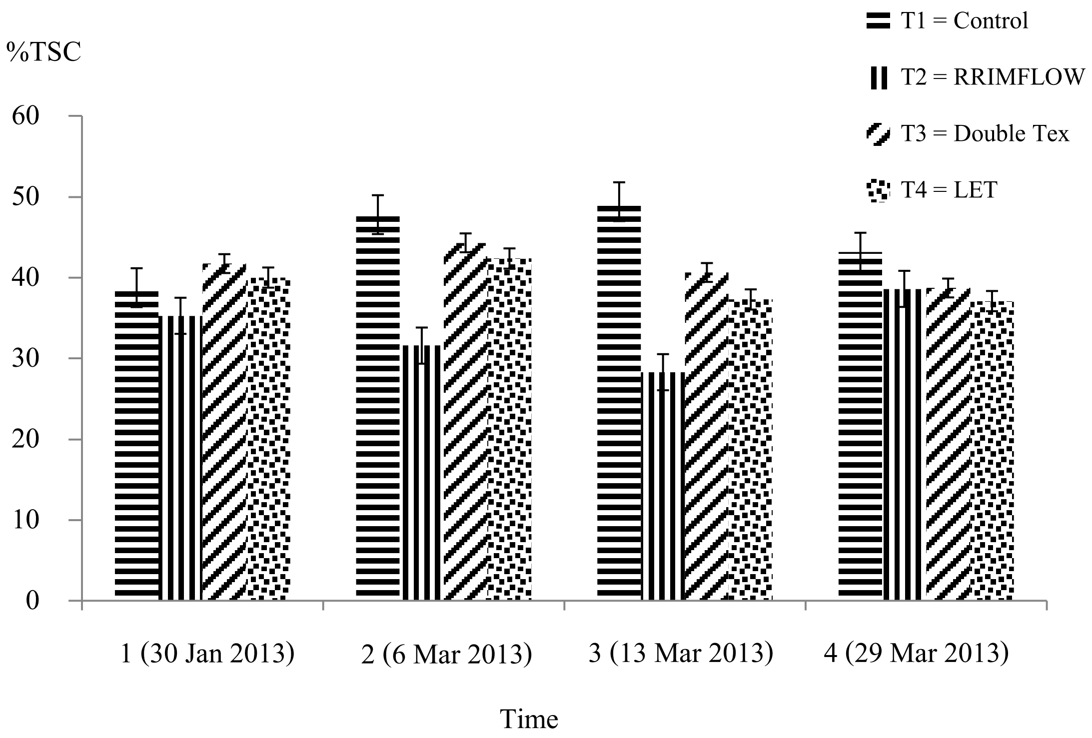

Figure 2.5 Trend of total solids content in latex from 4 tapping methods at the Thepa Research Station

Figure 2.5 shows four bar charts that compare and contrast data on the %TSC in latex tapped from rubber trees with 4 tapping methods and selected 4 times. According to the data at the first tapping, the %TSC values were homologous data with an average of 38% and the %TSC value of T2 was the lowest at around 35%. The %TSC value of T3 was the highest at 40%. At the second tapping, the %TSC value of T2 dropped gradually but the T1 value increased sharply and was the highest value at this time. The values of T3 and T4 were similar. At the third tapping, the %TSC value of T2 fell to the lowest point to 28% while T1 reached a peak at 49%. The values of T3 and T4 decreased gradually and were similar to the second tapping. At the fourth tapping, the T2 %TSC value increased sharply to 38% which was near the T3 and T4 %TSC values while they dropped slightly from the third tapping. The %TSC value of T1 fell sharply to 43% but this value remained the highest at this tapping.

2.3.1.3 Magnesium Content

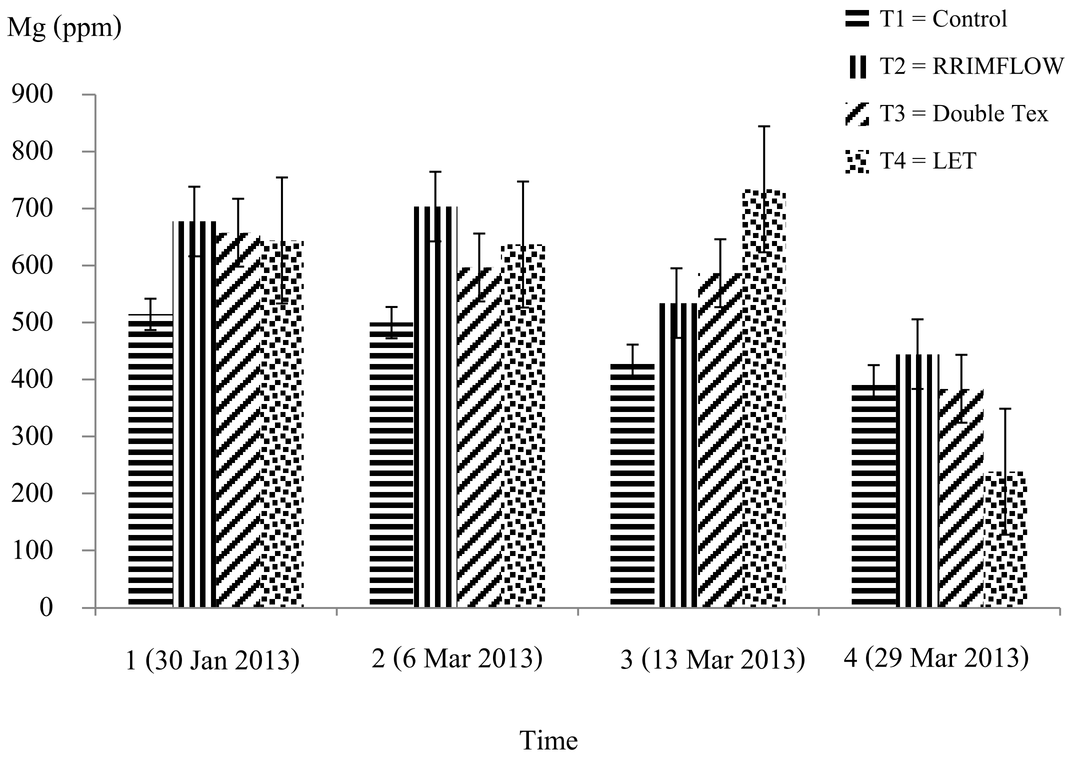

Figure 2.6 Trends of magnesium content in latex from 4 tapping methods at the Thepa Research Station

Figure 2.6 shows four bar charts that compare and contrast data on the quantity of magnesium content in the latex which was tapped from rubber trees with 4 tapping methods and was collected 4 times. At the first tapping, the magnesium levels were 677, 657, and 644 ppm for T2, T3, and T4, respectively, which used ethylene gas in tapping and they were higher than the control tapping (T1) at 514 ppm. At this time, the value of the magnesium content in T2 was the highest and T1 was the lowest. At the second tapping, the level of magnesium for T2 and T4 increased gradually but T1 dropped slightly and T4 fell gradually. The magnesium levels of T2 and T1 remained high and low, respectively. At the third tapping, the T4 magnesium level rose sharply and the T3 level increased slightly while the T2 level dropped sharply and T1 fell slightly. At this time, the value of magnesium of the T1 method was the lowest but T4 reach a peak above all of them at 733 ppm. At the fourth tapping, the values dropped sharply in the T3/T4 methods and gradually in the T1/T2 methods. Although the T2 method was the highest at 444 ppm and the T4 method was the lowest at 238 ppm, all methods had magnesium values less than 500 ppm.

2.3.2 Discussion

In this experiment, the latex from the four tapping methods consisted of one control tapping (T1 = control or normal tapping) and ethylene gas tapping which included three methods (T2 = RRIMFLOW, T3 = Double Tex, and T4 = LET) which produced different quality results.

In this case, the ethylene gas tapping was used in mature rubber trees when they were around 20 years old to increase the volume of latex before destruction of the rubber trees.

Normally, the parameters that show the productivity of latex from the tapping methods consist of the percentage of total solids content (%TSC) or dry rubber content (%DRC), sucrose content, Pi content, and thiol content.

But, this research considers the parameters of %TSC and magnesium content only. These parameters are important properties of the fresh natural rubber latex (F-NRL) for use in the concentrated latex process, especially the magnesium content since magnesium in the F-NRL is a cause of concentrated latex sludge when the magnesium ions in the F-NRL interact with ammonia and phosphate anions in the concentrated latex process.

First, the %TSC in latex from all methods was within the normal range (27– 48%). The average %TSC for the control tapping (T1) was the highest while the %TSC from the ethylene gas tapping in T2, T3, and T4 were of low values; especially the average value of T2 was the lowest every time.

The %TSC results decreased in a similar fashion as reported by Sdoodee et al (2010), Doungmusik (2013) and Sainoi et al (2012) that used ethylene gas tapping in mature rubber trees and young rubber trees, respectively. Of note, the %TSC values of RRIMFLOW (T2) were the lowest in every experiment. Moreover, the RRIMFLOW decreased the sucrose content in the F-NRL after tapping (Sdoodee et al., 2010 and Doungmusik, 2013).

Although the %TSC values of the latex from ethylene gas tapping were lower than the control tapping, these values were similar to stimulation and latex rheology theory which gave low %TSC values of the latex after tapping (Coupé and Chrestin, 1989).

In addition, the %TSC values from ethylene gas tapping decreased in a similar way as the %DRC after the use of ethylene gas for tapping (Paechana, 2001, Sdoodee et al., 2010, Sainoi et al., 2012 and Doungmusik, 2013) since the ethylene gas can move the water molecules into the latex vessel and it reduces the viscosity of the latex (Sadoodee et al, 2010 refer to Lacote et al, 1988).

Secondly, the magnesium content in the latex from this experiment was high, especially in the latex from the ethylene gas tapping in the T2, T3, and T4 methods and the magnesium content in the T2 method was the highest. The T3 and T4 methods were high but varied due to occasional gas leakage from the equipment and the injection into the bark was not complete. Although the level of magnesium of the control tapping (T1) was high, it was generally lower than in the ethylene gas tapping methods.

In addition, the magnesium content from all samples dropped at the fourth tapping in March maybe due to high temperatures, low rainfall, and high water evaporation. So, the rubber trees could not uptake water and nutrients for the synthesis of latex and the ethylene gas could not move the water molecules from the surrounding cells into the synthesis cells for the synthesis of latex (Zhu et al., 2009 and Doungmusik, 2013). Similarly, the latex from ethylene gas tapping was low in magnesium content because of decreased coagulation of the latex (increased stability of the lutoids) (Coupé and Chrestin, 1989) that may be dependent on the weather.

But, in this case, the total magnesium content was different from theory. There was a tendency of the magnesium content in both normal tapping and ethylene gas tapping to be higher than the magnesium standard at 40 ppm in the concentrated latex (Notification of the Ministry of Industry, 2009). Although the magnesium content decreased or varied sometimes according to the weather, the values were still high. It is possible that the ethylene gas can move the magnesium ions in the water and nutrients from the soil for the synthesis of the latex.

Moreover, if the F-NRL has high magnesium content, the factory that produces concentrated latex by centrifugation needs to add much diammonium phosphate (DAP) to precipitate the magnesium out of the F-NRL. This reaction creates a high quantity of waste which equates to concentrated latex sludge. It is a cause of plugging on the disc in the centrifuge machine during the concentrated latex process which results in wasted time and water loss to clean the machine.

Finally, it does not decompose or decay easily in the soil and leads to pollution such as malodors and waste water (leachate) when this waste is disposed incorrectly at a dumping site or outdoor burning.

2.4 Conclusion

The difference of tapping methods for mature rubber trees has an effect on the quality of the latex especially for the ethylene gas tapping method.

In the agriculture sector, the ethylene gas tapping method increases latex production, but there was a tendency for the %TSC to decrease (low %DRC) although the values were within the normal range. In contrast, the magnesium content tended to be very high.

Although the magnesium content is not a major factor for direct improvement of the latex production, it is very important in the concentrated latex process.

In the concentrated latex industry sector, the magnesium content in the F-NRL is precipitated out by adding DAP in the concentrated latex process. Since the magnesium content is a cause of concentrated latex sludge or waste, it becomes a major problem for disposal.

The latex from the ethylene gas tapping methods was high in magnesium content and this may lead to increased concentrated latex sludge at the factories and affect the environment in the long term.

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CHAPTER 3

Magnesium (II) Ions Removal from Fresh Natural Rubber Latex Using Macroporous Cationic Exchange Resin

Abstract

Magnesium ions (Mg^{2+}) in fresh natural rubber latex (F-NRL) are the cause of concentrated latex sludge or waste in the concentrated latex process. In this process, F-NRL is treated with diammonium phosphate (DAP) to remove Mg^{2+} ions before transfer to the centrifuges to produce concentrated latex. But in the process, the chemical reaction between DAP and Mg^{2+} ions produces a sludge that is a waste product. In this research, adsorption technology (ion exchange resin) is used to solve the waste product problem in the concentrated latex process by removal of the Mg^{2+} ions from the F-NRL instead of using chemical precipitation. Thus, this research aimed to study the effects of using adsorption technology (ion exchange resin) to reduce the quantity of magnesium in F-NRL in concentrated latex process by using macroporous cationic exchange resin. The results found the resin can reduce the level of Mg^{2+} ions in F-NRL to less than 100 ppm after immersion, filtration with a syringe pump, a gravity column test or a gravity flow filter tank. After regeneration by HCl and NaOH, the performance of the resins rose and could be reused to minimize magnesium content in F-NRL. Moreover, the particle size of the F-NRL and resins before and after treatment/filtration, and properties of the F-NRL did not change after treatment with either the resin or regenerated resin even though rubber had covered the surface of the resin beads. In addition, in this experiment there was no sludge or waste during the separation process of removing the magnesium. So, it is possible to use macroporous cationic exchange resin to separate or remove magnesium ions from the F-NRL.

Keywords: magnesium, fresh natural rubber latex, macroporous cationic exchange resin

3.1 Introduction

Generally, most factories in the concentrated latex industry use chemical precipitation to separate magnesium ions (Mg^{2+}) from the fresh natural rubber latex (F-NRL). Normally, magnesium cannot be removed from the ecosystem because magnesium is an alkaline earth metal (Stefan et al., 2014) and it is an important plant nutrient (Osotsapar, 2000). Magnesium is the central atom in the chlorophyll molecule and plants take up dissolved magesium in soil solution in the form of Mg^{2+}ions (Magnesium in plants and soil, n. d.). In rubber trees, magnesium affects the growth and increases the volume of latex that improves the total productivity of rubber because it is a component of chlorophyll in the leaves that performs the process of photosynthesis and it is an enzyme accelerator. However, magnesium decreases the amount of potassium in rubber leaves (Sungwatin, 2008).

So, magnesium is found as magnesium ions (Mg^{2+}) in F-NRL which is an important component of rubber trees. The levels of magnesium in F-NRL range from 100 to 1,000 ppm. The cause of high levels of magnesium in F-NRL can be from many factors such as the use of magnesium fertilizers, the rubber tree clone, and seasonal variation (Rubber Research Institute of Thailand, 1989). A high level of magnesium affects the quality of concentrated latex and the centrifugation process, and it is the major cause of destabilization of natural rubber latex (NRL) (Karunanayake et al., 2006) which reduces centrifuge efficiency and increases the sludge content in concentrated latex process. These are important considerations when making thin walled articles such as rubber gloves (Rubber Research Institute of Thailand, 1989).

In addition, magnesium is the main cause of concentrated latex sludge or waste in the concentrated latex process. This waste comes from the precipitation of Mg^{2+} ions from F-NRL with diammonium phosphate (DAP) before transfer to the centrifuges for concentration in the latex process. The amount of waste through the operations is approximately 1% of the F-NRL (Tekprasit, 2000) which is the main problem for disposal in a factory.

The origin of the waste starts in the F-NRL from the rubber trees when they are tapped until preservation with ammonia and transferred to the factory for use in the concentrated latex process. This process needs to separate or remove the Mg^{2+} ions from the F-NRL with chemical precipitation by adding diammonium phosphate (DAP) to reduce the level of

Mg^{2+} ions in the F-NRL (Rubber Research Institute of Thailand, 1989). The interreaction of Mg^{2+} ions with ammonia and DAP results in a concentrated latex sludge (magnesium ammonium phosphate (Blackley, 1997)) which does not decay or decompose easily in soils and leads to pollution. The reaction of the ammonia with the magnesium is shown in the equation below.

$$Mg^{2+} + NH_3 + HPO^{2-}_4 \longrightarrow MgNH_4PO_4 \downarrow$$

Source: Blackley, 1997.

However, adsorption technology (ion exchange resin) is an alternative method to reduce Mg^{2+} ions in F-NRL which can minimize the waste from the concentrated latex process. This research uses macroporous cation exchange resin to remove the Mg^{2+} ions from the F-NRL to solve the waste problem in the concentrated latex process instead of using chemical precipitation. This method does not produce any sludge or waste during the separation of the Mg^{2+} ions from the F-NRL and it can reduce the Mg^{2+} ions concentration in F-NRL to a very low level (Abdelwahab et al., 2013) with a reduction in the volume of sludge (Yu et al., 2009).

Ion exchange resin is a part of adsorption technology that is widely applied and has been accepted for many years in water conditioning (Myers, 1943), but also for various other applications such as separating out some substances or elements (Alchin, n.d), for example, water softening (remove magnesium, calcium, iron, manganese salts from water) (The Editor of Encyclopedia Britannica, n. d.) and the removal of nitrates and ammonia from ground water (Inglezakis and Poulopoulos, 2006). Moreover, they are used for environmental protection such as waste water industrial treatment (Adsorption Resin Apply, n. d.).

Ion exchange resins are polymers that consist of a polymeric matrix and a functional group (Ion Exchange Technologies, n. d.), and they are able to exchange specific ions inside the polymer with other mobile ions in solution to be treated that pass through them (Alchin, n. d.). Moreover, this process is a reversible chemical reaction that removes dissolved ions from solution and replaces them with other similarly charged ions and uses ion exchangers to separate the ions from the solution. The particle sizes of the resins in the process are around 16-50 mesh (0.3 to 1.2 mm) as either a gel or macroporous structure (Ion Exchange Technologies, n. d.).

Ion exchange resins are classified into two types. The anion exchange resins have negatively charged mobile ions and the cation exchange resins have positively charged mobile ions (Resin Types, n. d.). So, this process has anion and cation exchangers that are material exchangers which bring anions and cations into the reaction (Inglezakis and Poulopoulos, 2006). Generally, ion exchange materials (ion exchangers) have many kinds of functional groups on the matrix, such as a strong acid cation exchanger and strong base anion exchanger, weak acid cation exchanger and weak base anion exchanger, and other acids (cation exchangers) such as selective heavy metal chelating resins (Inglezakis and Poulopoulos, 2006).

In particular, chelating ion exchanger resins have the same bead form and polymer matrix as the typical ion exchangers which are composed of a two constituents which are the polymeric matrix and chelating functional groups, such as amidoxime, aminophosphonic acid, and iminodiacetic acid (IDA). But in this research, it is specific only for the iminodiacetic groups as this type is related to the alkaline earth metals (Inglezakis and Poulopoulos, 2006). Moreover, they have many active sites. For instance Dowex A-1, Lewatit TP 207, Amberlite IRC 748 (formerly, IRC 718), Chelex 100, Diaion CR-10, and Purolite S-930 are used for recovery of Ca^{2+} and Mg^{2+} ions from aqueous solutions (Yu et al., 2009). Otherwise, iminodiacetic groups are applied using the mechanism of sorption equilibrium in the recovery of zinc, calcium, and magnesium from waste water using iminodiacetate resins (Timofeev and Naboichenko, 2013).

Therefore, in this research, it is possible to separate or remove the Mg^{2+} ions from the F-NRL with a cationic exchange resin in the same way that positively charged ions (calcium and magnesium) are removed from hard water. So, the experiment used a macroporous cationic exchange chelating resin (Purolite S-930) to remove Mg^{2+} ions from F-NRL in an ion exchange process.

Purolite S-930 is a macroporous copolymer (styrene–divinylbenzene) based on a chelating resin with iminodiacetic acid functional group that is designed to remove cations of heavy metals from industrial effluents. Otherwise, it is used for separating calcium and magnesium (alkaline earth metals) from water, and is used for recovery and extraction of metals from ores, pickling baths, effluents, and galvanic plating solutions. Moreover, it can be used to minimize poisonous heavy metals to lower the hazardous concentration levels that are often less than the levels achieved from precipitation reactions. It can be used to separate residual minerals or compound substances from a liquid or solution such as demineralized water (Chelation Systems, n. d.).

The applications of Purolite S-930 ion exchange resin include adsorption of some metal complexes (Al-Ameri et al., 2011), sorption of Zn (II) and Pb (II) ions in the presence of a biodegradable complexing agent (Jachula et al., 2012), sorption of heavy metal ions on ion exchangers (Kolodynska et al., 2013), and the simultaneous removal of Ca^{2+}, Ni^{2+}, Pb^{2+} and Al^{3+} ions from aqueous solutions (Stefan et al., 2014).

3.2 Materials and methods

3.2.1 Materials

The fresh natural rubber latex (F-NRL) was purchased from a rubber cooperative. The macroporus cationic exchange resin was Purolite S-930 purchased from Behn Meyer Chemical (T) Co., Ltd., Thailand. The resin is a small bead form and the diameter of the beads is around 0.5 mm. The properties of the resin are in Figure 2 and Table 2. KCN, EDTA, NaOH, HCl, NH_4Cl, $MgSO_4$ and Eriochrome Black T were purchased from JP Chemical., PART, Thailand. Deionized water was used to prepare all solutions and for cleansing and regeneration of the resin.

3.2.2 Macroporous cationic exchange resin experiment

3.2.2.1 To study the characterization of F-NRL and resin

The particles sizes of the F-NRL and resin were determined with a laser particle size analyzer (COULTER LS230, USA). The external surface area was photographed by scanning electron microscopy (SEM) (JSM-5800LV, JEOL, Japan) and energy dispersive X-ray (EDX) (ISIS 300, Oxford, England). The characteristics of the F-NRL were tested for dry rubber content (%DRC) and total solids content (%TSC) which were determined according to ISO 126. The volatile fatty acid number (VFA No.) and magnesium content were tested by ISO 506-1992 and TIST 980-2552 (2009), respectively.

3.2.2.2 To study the magnesium content of F-NRL before and after using macroporous cationic exchange resin

This experiment was classified into three sub-experiments. The magnesium content in the F-NRL and all sub-experiments was determined by titration with EDTA according to TIST 980-2552 (2009) (Notification of the Ministry of Industry, 2009) which also carefully examined the quantity of magnesium content.

Experiment 1: Immerse resin in F-NRL

This experiment was performed under two conditions. In the first condition, 1 g of the resin was immersed in 10 g of F-NRL. After immersion, the treated F-NRL was collected at six time points: 0.5, 1, 3, 6, 27, and 48 hours. The treated F-NRL was titrated with EDTA to determine the magnesium concentration. In the second condition, 1 g of the the resin was immersed in 10 g of F-NRL and stired constantly by a magnetic bar. The treated F-NRL was collected at 0.5, 1, 3, 6, 27, and 48 hours and titrated with EDTA to determine the magnesium content.

Experiment 2: Pass F-NRL through resin with pressure syringe pump

The testing was done five times using a 10 ml syringe with five different amounts of resin (2, 3, 4, 5, and 6 g) which were put into the syringe. At the bottom of the syringe an 80 mesh sieve was placed to prevent the resin from leaving the syringe. The end of the syringe was closed with parafilm. An 80 mesh sieve was placed at the top surface of the resin for protection. Next, the syringe was filled with 10 ml of F-NRL and the plunger was put into the syringe. Then the syringe was moved to a syringe pump. Finally, the F-NRL was passed though the resin inside the syringe at a controlled flow rate of 60 ml/hr. The time period was recorded and the effluent was collected to test the magnesium concentration.

Experiment 3: Pass F-NRL through resin using a gravity column test

Into a gravity column (Thailand petty patent No. 7720), 50 g of resin was placed in the column and F-NRL was allowed to flow by gravity. The effluent was collected and titrated with EDTA to calculate the magnesium concentration. The gravity column is illustrated in Figure 3.1.

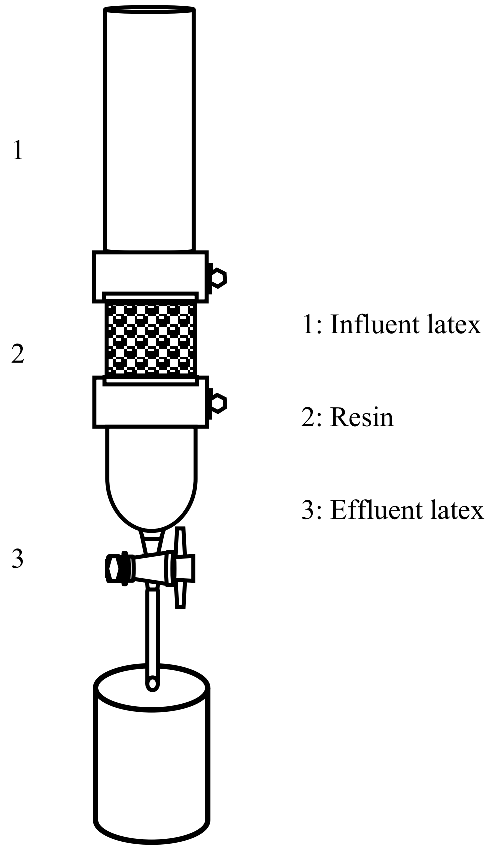


Figure 3.1 Gravity column

Source: Department of Intellectual of Property, Thailand petty patent No. 7720

3.2.2.3 To study the properties of F-NRL before and after using macroporous and macroporous regenerated cationic exchange resin

This part consisted of two sub-experiments to test the properties of F-NRL that consisted of magnesium content, dry rubber content (%DRC), total solids content (%TSC), and volatile fatty acid number (VFA No.).

Experiment 1: Immerse and pass F-NRL through the resin

In the initial experiment, 0.5, 1.0, 2.0, and 3.0 g of the resin were immersed in four 20 g samples of F-NRL, respectively. After immersion, the F-NRL was collected at eight time points to test the properties: 0, 1, 2, 6, 12, 24, 36, and 48 hours. The best condition was selected to test in the pilot scale. In the pilot scale, 10 kg of F-NRL was passed through 1 kg of resin in a gravity flow filter tank and the effluent was collected to test the properties.

Experiment 2: Pass F-NRL through regenerated resin

The used resin from experiment 1 was collected and cleaned using DI water. The resin was cleansed with DI water until the DI water was not contaminated with rubber. Next, the resin was immersed in 2 N HCl solution for 60 minutes and then moved for immersion in DI water for 30 minutes to remove the acid solution. The resin was then immersed in 0.5 N NaOH solution for 30 minutes. Finally, the resin was rinsed with DI water until the conductivity of the water before and after were the same. In the next step, the F-NRL was tested for the magnesium content.

3.3 Results and discussions

3.3.1 Macroporous cationic exchange resin experiment

3.3.1.1 The characterization of F-NRL and resin

The properties of unpreserved F-NRL collected from the rubber cooperative are shown in Table 3.1. The F-NRL was preserved with ammonia solution (4%) before immersion in the resin and collected to test the properties.

Table 3.1 Properties of F-NRL

Property	Value
1. Dry rubber content (%DRC)	32.1 ± 0.3
2. Total solids content (%TSC)	35.9 ± 0.2
3. Volatile fatty acid number (VFA No.)	0.03
4. Magnesium content (ppm)	300

The macroporous cationic resin is a spherical particle that is very porous (Figure 3.2). The SEM images of the macroporous resin beads and their properties are shown in Figure 3.3 and Table 3.2, respectively.

Figure 3.2 Purolite S-930

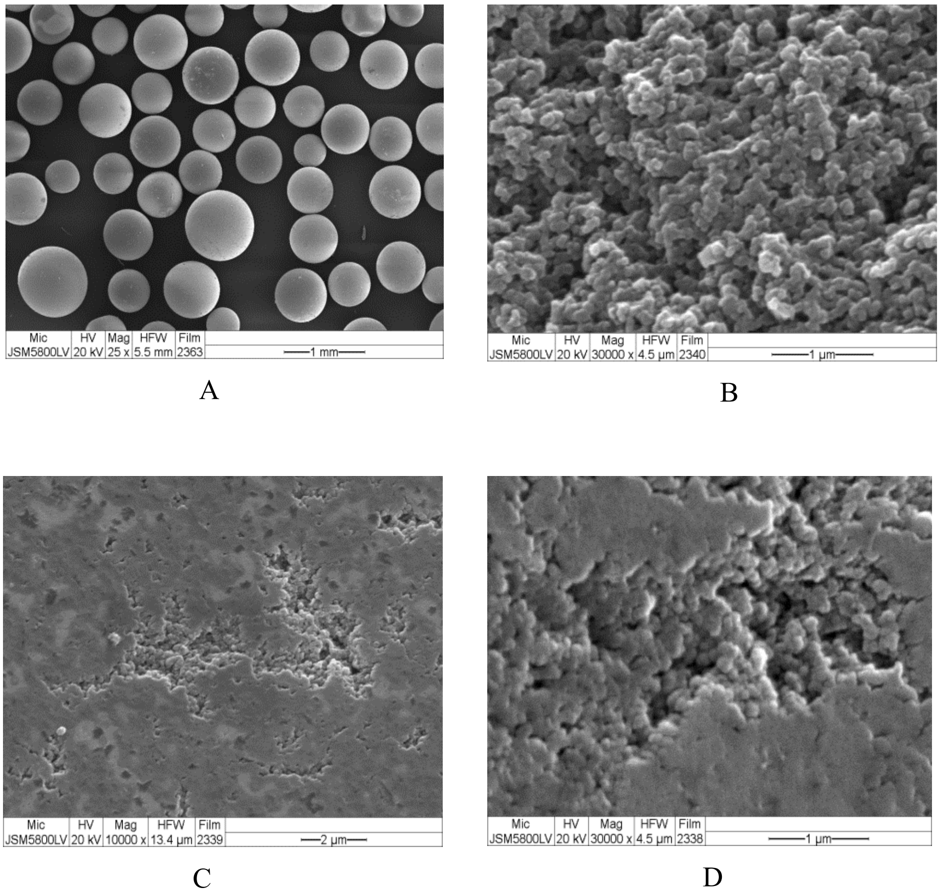


Figure 3.3 SEM image of macroporous resin beads

A) Size of resin beads, B) Interior of resin bead,

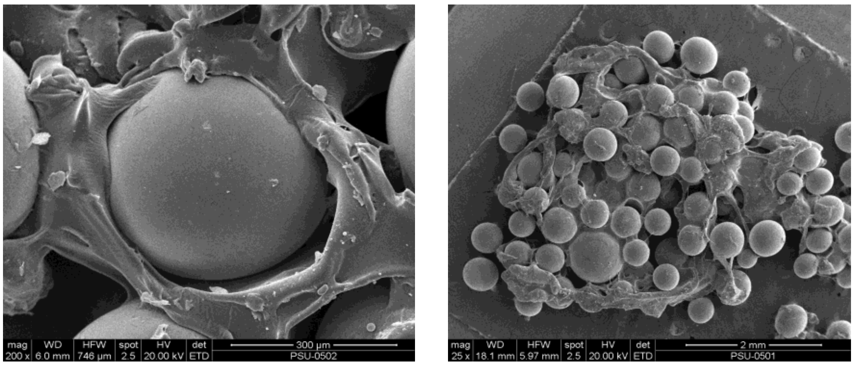
C and D) Outside surface (background) of resin bead

Table 3.2 Properties of Purolite S-930

Chemical and physical properties of Purolite S-930	
Chemical name	Sodium polyvinyl iminodiacetate
Polymer matrix structure	Macroporous polystyrene crosslinked with divinylbenzene
Physical form and appearance	Opaque beige spheres
Functional group	Iminodiacetic acid
Ionic form as shipped	Na^+
Particle size range	+1.0 mm <10%, -0.3 mm <1%
Moisture rentention	55-65% (H^+ form)
Reversible swelling, $H^+ \longrightarrow Na^+$	<20%

Source: Chelation Resins and *Al-Ameri et al., 2011.

The macroporous cationic exchange resin beads after immersion in the F-NRL were covered by rubber on the surface of the resin as shown in Figure 3.4. The magnesium ions were separated from the F-NRL by the adsorption process which is dependent on the surface area of the resin.



A B

Figure 3.4 A and B: SEM images of resin beads after immersion in F-NRL

Source: Puangmanee and Taweepreda, 2014.

Particle size of F-NRL

The average particle size of F-NRL before immersion with the resin was 1.126 µm (range, 0.040-4.240 µm) and after immersion it was approximately 1.142 µm (range, 0.040-4.655 µm). These values were similar and the graphs of the particle sizes are shown in Figures 3.5 and 3.6.

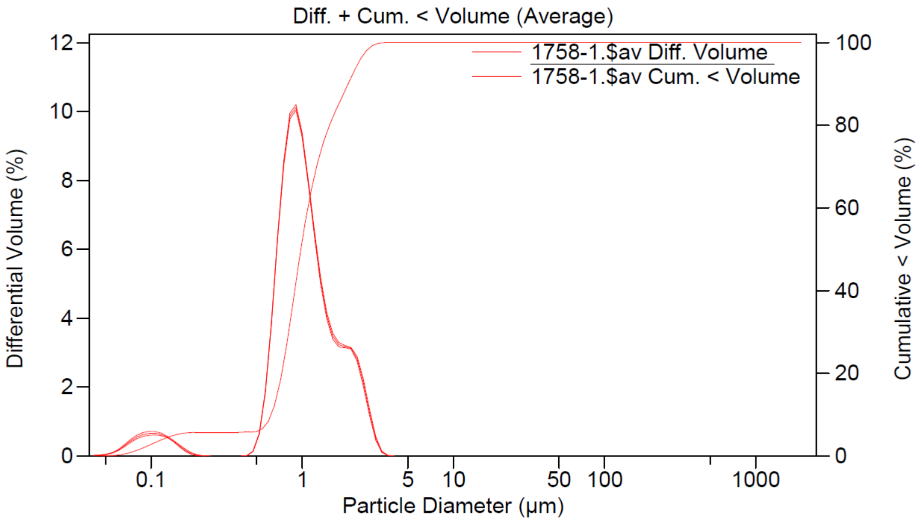


Figure 3.5 Particle size of F-NRL before immersion in resin.

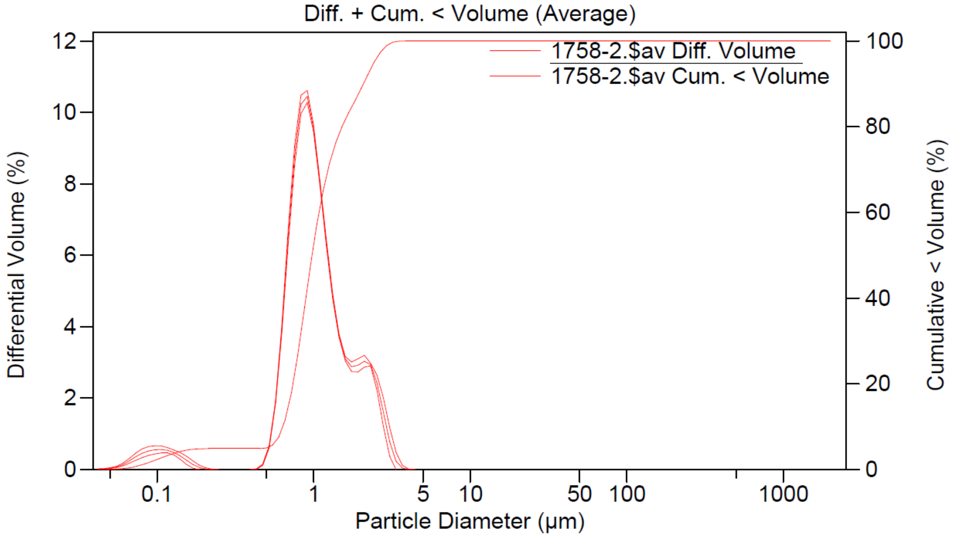


Figure 3.6 Particle size of F-NRL after immersion in resin.

3.3.1.2 Magnesium content of F-NRL before and after using macroporous cationic exchange resin

Experiment 1: Immersed resin in F-NRL

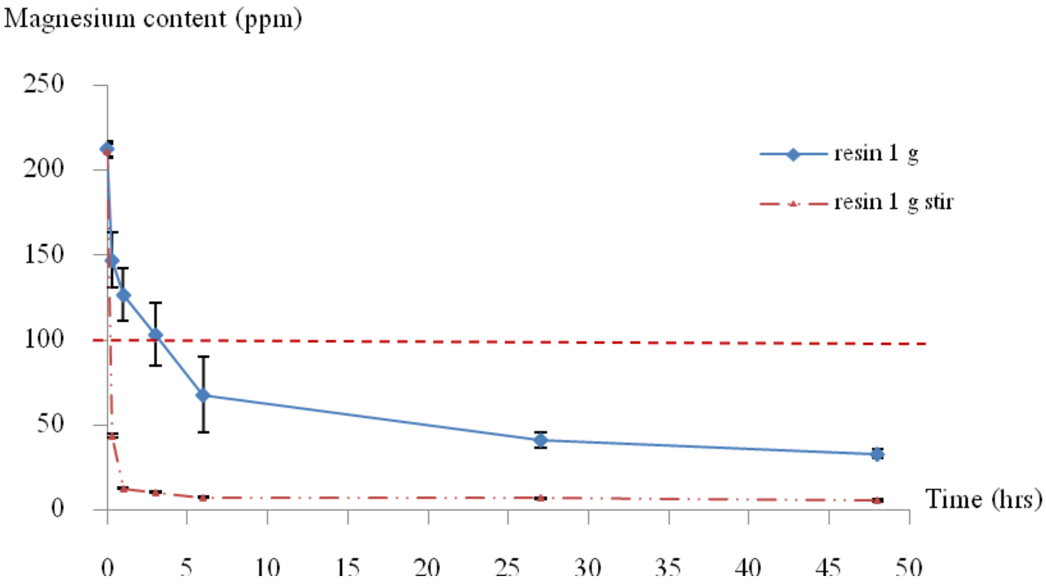


Figure 3.7 Magnesium content in F-NRL before and after immersion with resin.

Figure 3.7 shows the quantity of magnesium content in F-NRL compared between immersion with 1 g of resin and immersion with 1 g of resin by stirring. The F-NRL was collected for titration with EDTA at 0.5, 1, 3, 6, 27, and 48 hours. Initially, the magnesuim content in the unstirred F-NRL and stirred F-NRL were 214 and 211 ppm, respectively. The magnesium content in the unstirred sample dropped sharply at 30 min to approximately 147 ppm, while the magnesium content in the stirred sample decreased quickly to around 43 ppm. At 1 and 3 hours, the magnesium levels of the unstirred sample dropped gradually to 126 and 103 ppm, respectively.

Following this pattern the magnesium levels of the stirred samples at 1 and 3 hours declined rapidly to around 12 and 10 ppm, respectively, and decreased quickly more than the unstirred sample. At 6, 27, and 48 hours, the magnesium level of the unstirred sample fell only gradually to about 67, 41, and 33 ppm, respectively, while the level of magnesium in the stirred sample dropped slightly to around 7, 7, and 5 ppm, respectively. All the results were not over the industry standard limit of 100 ppm.

Experimment 2: Passed F-NRL through resin with syringe pump

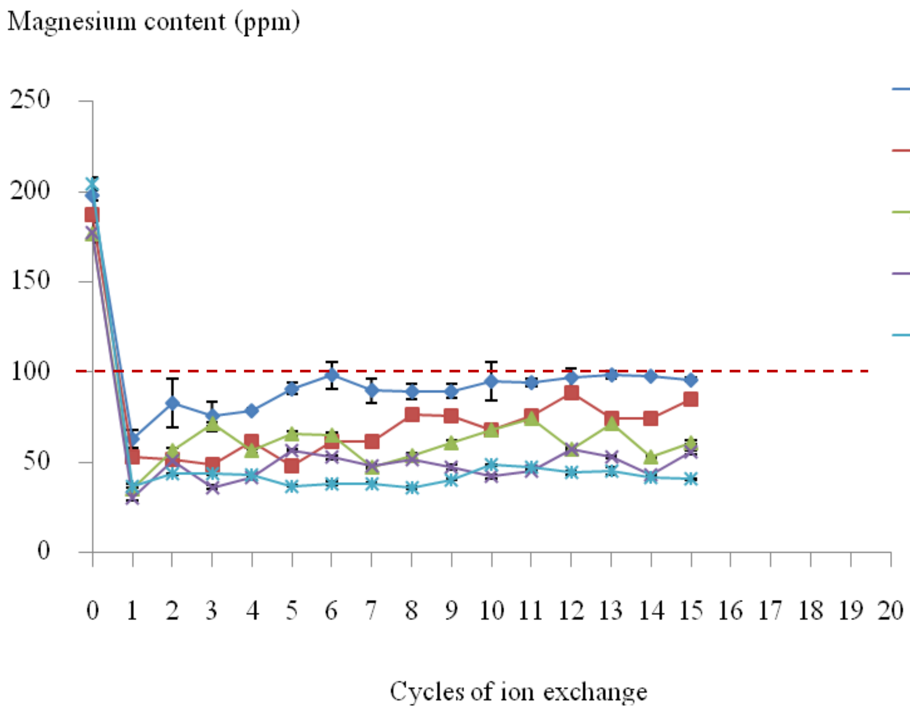


Figure 3.8 Magnesium content in F-NRL before and after removing magnesium using resin with pressure syringe pump

Figure 3.8 shows the concentration of magnesium in F-NRL which passed through five different amounts of resin in the syringe pump. Fifteen cycles of F-NRL were pumped through the syringe without regeneration for each amount of resin. The amounts of resin were 2, 3, 4, 5, and 6 g. The initial concentrations of magnesium were between 176 and 204 ppm. At the end of the first cycle of F-NRL through the syringe pump, the magnesium concentrations dropped to 63, 52, 35, 30, and 36 ppm for the 2, 3, 4, 5, and 6 g amounts, respectively.

After the first cycle, most values increased, but the concentration of magnesium for 3 g of resin declined to 51 ppm and fell to 48 ppm at the third cycle, while the magnesium concentration for 2 g and 5 g of resin dropped to 75 and 63 ppm. From the fourth to the seventh cycle all concentrations fluctuated. For example, for the 2 g of resin the magnesium concentation increased sharply and reached a peak at 98 ppm, while for 3 g of resin the magnesium concentration fell to the lowest point at 48 ppm.

For the 4 and 5 g of resin the concentrations of magnesium moved up and down at the seventh cycle at 47 and 48 ppm, respectively, but for 6 g of resin it dropped slightly. After the seventh cycle, the magnesium concentrations trended higher with fluctuation, but the concentrations were not over the limit of 100 ppm. However, the concentation of magnesium for the 2 g of resin was higher than all other amounts of resin and it reached a peak of 95 ppm at the fifteenth cycle.

In addition, the concentrations of magnesium for 3, 4, and 5 g of resin were lower than the 2 g of resin at 85, 61, and 55 ppm, respectively. The magnesiun concentration for 6 g of resin was the lowest at 40 ppm. The magnesium concentrations in the 2, 3, 4, 5, and 6 g of resin had peak and low values of 98/63, 88/48, 74/5, 48/36, and 48/36 ppm, respectively.

Experiment 3: Passed F-NRL through resin using a gravity column test

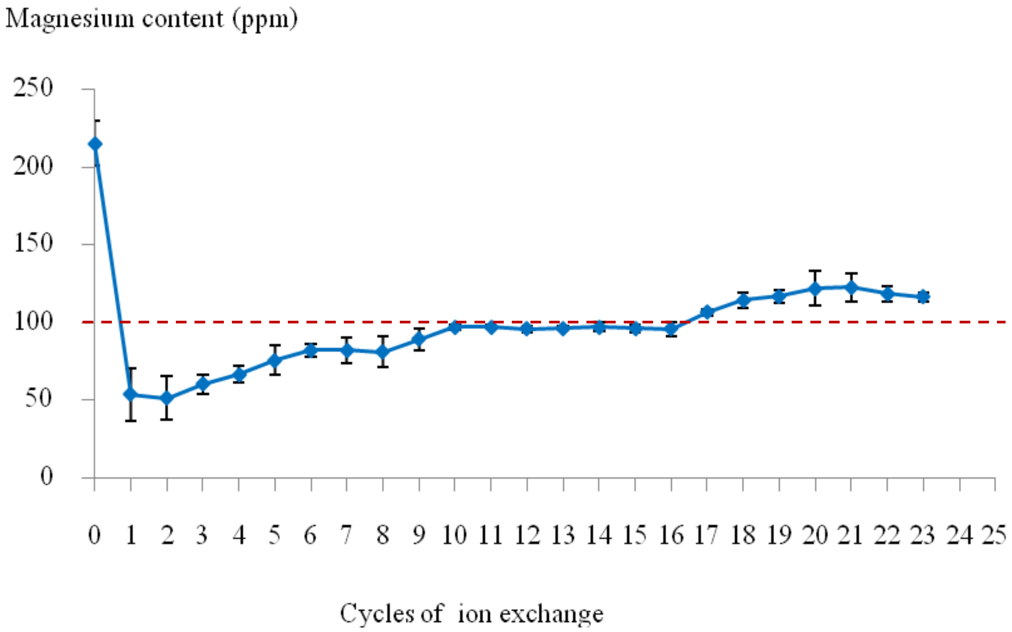


Figure 3.9 Magnesium content in F-NRL before and after removing magnesium using resin with a gravity column test

Figure 3.9 shows the magnesium concentration in F-NRL which passed through the resin in the gravity driven column test. Initially, the magnesium concentration was 215 ppm. During the first cycle of ion exchange, the concentration of magnesium dropped quickly to around 53 ppm and fell to the lowest point of 51 ppm. Then the magnesium concentration rose gradually during the third to the sixth cycle from approximately 60 to 82 ppm and then moved up and down in a range of 82 to 88 ppm between the sixth to the nineth cycle. After that, the magnesium concentrations remained stable at an average of 96 ppm. After the seventeenth cycle, the magnesium concentration increased and reached a peak of 121 ppm at the twenty-first cycle.

Most of the magnesium concentrations dropped, although some the concentrations increased in the final cycle.

3.3.1.3 Properties of F-NRL before and after using macroporous and macroporous regenerated cationic exchange resin

Experiment 1: Immerse and pass F-NRL through resin

- Magnesium content in F-NRL before and after immersion

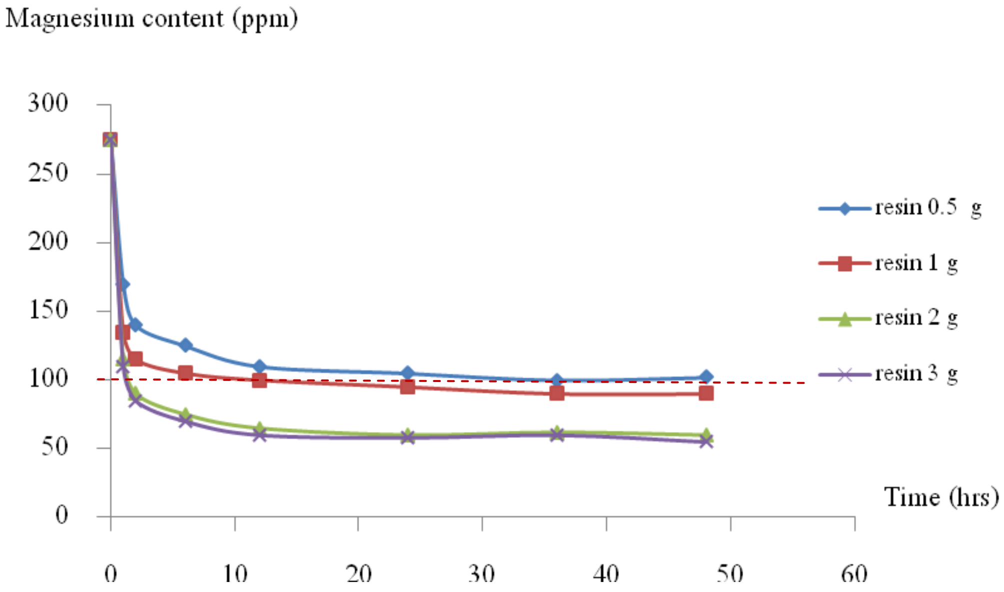


Figure 3.10 Magnesium content in F-NRL before and after immersion in macroporous resin

Figure 3.10 illustrates the comparison in the levels of magnesium in the F-NRL between four F-NRL samples of 20 g each which were immersed with 0.5, 1, 2, and 3 g of resin, respectively. The level of magnesium in each sample was determined at 7 time points: 1, 2, 6, 12, 24, 36, and 48 hours. The level of magnesium in all samples before immersion in the resin was

275 ppm. After immersion in the resin the level of magnesium dropped rapidly from 170 in sample 1 at 1 hour to 70 ppm in sample 4 at 6 hours.

The trend in the levels of magnesium was to decrease gradually as the amount of resin and time increased. At 48 hours, the levels of magnesium of samples 1 to 4 were 102, 90, 60, and 55 ppm, respectively. Moreover, the levels of magnesium in samples 3 and 4 decreased more than samples 1 and 2 at every time point. Although the lowest level was in sample 4, the amount of resin was much more. In this experiment, sample 3 (2 g resin) was suitable for application in the pilot scale since it was a low quantity of resin, but it could reduce the level of magnesium to less than 100 ppm which was close to 3 g of resin (sample 4).

- Magnesium content and properties of F-NRL before and after passing through regenerated resin

The pilot scale used 10 batches of 10 kg each of F-NRL preserved with ammonia solution. Each batch of F-NRL passed through the same amount of resin (1 kg) in a free gravity flow filter tank. The properties of F-NRL before and after the process of Mg^{2+} ion removal with resin did not change except for the Mg^{2+} ion levels. The results are shown in Tables 3.3 and 3.4.

Table 3.3 Properties of F-NRL before processing

Parameters	**F-NRL batches**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
%TSC	37	38	36	35	37	38	37	37	35	34
%DRC	36	36	35	33	35	37	35	36	34	33
VFA No.	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Mg content (ppm)	230	220	210	245	215	195	205	210	200	235

Table 3.4 Properties of F-NRL after processing

Parameters	**F-NRL batches**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
%TSC	37	38	36	35	37	38	37	37	35	34
%DRC	36	37	35	34	36	37	36	36	34	33
VFA No.	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Mg content (ppm)	65	67	73	87	95	99	112	135	155	185
%Mg reduction	72	70	65	64	56	49	45	36	23	21

The results found that the values in three parameters did not change. The values of the %TSC and %DRC were in the ranges of 34-38 and 33-37, respectively. The VFA values for 8 of the 10 batches were equal to 0.02. However, the levels of magnesium were significantly reduced. The levels of magnesium for each batch before processing were in the range of 195-245 ppm. The levels of magnesium after removal of Mg^{2+} ions dropped rapidly to lower than 100 ppm for batches 1-6. After that, they increased gradually to levels above 100 ppm. Even though the levels of magnesium content in batches 7-10 were higher than 100 ppm, the levels were lower than in the F-NRL collected from the field (F-NRL from rubber cooperative) (Figure 3.11).

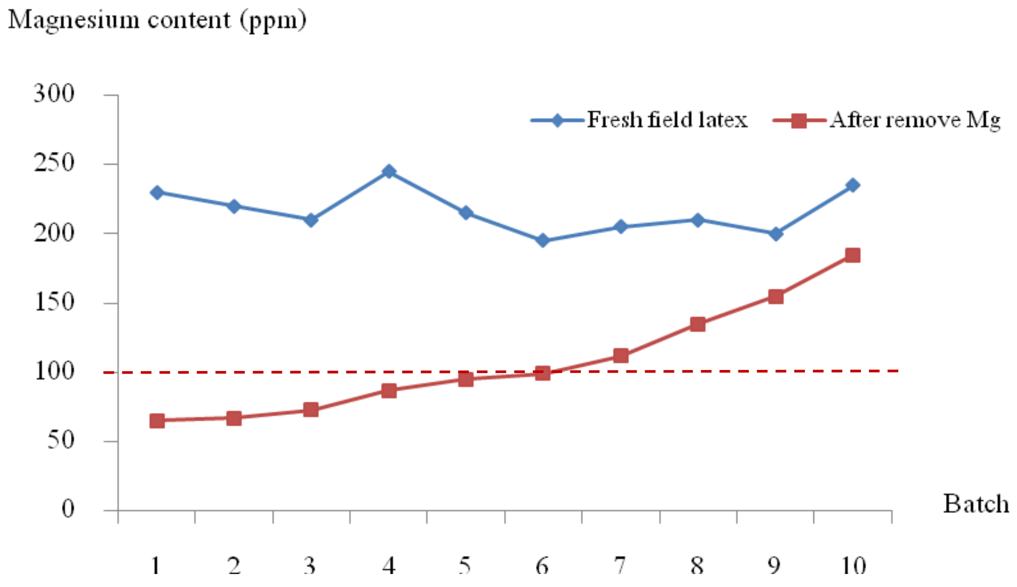


Figure 3.11 Magnesium content in F-NRL before and after removing magnesium using resin

The experiment found that 1 kg of resin adsorbed Mg^{2+} ions from the F-NRL and reduced the level of magnesium. The levels of Mg^{2+} ions were lower than 100 ppm in batches 1-6. This indicated that the same resin could be used 6 times to process 60 kg of F-NRL. Although, the price of resin per kilogram is high (850 Baht/kg), the resin can be regenerated to add cations onto the surface area of the resin and the resin can be reused until the level of Mg^{2+} ions in the F-NRL goes over the limit of 100 ppm.

Experiment 2: Pass F-NRL through regeneration resin

After the resin particles were used to process the F-NRL, the resin was allowed to dry. The SEM images showed that rubber covered the resin particles (Figures 3.4 A and B). In this case, the rubber reduced the effective surface area of the resin and the resin could not efficiently exchange ions and remove the Mg^{2+} ions from solution. Thus, the resin had to be cleaned before reuse in magnesium removal. After resin regeneration, the resin could again remove Mg^{2+} ions. The properties of the F-NRL before and after removal of magnesium ions with regenerated resin are shown in Tables 3.5 and 3.6, and Figure 3.12. The level of magnesium ions in the F-NRL decreased when it passed through the regenerated resin.

Table 3.5 Properties of F-NRL before passing through the regenerated resin

Parameters	**F-NRL batches**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
%TSC	38	37	39	37	38	38	37	38	36	35
%DRC	36	35	37	35	36	36	35	36	34	33
VFA No.	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Mg content (ppm)	215	200	210	220	195	190	210	215	205	235

Table 3.6 Properties of F-NRL after passing through the regenerated resin

Parameters	**F-NRL batches**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
%TSC	38	37	39	37	38	38	37	38	36	35
%DRC	36	35	37	35	36	36	35	36	34	33
VFA No.	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Mg content (ppm)	76	75	81	87	88	109	125	152	175	202
%Mg reduction	65	63	61	60	55	43	40	29	15	14

All data from the regenerated resin were similar to the results obtained from unregenerated resin. The data that consisted of the %TSC and %DRC values were in the ranges of 35–39% and 33–36%, respectively. The VFA numbers were in the range of 0.01-0.02. The results of the magnesium content levels in the F-NRL that used unregenerated resin and regenerated resin were similar. The magnesium content levels in the F-NRL before processing were high (195-215 ppm) and after processing the magnesium content levels were low. The levels of magnesium content after removal of Mg^{2+} ions decreased sharply (<100 ppm) in batches 1-5, after that, they rose gradually. Although the values were higher than 100 ppm in batches 6-10, these levels were lower than the F-NRL that was not processed through the regenerated resin. In addition, the percentages of reduction were in the range of 65-14% which was the greatest in the first batch. The percentage of magnesium content level reduction gradually reduced until the tenth batch. The percentages of reduction of magnesium content in F-NRL that used the unregenerated resin were in the range of 72-21%. This trend of data in the process that used unregenerated resin resembled the results of the process that used the regenerated resin.

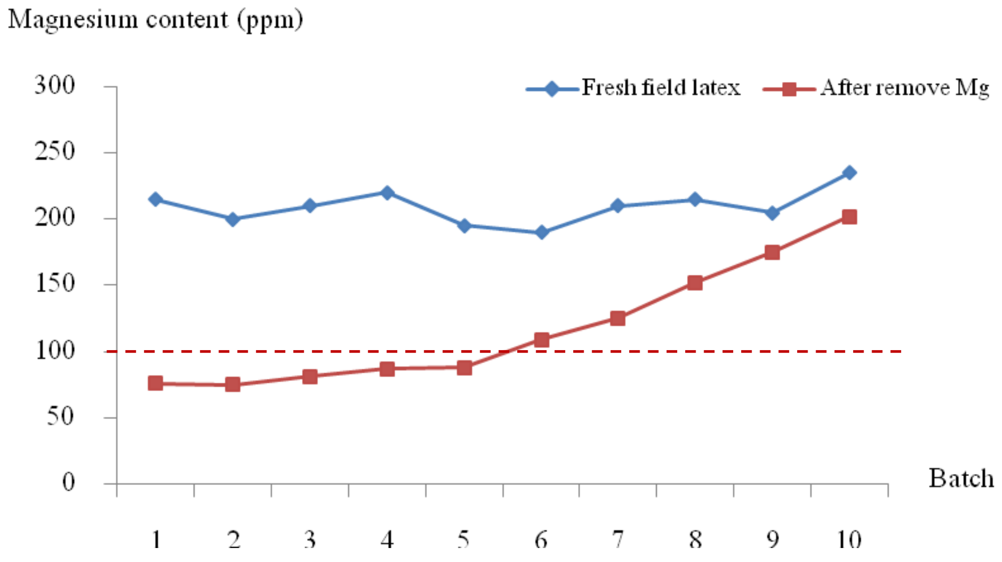


Figure 3.12 Magnesium content in F-NRL before and after removing magnesium using regenerated resin

The results found that the level of magnesium ions decreased after passing through the regenerated resin that had no new resin added. Therefore, regenerated resin can be used to reduce the cost of magnesium reduction and is even more cost effective if the regenerated resin is used more than one time or until the resin becomes saturated and cannot be regenerated or recovered. When the resin is used in the ion exchange process until saturation or cannot be recovered it is then called saturated ion exchange resin (Notification of the Ministry of Industry, 2006) and it becomes a waste resin. The saturated resin (waste resin) is stable and is non-reactive under normal condtions of handling and storage transport, and there are no known dangerous reactions. Further, it is insoluble in water and organic solvents (Purolite safety data sheet, 2015).

For waste resin management and disposal, the waste resin must be kept in a tightly closed container and covered with a plastic sheet to prevent spreading and stored away from incompatible materials (strong oxidising agents, nitric acid). In addition, it must be kept away from heat, sparks, flames and elevated temperatures due to the thermal decomposition or combustion (outdoor burning) which may liberate carbon oxides and other gases or vapors (Purolite safety data sheet, 2015).

The waste resin should be disposed by co-incineration in a cement kiln which is the correct and suitable method in accordance with the Notification of the Ministry of Industry in the criteria for waste or unusable materials B.E. 2548 (2005) [Appendix 1 in the section for type and category of waste or unusable material and Appendix 4 in the section of guidelines and methods for waste and unusable waste material management (Notification of the Ministry of Industry, 2006)].

Discussion

In this research project, after the resins were immersed in F-NRL it was found that the rubber particles had not changed, although the particle size of the resin was a little bit bigger because rubber covered the surface of the resin particles. But the concentration of magnesium decreased only after F-NRL passed through the resin. In addition, the properties of the F-NRL did not change after treatment with either the unregenerated resin or regenerated resin.

In the removal of magnesium ions using a syringe pump, a gravity column test, and a gravity flow filter tank found that the magnesium concentrations were reduced to less than 100 ppm in F-NRL. The magnesium concentrations were greatly reduced in the first experiment by immersion and immersion with stirring. The concentrations of magnesium immediatly dropped and then increased gradually in the pressure syringe pump test, the gravity column test, and the gravity flow filter tank but did not go over the limit of 100 ppm until the loss of sorption occurred. Then the concentrations of magnesium were higher and the resins needed to be cleaned and regenerated with HCl and NaOH for the performance recovery of the resins.

In this experiment, the magnesium content in the F-NRL decreaesd in the ion exchange process. In this processes the magnesium ions (Mg^{2+}) (counterions or mobile ions) were adsorped onto the matrix which has the iminodiacetic acid functional group (fixed ion) on the resins which had the Na^{+} ionic form. The exchange took place without any physical alteration to the resins (Alchin, n. d.). So, the concentrations of magnesium ions in the F-NRL were reduced only after the ion exchange process.

3.4 Conclusions

The macroporous cationic exchange resin can reduce the concentration of Mg^{2+} ions in F-NRL to less than 100 ppm after immersion, passing through a syringe pump, a gravity column test or a gravity flow filter tank. The performance of the macroporous resins rose after regeneration by HCl and NaOH, and can be reused to minimize magnesium content in F-NRL.

In addition, the physical size of the particles of F-NRL and resins, and the properties of the F-NRL did not change after treatment with resin and regenerated resin. However, the surface of the resins was found to be covered with rubber. Moreover, in this experiment there was no sludge or waste during the separation process of removing the magnesium. So, it is possible to use the adsorption technology (ion exchange resin) with macroporous cationic exchange resin to separate or remove magnesium ions in F-NRL and improve F-NRL quality.

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CHAPTER 4

Primary Studies of Environmental Impact and Economic Costs of New Technology for Magnesium Reduction in Fresh Natural Rubber Latex

Abstract

This research aimed to study the environmental impact and economic costs using adsorption technology (ion exchange resin) as a new technology to reduce the quantity of magnesium in fresh natural rubber latex (F-NRL) and compare it with chemical precipitation using diammonium phosphate (DAP). The new technology can reduce the level of magnesium ions (Mg^{2+}) in the F-NRL and not produce concentrated latex sludge or waste during the separation process and it can minimize the quantity of waste at the centrifuge machine after centrifugation. The properties of F-NRL before and after the process did not change except for the reduction in the level of Mg^{2+}. Moreover, the properties of the waste resin from the process can be used in co-incineration in a cement kiln in the cement production process. Although the initial cost of this technology is more expensive than chemical precipitation with DAP due to the higher cost of the resin, the same resin can be used more than one time.

Key words: environmental impact, economic cost, magnesium reduction technology, fresh natural rubber latex

4.1 Introduction

In Thailand, para rubber is an economic plant that produces a high income of between 5-6 million baht per year. Moreover, Thailand has been a big rubber producer in the world since B.E 2534 (1991) and the products continued to increase in the 6 years between B.E. 2551 and 2556 (2008-2013). The quantity of products increased an average of 5.38% per year. The total production of rubber products in B.E. 2556 (2013) was 4,170,428 tons that rose 10.39% from B.E. 2555 (2012) due to the increased price of rubber from B.E. 2550 (2007) which reached the highest in B.E. 2554 (2011). So, the agriculturists produced rubber crops instead of other plants due to the high income (Sikarinmart et al., 2014).

In addition, Thailand exports two types of products that consist of fresh natural rubber latex and rubber scrap/cup lump. In the case of fresh natural rubber latex, there are two kinds of products from concentrated latex. The first includes final products such as balloons, condoms, nipples for baby bottles, mattresses, pillows, and sponges. Dry rubber is produced as ribbed smoked sheet, unsmoked sheet and standard Thai rubber, and crepe rubber.

Moreover, 80% of concentrated latex, standard Thai rubber, and ribbed smoked sheet are exported and 20% is used within the country. Rubber scrap and cup lump are used to produce standard Thai rubber and crepe rubber (The Agricultural Futures Exchange of Thailand, 2014).

As the demand of rubber increases, it causes an increased production in the rubber industry. As production increases there is an impact on the environment such as effluent waste water, malodors, and solid waste problems, especially in the concentrated latex industry.

The concentrated latex factories are important as they produce high incomes for the local communities and the country as a whole due to the higher demand of rubber products of people in the world. These products are produced from concentrated latex which is in the upstream industry (Danteravanich et al., 2002).

Normally, the concentrated latex industry not only produces two main products which are concentrated latex and skim latex but the latex industry also creates waste products in the form of waste water, solid waste, malodors, vapors, and noise (Roongtawanreongsri, 2015). These wastes are sources of pollutants that are the cause of pollution problems (externality) in the environment.

In the case of the concentrated latex industry, the environmental impacts from these factories are related economically. These impacts produced by the production process of the factories are called externalities (Roongtawanreongsri, 2006). These externalities refer to costs or benefits of third parties which are not related to the production process or service, and are not reflected in the price of the goods or services. In other words, the prices of the goods do not reflect the real cost and benefits to society (Roongtawanreongsri, 2015) as the activities of the first party may affect the well-being of a second party without an impact on the first party (Thongrak, 1999).

These externalities have two kinds that consist of external costs or external social costs and external benefits or external social benefits (Roongtawanreongsri, 2015). In addition, these externalities can be classified into two types: pecuniary externalities and technological externalities. Technological externalities can only produce market failure that consists of external economics and external diseconomy (Thongrak, 1999).

Externalities can be the cause of a market failure. Market failure means the management of the manufacturing and consumption is defective due to external costs that cause management to not achieve maximum efficiency. In the end, society needs to bear the burden of the external costs (Roongtawanreongsri, 2006).

Economically, when the resources cannot manage to get efficiency, the sustainability of the resources and environment cannot continue long term because it will incur environmental costs that were not part of the decision-making in the production process and consumption. These impacts can work back to the sustainability of the latex industry (Roongtawanreongsri, 2006).

In addition, the environmental impacts from the concentrated latex industry such as effluent waste water, malodors and vapor, and solid waste products are valueless in the market and it is impossible to merge them into the production process and consumption until the impact can be evaluated in the form of money or environmental costs. Moreover, most of the environmental costs (external costs) are not merged with the costs of production (Roongtawanreongsri, 2005) or the manufacturing costs (Korsermsri, 2007) in the production process.

Most factories ignore these problems due to the high cost to treat and dispose of the waste to reduce the volume or concentration to levels below the standards of pollution according to the law. These costs are called abatement costs which are associated with a process to minimize the quantity and concentration of waste before release of the pollutants into the environment (Roongtawanreongsri, 2015).

Generally, abatement costs are the methods, techniques, and technologies that are available to minimize, treat, and dispose of the waste. However, some technologies and methods are expensive such as clean technology (cleaner production, pollution prevention, and waste minimization), waste water treatment plant, sanitary landfill, and incineration. When a factory uses these methods in the process of production, these costs are added to the cost of production in the process which increases the cost of production per unit.

Although the cost of production increases, it can decrease the damage the pollution causes to humans and the environment. Even though the technology to reduce the pollution has a high cost, it is environmentally friendly.

Generally, the concentrated latex industry produces concentrated latex by chemical precipitation with diammonium phosphate (DAP). Greater abatement costs are necessary to treat and dispose of the two main waste products which are solid wastes and waste water. Sometimes, these and other waste materials are discharged and abandoned during the process. So, it becomes necessary for the factories to add new abatement costs to solve the waste management problems.

In fact, other waste products that are released during the process of production and waste treatment/disposal include malodors and vapors from the chemical solutions and gases (NH_3, H_2S, H_2SO_4 and volatile organics), concentrated latex sludge, waste water in the production process and waste water at the treatment plant. There are many sources of waste water in the process such as wash water in the production process of concentrated latex and skim latex. In addition, solid waste materials consist of rubber and non-rubber. Rubber waste comes from rubber scrap from the rubber tank, waste water treatment pond, residual rubber scrap in rubber containers and drainpipes. Non-rubber materials are concentrated latex sludge from two main sources which are storage tanks (rubber tank) and centrifuge machines. Moreover, there is noise pollution from the centrifuge machines (Roongtawanreongsri, 2005).

In any case, most factories release the pollutants into the environment instead of treating and disposing the waste using proper methods in order to save or reduce abatement costs. Since the factories prefer to maximize the profits of the finished goods rather than solve the problems and reduce the amount of waste, they show irresponsibility towards society and the environment.

However, some wastes that are released during the process can be reduced by using new methods and technologies to minimize the waste before disposal or treatment in the end of the process. Since magnesium ions are the cause of concentrated latex sludge or waste in the concentrated latex process, ion exchange resin technology can be used to reduce the quantity of magnesium ions in fresh natural rubber latex, thus reducing the volume of the sludge (waste) which in turn would reduce the number of dumping sites or sanitary landfills for disposal of the waste. In addition, the reduction of malodors and waste water would lessen the impact on the environment. However, the new method (ion exchange resin technology) has a high abatement cost as the resins have a high cost and they need to be used with specific equipment. In addition, the factory needs to pay the installation costs of the new equipment, services, maintenance, and portage charge to transfer the waste resin for disposal to an incineration cement kiln that is far from the factory. So, these abatement costs are added to the costs of production.

Ion exchange resin technology can reduce the impact on the environment by reducing the volume of concentrated latex sludge or waste, malodors, and minimize the amount of land area used as waste dumping sites or sanitary landfills. Moreover, waste resin from this method can be reused and disposed as a new raw material in a co-incineration cement kiln instead of dumping it in a landfill. In addition, the ion exchange technology saves time, the number of laborers and water to clean the centrifuge machine compared with chemical precipitation with diammonium phosphate (DAP).

Although, the ion exchange resin method has high abatement costs, it can remove magnesium ions from fresh natural rubber latex instead of using chemical precipitation with DAP. In addition, the quantity of concentrated waste latex sludge from this method is decreased in the process which results in a lower volume of waste for disposal.

In this study, instead of assessing the cost of externalities from the concentrated latex sludge, we attempt to assess the increase in production costs as a way to represent an abatement cost. Factories can then decide whether the increase is worth the investment to reduce the associated environmental impact generated by their factories to demonstrate their responsibilities to the society and environment. The increased production cost with this new technology would result in a reduction in environmental costs from concentrated latex sludge, malodors, waste water (wash water), leachate, and illegal open dumping of waste. It should be noted that the increased cost does not deduct the benefit of selling a new raw material to a co-incineration cement kiln.

For cost accounting, the cost of production or cost means the value of the resource that is lost to achieve assets, goods, and services and the values are measured by currency or the amount of money that is paid to achieve the assets, goods, and services (Aujirapongpan, 1997). The costs can be classified into many groups (cost classification) (Korsermsri, 2007), but in this research cost refers to the group of costs related to the level of activity (cost behavior) (Aujirapongpan, 1997).

Cost behavior refers to the classification analysis of costs that change or vary and follow the level of activity or production volume (Aujirapongpan, 1997). They are shown in production per unit, production per hour, hours per labor, or hours per machine (Korsermsri, 2007). These costs are comprised of three types which are fixed costs, variable costs, and mixed costs (Aujirapongpan, 1997).

Generally, economic costs refer to the cost of production or manufacturing and are well known as fixed costs and variable costs that relate to production factors which are used in the production process and service (Roongtawanreongsri, 2015). In this study, variable cost is used to calculate the economic cost only in the experiment. The fixed costs of materials and equipment in two conditions were controlled except the cost of the DAP and the cost of the resin.

The variable cost is the total cost that changes or varies with the proportionate level of activity or production volume, while the cost of production per unit is fixed in each unit (Aujirapongpan, 1997).

This research studied the primary environmental impact and the economic costs of a new technology for the reduction of magnesium in fresh natural rubber latex. The economic cost considered the manufacturing cost as part of the operation cost which is the variable cost of production per unit only.

4.2 Objective

To study the environmental impact and economic costs using magnesium reduction technology to reduce the quantity of magnesium in fresh natural rubber latex by a comparison of chemical precipitation using diammonium phosphate (DAP) with adsorption technology using ion exchange resin.

4.3 Scope

4.3.1 Research area

The study site was at a factory in Sadao District of Songkhla Province.

4.3.2 Research scope

This research is a case study on the primary environmental impact and economic costs in the concentrated latex process as a result of the reduction of magnesium in fresh natural rubber latex (F-NRL) from chemical precipitation using diammonium phosphate (DAP) compared with adsorption technology (ion exchange resin) that is a new technology for the removal of magnesium ions.

The environmental impact considered the volume of concentrated latex sludge after the use of the new adsorption technology, the properties of the waste resin, and management of the waste resin.

The economic cost considered only the variable costs of the operation which used the materials, energy, and labor to calculate the variable cost of production per unit.

An evaluation of the environmental impact and economic cost of the new adsorption technology cannot cover every issue because the new adsorption technology was in the very early stages in the factory. In addition, there were legal issues for the use of the equipment which is under the protection of petty patent/patent between the owner of the petty patent/patent and the industry.

4.3.3 Collected data

4.3.3.1 The first data were collected from an experiment in a laboratory at a factory in Sadao District of Songkhla Province, The Siam Cement (Thung Song) Co., LTD Laboratory, and SCI ECO Services Co., LTD which is a subsidiary company of SCG Cement.

4.3.3.2 The secondary data were collected from sources that included surveying, inquiries and interviews, text books, research, theses, articles, laws, workers in the concentrated latex factory, and waste disposal companies that were related to the environmental impact and economic costs of the concentrated latex industry and magnesium reduction technology.

4.4 Method

4.4.1 To study the fresh natural rubber latex (F-NRL) properties

4.4.1.1 Comparative study of F-NRL properties between chemical precipitation (DAP) and adsorption technology (ion exchange resin or new technology) in a pilot-scale process.

The experiment was scaled up to test the concentrated latex process under factory conditions. A total of 1,000 kg of F-NRL were collected from a rubber tank at the factory and kept inside a bulk tank. Next, 30 g of F-NRL were collected from the bulk tank to test the properties that included total solid content (%TSC), ammonia (NH_3), magnesium content (Mg^{2+}), and volatile fatty acid (VFA). After that, the F-NRL was separated into two bulk tanks of 500 kg per tank. They were then adjusted with some chemicals and water in two conditions that consisted of DAP and ion exchange resin conditions**.**

For the DAP condition, NH_3 (2.8 kg), TMTD/ZnO (TZ) (600 g), water (109 kg), lauric acid (250 g), and DAP (8 kg) were added into the 500 kg of F-NRL. For the ion exchange resin condition, NH_3 (2.8 kg), TMTD/ZnO (TZ) (600 g), water (112 kg), lauric acid (250 g), and resin (5 kg) were added into the 500 kg of F-NRL.

After mixing the compositions, sampling the mixtures of the F-NRL from the two conditions was done to test for %TSC, NH_3, Mg^{2+}, VFA, and dry rubber content (%DRC). The DAP condition was allowed to rest one night and wait for centrifugation. The ion exchange resin condition was sampled and tested the same as the DAP condition but for the ion exchange resin condition, samples were collected every hour to test for the level of Mg^{2+} while stirring was performed in the bulk tank until the level of Mg^{2+} was lower than 50 ppm. Finally, the total volume of each bulk tank was processed by centrifugation and the volumes of concentrated latex sludge from the centrifuge machine of each condition were weighed.

4.4.2 To study the properties of waste resin and waste resin management

Waste resin was collected at the laboratory and dried at room temperature to test the properties of unusable material for the production of cement according to the management of waste resin in the Notification of the Ministry of Industry B.E. 2548 (2005); Appendix 4 the guideline and method for waste and unusable waste material management (Notification of the Ministry of Industry, 2005) at The Siam Cement (Thung Song) CO., LTD.

4.4.3 Calculating the economic cost

4.4.3.1 Comparative study of variable costs of production per unit between chemical precipitation (DAP) and adsorption technology (ion exchange resin or new technology) in a pilot-scale process.

The economic cost data in this study refer to the variable costs only (operation costs). Some variable costs were collected from the workers related to the concentrated latex process in the factory by observation, surveying, inquiries, and interviews.

Data were classified into four parts: the proportion of material, total variable cost, unit of production, and variable cost of production per unit to produce concentrated latex in a pilot-scale process. A comparison was done between chemical precipitation with diammonium phosphate (DAP) and adsorption technology (ion exchange resin).

The variable cost of production per unit can be calculated from this equation (Korsermsri, 2007).

$$\text{Variable cost of production per unit} = \frac{\text{Total variable cost of production}}{\text{Unit of production}}$$

4.5 Results and discussions

4.5.1 Properties of fresh natural rubber latex (F-NRL)

4.5.1.1 Properties of F-NRL under the conditions of chemical precipitation (DAP) and adsorption technology (ion exchange resin or new technology) in a pilot-scale process.

In the experiment, the properties of F-NRL before and after adjustment of some chemicals and water found that the %TSC values decreased from 39.69% (F-NRL) to 32.12% (F-NRL + DAP) and 31.49% (F-NRL + Resin) and the %DRC values decreased from 37.3% (F-NRL) to 30.1% (F-NRL + DAP) and 29.29% (F-NRL + Resin). The NH_3 values dropped gradually in the DAP condition and increased slightly in the resin condition, but the VFA values remained the same at 0.04.

The level of Mg^{2+} ions in the F-NRL in the two conditions decreased, but in the resin condition the level of Mg^{2+} ions dropped more rapidly than the DAP condition in a shorter period of time. The lower level of Mg^{2+} ions in the resin condition reduced the quantity of waste in the concentrated latex process. It can be seen that the new technology can reduce the amount of concentrated latex sludge compared with the chemical precipitation with DAP in the concentrated latex process.

The properties of the F-NRL and the quantity of concentrated latex sludge on the centrifuge machine are shown in Table 4.1 and Figure 4.1, respectively.

Table 4.1 Properties of fresh natural rubber latex in the experiment.

Parameters	F-NRL samples			%Mg reduction	
	F-NRL	F-NRL + DAP	F-NRL + Resin		
%TSC	39.69	32.12	31.49	DAP	Resin
%DRC	37.30	30.10	29.29		
NH_3	0.35	0.34	0.38		
VFA	0.04	0.04	0.04		
Mg^{2+} (ppm)	234.00	105.00	81.00**	55.12	65.38
		25.00*	73.00**	89.32	68.80
			60.00**		74.36
			56.00**		76.07
			51.00**		78.21
			32.00**		86.32

Note *rested for one 1 night

**tested every hour

A B

Figure 4.1 Concentrated latex sludge

A) Concentrated latex sludge from precipitate with DAP

B) Concentrated latex sludge from ion exchange resin

From the preliminary test results in the pilot–scale process, the quantity of concentrated waste latex sludge in the centrifuge machine following the ion exchange resin method was much less than the quantity of sludge following treatment with DAP. Normally, the volume of waste in the centrifuge machine is around 2 kg (Rubber Industry, n. d.), but in the new adsorption method the amount of waste produced was approximately 0.5 kg which represented a 75 percent decrease from the DAP method.

The new adsorption technology was able to reduce the amount of waste sludge from the concentrated latex process. When the volume of waste was low, it saved time, water and the number of man-hours in labor to clean the centrifuge machines, and it reduced the land area needed as a dumping site or sanitary landfill. In addition, the resin in this process can be reused more than one time.

Although this experiment was a preliminary test in a pilot-scale process at a factory under factory conditions, it is just an estimate of the trend of concentrated latex sludge and waste resin only. However, it can forecast the quantity of reduced waste after implementation of the new adsorption technology.

Normally, environmental problems in the concentrated latex industry include many issues such as effluent waste water, odors/vapors, noise, and solid waste (Danteravanich et al., 2002 and Roongtawanreongsri et al., 2005). However, in this research, the problem focused on the concentrated latex sludge as a solid waste.

This waste comes from the precipitation of Mg^{2+} ions primarily from the F-NRL with DAP. The amount of waste produced is approximately 1% of the F-NRL (Tekprasit, 2000). Most of the waste is disposed at a dumping site, landfill, or by outdoor burning. These methods are not suitable for disposal because they are the cause of air pollution due to malodors and the components of the liquid waste can leach into the soil and water sources.

Although the leachate is nontoxic, it can continue to increase in concentration. When the rain leaches the waste components from the waste into the natural water sources, it has an effect on the environment (Suksaroj et al., 2011). In fact, the correct method for disposal of this kind of waste is sanitary landfill (Rubber Industry, n. d.).

Although the waste includes important nutrients such as nitrogen (N), phosphorus (P) in the form of P_2O_5, potassium (K) in the form of K_2O, magnesium (Mg), zinc (Zn), and others

(Tekprasit, 2000) that are nutrients for plants and can be made into fertilizers, this waste consists of rubber content that contaminates the waste and in high quantities it can change the properties of the soil. The rubber content in the waste does not biodegrade easily and in the long term it can plug the soil surface or soil layer and reduce water adsorption in the soil (Danteravanich et al., 2005).

In addition, many researchers tried to reduce the waste from all procedures in concentrated latex processes. For example, they separated the rubber content from the waste with sulfuric acid and used this waste in agriculture and in making concrete. For example, the waste can be used to make fertilizer and can be used as an admixture for construction materials.

However, the research is mainly in the prototype stages and further development is needed with field installations in the industry. Therefore, the amount of waste has not yet been reduced. Although the industry tries to minimize the volume of waste, the amount of waste continues to increase each year.

Therefore, ion exchange resins which are a part of adsorption technology can be used to reduce the level of Mg^{2+} ions in F-NRL without producing concentrated latex sludge or waste during the magnesium separation process, minimize the quantity of waste at the centrifuge machine in the centrifugation process, and greatly reduce the odors. In addition, the properties of the F-NRL before and after the process of Mg^{2+} removal with this method did not change except for the levels of Mg^{2+} (CHAPTER 3).

4.5.2 The properties of waste resin and waste resin management

Although the new adsorption technology used resins that are thermoset materials and cannot be recycled in the latex process, the resin can be a useful waste product. The properties of the resin after removal of the Mg^{2+} ions from the F-NRL allow it to be used in the cement industry. The waste resins are shown in Figure 2. They can be used as an ingredient material and as a renewable fuel material in the cement production process (Tables 4.2 and 4.3)(The Siam Cement (Thung Song) CO., LTD, 2001).

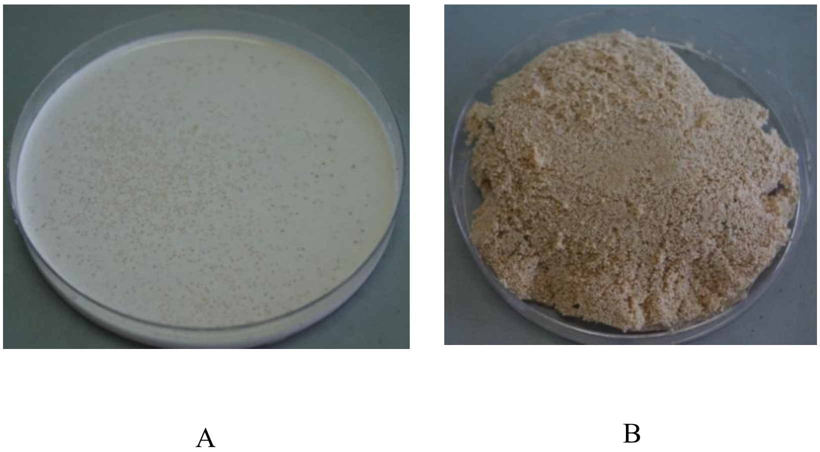

Figure 4.2 Waste resin

A) Wet waste resin

B) Dry waste resin

Table 4.2 Criteria of ingredient materials used in the cement production process.

Parameter	**Criteria**	**Results** **(Dry waste resin sample)**	**Unit**
SiO_2	-*	0.1318	%
Al_2O_3	-*	0.03813	%
Fe_2O_3	-*	0.05793	%
CaO	-*	0.1526	%
MgO	≤ 3.7	0.0469	%
SO_3	≤ 1.00	0.04488	%
Total Alkali Content, K_2O	≤ 1.25	0.1065	%

Notation -* Criteria not defined

The Siam Cement (Thung Song) CO., LTD, 2001.

The values of MgO, SO_3, total alkali content, and K_2O in the dry waste resin are lower than the standard criteria in the cement production process (Table 4.2). Although other values are not found in the criteria, all values are very low.

Table 4.3 Criteria of unusable materials used as a renewable fuel in the cement production process.

Parameter	Criteria	Results (Dry waste resin sample)	Unit
As	$\leq$ 10	ND*	%
Cd	$\leq$ 10	0.00023	%
Cr	$\leq$ 10	0.001	%
Cu	$\leq$ 10	0.00024	%
Pb	$\leq$ 10	0.00018	%
Hg	$\leq$ 10	0.0001	%
Ni	$\leq$ 10	0.00054	%
Sb	$\leq$ 10	0.0003	%
Tl	$\leq$ 10	ND*	%
V	$\leq$ 10	0.00217	%
Total Sb, As, Cr, Co, Cu, Mn, Ni, V	$\leq$ 10	0.00679	%
Cl	$\leq$ 6	0.0271	%

Note - *Not detected

The Siam Cement (Thung Song) CO., LTD, 2001.

Table 4.4 Other criteria of unusable materials used in the cement production process.

Parameter	**Criteria**	**Results** **(Dry waste resin sample)**	**Unit**
Na	-*	0.1816	%
P	-*	0.1561	%
Mn	-*	0.00229	%
Co	-*	0.00025	%
Zn	-*	0.03511	%
Ga	-*	ND**	%
Ge	-*	ND**	%
Se	-*	ND**	%
Br	-*	ND**	%
Rb	-*	0.00052	%
Sr	-*	0.00027	%
Y	-*	0.00043	%
Zr	-*	0.00013	%
Nb	-*	0.00014	%
Mo	-*	0.00067	%
Ag	-*	0.0002	%
Sn	-*	0.00177	%
Te	-*	0.0003	%
I	-*	0.0003	%
Cs	-*	0.0004	%
Ba	-*	0.00053	%
La	-*	0.0002	%

Note - [*]criteria not defined

[**]not detected

The Siam Cement (Thung Song) CO., LTD, 2001.

The results of all the tables show that the values of the waste resin components are within the criteria and can be used in co-incineration in the cement kiln for the cement production process. The waste resins can be disposed in the same way as saturated ion exchange resins used in the preparation of drinking water or in the treatment of industrial waste at water treatment plants that dispose the resins in co-incineration in a cement kiln according to Notification of the Ministry of Industry B.E. 2548 (2005); Appendix 4 the guideline and method for waste and unusable waste material management (Notification of the Ministry of Industry, 2005).

4.5.3 The economic cost

4.5.3.1 The variable costs of production per unit in concentrated latex process with DAP and ion exchange resin in a pilot-scale process.

Normally, the data and information in a factory that are used to calculate the costs and benefits are confidential. In this case, limited amounts of data were permitted by the factory for use in this research only.

The records of the factory were used to estimate the variable costs of production per unit for this research only (Tables 5 and 6). The price per unit of fresh natural rubber latex and concentrated latex was taken from The Central Rubber Market years 1991–present (2015), Monthly Rubber Average Price 2014 for fresh latex, and the F.O.B Noon Price years 1997–present (2015) for concentrated latex from Rubber Research Institute of Thailand and the Office of the Rubber Replanting Aid Fund. In addition, the total price of fresh natural rubber latex was calculated from a DRC of 30%.

The chemical costs were market price that the factory paid beforehand for use in the process. Moreover, the cost of water usage can be calculated from the cost of electricity to pump water from groundwater. The cost of electricity for the concentrated latex process was taken as the quantity of electricity used for the centrifuge machines and concentrated latex centrifuge process only. The cost of labor considered only the employees who worked in the centrifuge process. All of the costs were the total variable costs of production used to calculate the variable cost of production per unit.

Finally, the total concentrated latex price is the revenue from the finished product. The quantity of concentrated latex is the final product of concentrated latex process that was taken as the unit of production which was used to calculate the variable cost of production per unit in this research.

Thus, the total variable cost and unit of production were used to calculate the variable cost of production per unit in concentrated latex process between chemical precipitation (DAP) and adsorption technology (ion exchange resin).

In addition, the variable cost of production per unit in this work was calculated by using the cost of materials in proportion to the pilot-scale process only. These proportions were reduced to suit the testing in the pilot-scale at the factory and were used to calculate the economic costs (Tables 4.5 and 4.6).

The results of the economic costs in Table 4.5 shows the proportions of materials, total variable costs, unit of production, and the variable cost of the production per unit of concentrated latex process with chemical precipitation (DAP). The proportions were decreased for use in the pilot-scale process and do not represent the actual conditions due to the confidentiality of the true factory conditions.

Generally, the variable cost of production per unit of concentrated latex process is calculated with one ton or one thousand kilograms of concentrated latex. But, in this research the proportions were decreased to suit the pilot-scale process. So, the variable cost of production per unit of concentrated latex process value is a primary cost that was evaluated from the experiment only.

The results found that the total variable cost to process 500 kg (DRC 30%) of fresh natural rubber latex was 8,830.05 baht that consisted of fresh latex natural rubber, chemicals, electricity, and the cost of labor to produce 242.59 kg (unit of production) of concentrated latex (DRC 60%) and the revenue was 10,761.29 baht. For chemical precipitation with DAP in the concentrated latex process the variable cost of production per unit was 36.40 baht.

Table 4.5[*] Variable costs of production per unit of concentrated latex process in chemical precipitation (DAP).

Description	Quantity (kg)	Price per unit (Baht)	Total (Baht)	Cost per unit (Baht)
1. Fresh latex (DRC 30%)	500.00	55.25[**]	8,287.50	
2. NH_3	2.80	29.00	81.00	
3. TMTD/ZnO	0.60	144.00	86.00	
4. Lauric acid	0.25	55.00	14.00	
5. DAP	8.00	38.00	304.00	
6. Water (calculated from electricity usage)	109.00		1.09	
7. Electricity, centrifuge + process			29.50	
8. Labor 20 persons			26.61	
Total variable cost			8,830.05	
Concentrated latex (DRC 60%)	242.59[****]	44.36[***]	10,761.29	36.40

Note [*] Refer to all data were adapted and applied from a factory that were used for calculated in pilot scale process in this experiment only

[**] Refer to Rubber Research Institute of Thailand, local price of unsmoked sheet, rubber scrap 100% and fresh field (factory, Songkhla, 2014), The central Rubber Market year 1991 (B.E.2534) - present (2015) and Thailand Monthly Rubber Average Price, 2014, Office of the Rubber Replanting Aid Fund.

[***] Refer to Rubber Research Institute of Thailand, F.O.B Noon Price year 1997 (B.E. 2543) – present (2015), Songkhla, 2014.

[****] Unit of production

Table 4.6[*] Variable costs of production per unit of concentrated latex process in adsorption technology (ion exchange resin).

Description	Quantity (kg)	Price per unit (Baht)	Total (Baht)	Cost per unit (Baht)
1. Fresh latex (DRC 30%)	500.00	55.25[**]	8,287.50	
2. NH_3	2.80	29.00	81.00	
3. TMTD/ZnO	0.60	144.00	86.00	
4. Lauric acid	0.25	55.00	14.00	
5. Resin	5.00	850.00	4,250.00	
6. Water (calculated from electricity use)	112.00		1.09	
7. Electricity, centrifuge + process			29.50	
8. Labor 20 person			26.61	
Total variable cost			12,776.05	
Concentrated latex (DRC 60%)	242.59[****]	44.36[***]	10,761.29	52.61

Note [*] Refer to all data were adapted and applied from a factory that were used for calculated in pilot scale process in this experiment only

[*] Refer to Rubber Research Institute of Thailand, local price of unsmoked sheet, rubber scrap 100% and fresh field (factory, Songkhla, 2014), The central Rubber Market year 1991 (B.E.2534) - present (2015) and Thailand Monthly Rubber Average Price, 2014, Office of the Rubber Replanting Aid Fund.

[**] Refer to Rubber Research Institute of Thailand, F.O.B Noon Price year 1997 (B.E. 2543) – present (2015), Songkhla, 2014.

[***] Unit of production

Table 4.6 shows the proportions of materials, total variable cost, unit of production, and variable cost production per unit of concentrated latex with adsorption technology (ion exchange resin). The proportions were the same as the DAP condition except the material to remove the magnesium ions was the resin instead of DAP.

The results found that the total variable cost to process 500 kg (DRC 30%) of fresh natural rubber latex was 12,776.05 baht to produce 242.59 kg (unit of production) of concentrated latex (DRC 60%) and the revenue was 10,761.29 baht. For the new method the variable cost of production per unit was around 52.61 baht. This cost is higher than DAP because the price per unit of resin is high even though the amount of resin used was low.

But, in this research the resin could be reused more than one time up to around 6 times (refer to a gravity flow filter tank in CHAPTER 3). So, when the resin is reused the total variable cost decreased to around 9,234.38 baht which reduced the variable cost of production per unit to 38.07 baht which is a drop of 14.54 baht. Thus, when the resin is reused the variable cost of production per unit is 38.07 baht which is only a little higher than the variable cost of production per unit for DAP which is 36.40 baht.

In addition, the cost of concentrated latex sludge or waste disposal from the survey found that the cost of waste disposal of the concentrated latex sludge in the DAP condition was 0.50 baht/kg for waste taken to a dumping site or sanitary landfill within the grounds of the factory (Num Hua Rubber Company Limited, 2014).

In the case of waste resin, the waste disposal cost was 1.2 baht/kg for incineration in the cement production process, but this cost does not cover the cost of transportation for transfer to the cement plant (The Siam Cement (Thung Song) CO., LTD, 2001).

Although the waste resin disposal cost is higher than concentrated latex sludge disposal cost, but it can be reused or recycled by mixed with other materials as renewable fuel in a co-incineration cement kiln in the cement production process according to the Notification of the Ministry of Industry B.E. 2548 (2005).

The waste resin is transferred to the cement plant and used as a raw material in a new procedure that can be called waste exchange process. Waste exchange refers to the waste product of one process which becomes the raw material for a second process. This is like using pre-consumer recycling material in a product. This method is a way of minimizing waste disposal and recycling a waste product (Waste exchange, n. d.).

Although the variable cost of production per unit of concentrated latex of ion exchange resin is higher than chemical precipitation with DAP, this cost can decrease when the resin is used more than one time. Another consideration is the cost of waste resin disposal which is higher than DAP due to the cost of waste management in a co-incineration cement kiln which has a high cost of operation.

On the other hand, the ion exchange resin can reduce the amount of concentrated latex sludge or waste compared with DAP, especially the volume of waste at the centrifuge machine. Moreover, the waste resin from this method can be used as new raw material in the cement production process and can minimize the materials needed for use in the cement plant.

4.6 Conclusion

The adsorption technology (ion exchange resin) or new technology can be used in the concentrated latex process. This method reduces the level of Mg^{2+} ions in the F-NRL and does not change the properties of F-NRL except for the reduction of Mg^{2+} ions. The new technology also reduces the quantity of concentrated latex sludge in the concentrated latex process. Compared with chemical precipitation with DAP, the new technology can minimize the quantity of waste at the centrifuge machine in the process which results in a reduction in the volume of concentrated latex sludge, malodors, waste water, and the land area used as dumping sites or sanitary landfills that impact the environment. In addition, this method can save time, the number of laborers, and water to clean the centrifuge machine. Moreover, the waste resin can be used as a new raw material in a co-incineration cement kiln in the cement production process. However, the adsorption technology has a high cost for operations and waste disposal.

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CHAPTER 5

General Discussions

This part presents an overall discussion for each part of the thesis. The discussions include CHAPTERS 2 through 4 that are related to the reduction of magnesium content in fresh natural rubber by ion exchange resin. The discussions cover the issues of agriculture, industry, economics, environment, and management.

Normally, in rubber cultivation, most researchers try to develop or improve the production to increase the income. But some research affects the environment. In this case (CHAPTER 2), the rubber plantation used new technology to improve rubber productivity with chemical stimulation in mature rubber trees with ethylene gas stimulation tapping.

Some researchers found positive results using ethylene gas or ethephon that is a stimulant in the liquid state that releases et hylene gas in mature rubber trees to increase rubber production or rubber yield and extend the tapping period (Gidrol et al., 1988, Barlow, 1978, Silpi et al., 2006, Coucaud et al., 2009, Lacote et al., 2010, and Doungmusik, 2013). The ethylene gas increased the duration of latex flow after tapping by delaying the plugging of latex vessels (Jetro and Simon, 2007 refer to Wenxian et al., 1986), activating the latex cell metabolism (Jetro and Simon, 2007, Lacote et al., 2010 refer to Lustinec et al., 1965; Buttery and Boatman, 1967; Pakianathan et al., 1976; Jacob et al., 1989; D’Auzac et al., 1997, and Traoré et al., 2011), improving latex stability (Coupé and Chrestin, 1989 refer to Boatman n. d.), increasing the volume of exported latex, and stimulating latex regeneration during the tapping (Renaud et al., 1994 refer to Coupé and Chrestin, 1989). The ethylene gas can move the water molecules from the surrounding cells into the synthesis cells for latex synthesis and the latex can flow for a longer time (Zhu et al., 2009 and Doungmusik, 2013) and accelerate the movement of sucrose which is a substance for latex synthesis. The cells can produce rubber particles rapidly after the particles are lost (Doungmusik, 2013 refer to Renaud et al., 2009).

However, the dry rubber content (DRC) is low after the use of ethylene gas for tapping (Paechana, 2001, Sdoodee et al., 2010 and Doungmusik, 2013). Moreover, the DRC decreased after ethylene gas was used in tapping young rubber trees (Sainoi et al., 2012) and the DRC was reduced in fresh natural rubber latex from young rubber trees that used 2.5% ethephon (Barlow, 1978, Phakagrong, 2010 and Paechana et al., n. d.). In addition, the dry rubber content is related to latex viscosity (Coupé and Chrestin, 1989).

This study found that the total solids content (TSC) decreased, but the values were within the normal range. Although the TSC values of the latex from ethylene gas tapping were lower than the control tapping, these values were similar to stimulation and latex rheology theory which gave low TSC values of the latex after tapping (Coupé and Chrestin, 1989 and Tungngoen et al., 2011 refer to Tjasadihardja and Kardjono, 1974; Coupé and Chrestin, 1989).

On the other hand, in this study the magnesium content tended to be very high. In contrast with a study by Yip and Chin (1977), the effect of treatment with yield stimulants on the distribution of K^{2+}, Ca^{2+}, and Mg^{2+} in cytosolic serum (C-serum) and lutoid serum (B-serum) found that the levels of Ca^{2+} and Mg^{2+} decreased and there was a slight increase in K^{2+} in the B-serum. Stimulation using ethephon released ethylene which decreased the calcium and magnesium concentrations in B-serum that supports the extended flow. The decreased calcium and magnesium in the latex might reduce to some extent the destabilizing activity that the B-serum has on the rubber particles in the course of plugging. The latex yield increased due to a decrease of calcium and magnesium in the B-serum after stimulation (Phakagrong, 2010 refer to Yip and Chin, 1977).

In the same way, the coagulation of latex by lutoids may be explained by the liberation of protons, divalent cations, and positively charged proteins, all of which contribute to the destabilization of the negative colloidal suspension, which is the latex (Coupé and Chrestin, 1989 refer to Yip and Southorn, 1968). In addition, the latex from stimulated trees coagulated less rapidly than latex from the unstimulated control trees (Coupé and Chrestin, 1989).

Although the ethylene decreased the calcium and magnesium content in the fresh natural rubber latex that used ethylene gas stimulation tapping, the very high values of magnesium content in this study may be explained by other factors such as the discharge of Mg^{2+} ions from lutoid swelling and bursting when in contact with the oxygen in the air outside the rubber tree. When lutoids are ruptured by tapping and preservation, the lutoid particles release magnesium ions into the serum. The lutoid membrane bursts by the mechanical force during tapping. The cations (Mg^{2+}) in the lutoid can distribute to the outside and catch the anions which surround the rubber particle and cause the rubber particle to coagulate. The coagulation can occur in fresh natural rubber latex quickly or slowly and depends on the clone, tapping system, temperature, and chemicals. (Chantuma, 2001 and Doungmusik, 2013); for example, a rubber clone that is unsuitable to produce concentrated latex is RRIM 600 (Barlow, 1978).

Moreover, ethylene increased water absorption from the surrounding cells into the xylem (Doungmusik, 2013) which possibly moved the magnesium ions in the water, fertilizers, and nutrients from the soil for latex synthesis. Likewise, Kungpisdan et al. (2004), who studied the response of Para rubber after tapping (unstimulated) by adding a nitrogen, potassium, and magnesium fertilizer in rubber clone GT1, found that adding the nitrogen, potassium, and magnesium fertilizer increased the magnesium in the latex.

In addition, Chaiprapat et al (2009) studied the effect of the soil on the level of magnesium in latex and found that the magnesium was high in fresh natural rubber latex from five rubber plantations just after tapping (unstimulated). Afterward the tapping was stopped while the rubber trees shed their leaves and that maybe fertilizer was added to accelerate the leaves in the latex synthesis; the magnesium levels were high (250-570 ppm). In Thailand, the magnesium in fresh natural rubber latex is in the range of 100-1,000 ppm (Rubber Research Institute of Thailand, 1989). However, the results of magnesium in the soil are in contrast to the magnesium in the latex; five areas had low and medium magnesium values that were in the range of 0.8-1.1 cmol (+)/kg which is in the standard range of 0.3-1.0 cmol (+)/kg for low and 1.0-3.0 cmol (+)/kg for medium. Moreover, the five areas did not add magnesium in the fertilizer mixtures.

Although both normal tapping and ethylene gas tapping affect the TSC directly, in this case the magnesium level cannot specifically identify the source and mechanism to produce magnesium in rubber trees because there are many variable factors and only some mechanisms can be described. So, studies are needed on the mechanism of magnesium in rubber trees and more focus should be placed on the physiology, biochemical, and rheology that affect the rubber tree and the environment since the Mg^{2+} ions in fresh natural rubber latex are the cause of concentrated latex sludge or waste in the concentrated latex industry and the Mg^{2+} ions have an effect on the quality of the latex.

Overall, all tapping systems (normal and ethylene gas tapping) affect the quality of the latex. The quality of the latex varies due to many factors, especially the metal ion content (magnesium) is affected by the tapping system, cultivar, soil type, and fertilizer treatment (Webster and Baulkwill, 1989).

In fact, most research aimed to increase the latex yield in the rubber plantations, but some research created other problems in the industrial end, especially the issue of magnesium in fresh natural rubber latex that affects the quantity of concentrated latex sludge or waste and the quality of fresh natural rubber latex before and after centrifugation in the concentrated latex process.

Normally, magnesium exists in nature in elemental form and in compound substances. It is impossible and undesirable to destroy or dispose of magnesium in rubber trees because magnesium is necessary for photosynthesis, growth, and it improves the volume of latex in rubber trees (Sungwatin, 2008).

So, in natural cultivation the quantity of magnesium in rubber trees cannot be controlled directly because the quantity of magnesium varies in each area. The factors that cause the level of magnesium to fluctuate in fresh natural rubber latex depend on the soil type, water, temperature, clone of rubber, fertilizer, and especially the technology to improve the volume of latex. Therefore, fresh natural rubber latex collected from many different rubber plantations is different in quality, especially in magnesium content.

When the fresh natural rubber latex is collected and transferred to a factory, the factory needs to measure the properties of the latex, especially the magnesium content, for quality control before it goes to the concentrated latex process. If the fresh natural rubber latex has high magnesium content, the factory needs to add much diammonium phosphate (DAP) to precipitate the magnesium out of the fresh natural rubber latex. This reaction creates a high volume of waste. In this case, waste refers to the concentrated latex sludge or waste in the centrifuge.

Nowadays, the concentrated latex sludge or waste is a problem that is not solved properly in most factories. Most factories continue to dump the waste on the ground or burn it outdoors. Some factories move the waste to landfills inside the perimeter of the factory area. So, to solve this problem, this research used the ion exchange resin to reduce the level of magnesium ions in fresh natural rubber latex to minimize the waste in the concentrated latex process since the magnesium ions are the cause of the waste in this process.

The ion exchange resin is a part of adsorption technology to separate the Mg^{2+} ions from the fresh natural rubber latex (CHAPTERS 3-4). Most researchers use adsorption technology to measure the reduction of Mg^{2+} ions in water or in other aqueous solutions to analyze the adsorption performance, the sorption percentage or adsorption behavior of metals on the ion exchange resin. In this study, the reduction of Mg^{2+} ions was measured by titration with the EDTA method. This method is suitable and proper for use in the concentrated latex process for the conditions at a real factory.

The experiments (CHAPTERS 3-4) found that the ion exchange resin could reduce the level of Mg^{2+} ions in fresh natural rubber latex to less than 100 ppm and the ion exchange resin method was able to minimize the quantity of concentrated latex sludge or waste in the concentrated latex process. The exchanger material adsorbs and exchanges the magnesium ions in fresh natural rubber latex while stirring an immersion of resin in the fresh natural rubber latex or while passing the fresh natural rubber latex through the resin with pressure or gravity flow.

The experiments found that the properties of fresh natural rubber latex before and after removal of the magnesium did not change except for the level of Mg^{2+} ions. In addition, it did not produce concentrated latex sludge or waste during the production process (Abdelwahab et al., 2013).

Therefore, the ion exchange resin or new technology can be used in the concentrated latex process to reduce the level of magnesium ions in fresh natural rubber latex, minimize the amount of waste on centrifuge machine in the centrifugation process, and the resin can be reused more than one time. Although the amount of waste in the centrifugation process decreased, this method produced a new waste which was the waste resin. However, it can be disposed in the form of a new raw material for co-incineration in a cement kiln instead of disposal in a sanitary landfill, dumping site or by outdoor burning which are sources of pollution. The waste resin is a material exchanger or new raw material that is used in other production processes. The method is called waste exchange.

However, the new technology has a high per unit cost because the resin is more expensive than DAP even though low quantities of the resin can be used. When comparing the operation cost in the form of variable cost in the process of production per unit of concentrated latex in this study, the variable cost of adsorption technology (ion exchange resin) was found to be higher than chemical precipitation with DAP.

Moreover, the resins need to be used with specific equipment in the concentrated latex process. The equipment has a petty patent and/or patent cost and maintenance costs which result in a higher operation cost and waste disposal cost.

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CHAPTER 6

General Conclusions

This part is the conclusion of the thesis that is included in CHAPTERS 2 through 4 that describe the reduction of magnesium content in fresh natural rubber by ion exchange resin.

In this research, for the agriculture section, the difference of tapping methods for mature rubber trees has an effect on the quality of fresh natural rubber latex (F-NRL) especially the quantity of magnesium content from the ethylene gas tapping method. The F-NRL from this method was higher in magnesium content than in the normal tapping method and it led to increased amounts of concentrated latex sludge or waste at the factory.

Although the magnesium content is not a major concern for improved latex yield in the rubber plantation, it is very important in the concentrated latex industry since the magnesium is a cause of waste in the concentrated latex process. When this waste is disposed by an incorrect method, such as outdoor burning or dumping site, it creates pollution in the environment in the long m.

The waste should be controlled and/or the quantity of magnesium in the form of magnesium ions (Mg^{2+}) should be decreased in the F-NRL from different tapping methods at the source in the rubber plantations. Alternately, the level of Mg^{2+} ions in the F-NRL should be reduced before transfer in the production of concentrated latex in the factory.

In this case, the Mg^{2+} ions in the F-NRL can be minimized with ion exchange resin. The ion exchange resin is a part of adsorption technology. It can be used for the removal of Mg^{2+} ions in the F-NRL in the concentrated latex process.

This method reduced the concentration of Mg^{2+} ions in the F-NRL to less than 100 ppm after immersion, immersion with stirring, passing through a syringe pump, a gravity column test or a gravity flow filter tank.

In addition, the physical size of the particles of F-NRL and resin beads and the properties of the F-NRL did not change after treatment with either resin or regenerated resin. However, the surface of the resin was found to be covered with rubber. Moreover, there was no sludge or waste during the separation process of removing the magnesium and the performance of the resin increased after regeneration with HCl and NaOH which demonstrated that the resin can be reused to reduce the Mg^{2+} ions in the F-NRL more than one time.

Although this method has a high cost for operations and waste disposal, it can reduce the quantity of the Mg^{2+} ions in the F-NRL that causes concentrated latex sludge or waste in the concentrated latex process and minimize the volume of waste at the centrifuge machine in the centrifugation process more than chemical precipitation with DAP. This method can also save time, water, and labor to clean the centrifuge machine and reduce the land area needed for either a dumping site or sanitary landfill.

In addition, the waste resin from this method is a waste exchanger that can be used as a new raw material in a co-incineration cement kiln and it can reduce the amount of raw material needed in the cement production process.

Therefore, it is possible to use adsorption technology with ion exchange resin to remove Mg^{2+} ions and improve the quality of the F-NRL.

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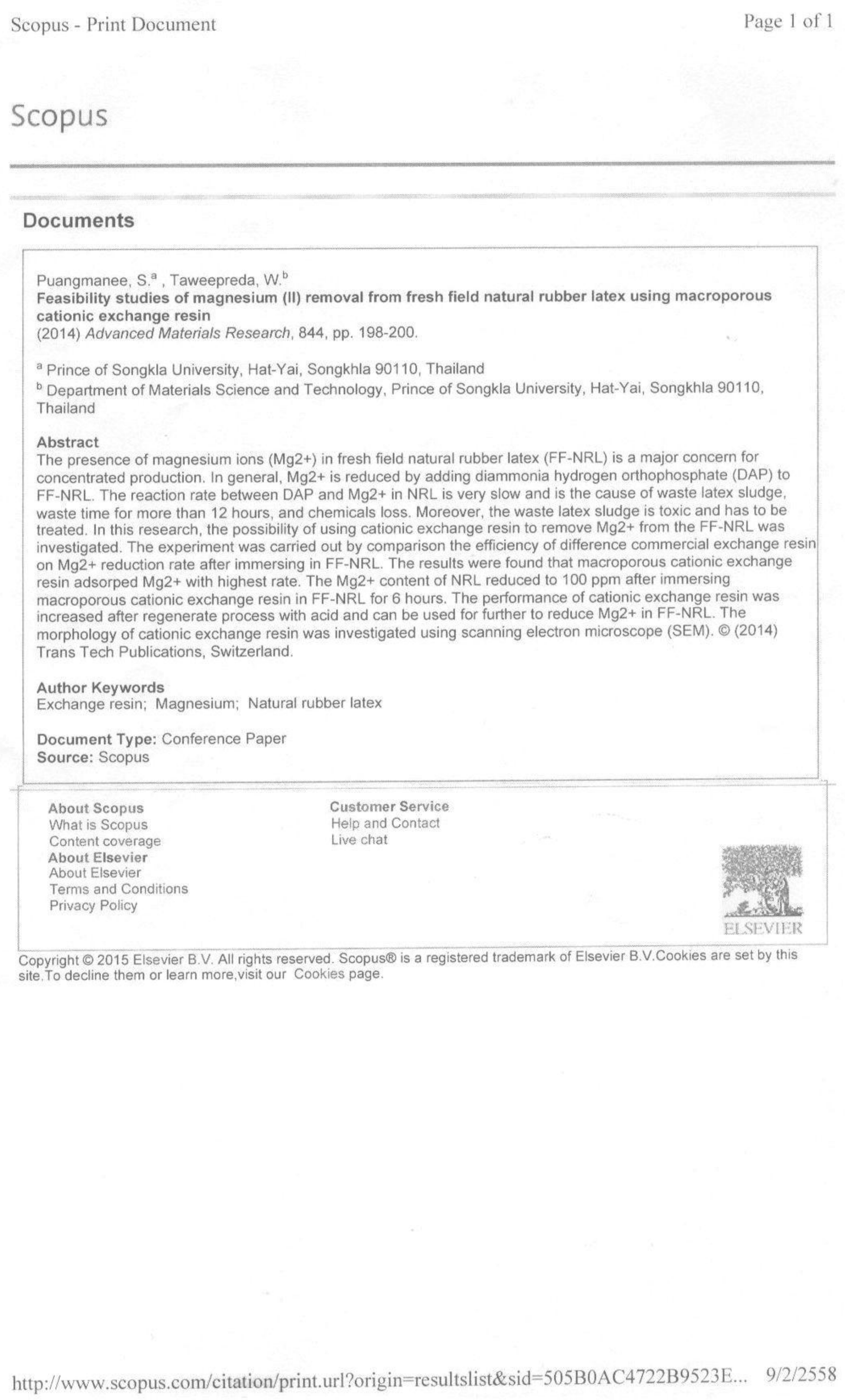
Appendix A

Publication and proceeding

Reprint



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Documents

Puangmanee, S.[a] , Taweepreda, W.[b]

Feasibility studies of magnesium (II) removal from fresh field natural rubber latex using macroporous cationic exchange resin

(2014) *Advanced Materials Research*, 844, pp. 198-200.

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Abstract

The presence of magnesium ions (Mg2+) in fresh field natural rubber latex (FF-NRL) is a major concern for concentrated production. In general, Mg2+ is reduced by adding diammonia hydrogen orthophosphate (DAP) to FF-NRL. The reaction rate between DAP and Mg2+ in NRL is very slow and is the cause of waste latex sludge, waste time for more than 12 hours, and chemicals loss. Moreover, the waste latex sludge is toxic and has to be treated. In this research, the possibility of using cationic exchange resin to remove Mg2+ from the FF-NRL was investigated. The experiment was carried out by comparison the efficiency of difference commercial exchange resin on Mg2+ reduction rate after immersing in FF-NRL. The results were found that macroporous cationic exchange resin adsorped Mg2+ with highest rate. The Mg2+ content of NRL reduced to 100 ppm after immersing macroporous cationic exchange resin in FF-NRL for 6 hours. The performance of cationic exchange resin was increased after regenerate process with acid and can be used for further to reduce Mg2+ in FF-NRL. The morphology of cationic exchange resin was investigated using scanning electron microscope (SEM). © (2014) Trans Tech Publications, Switzerland.

Author Keywords
Exchange resin; Magnesium; Natural rubber latex

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FEASIBILITY STUDIES OF MAGNESIUM (II) REMOVAL FROM FRESH FIELD NATURAL RUBBER LATEX USING MACROPOROUS CATIONIC EXCHANGE RESIN

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Keywords: natural rubber latex, magnesium, exchange resin

Abstract. The presence of magnesium ions (Mg^{2+}) in fresh field natural rubber latex (FF-NRL) is a major concern for concentrated production. In general, Mg^{2+} is reduced by adding diammonia hydrogen orthophosphate (DAP) to FF-NRL. The reaction rate between DAP and Mg^{2+} in NRL is very slow and is the cause of waste latex sludge, waste time for more than 12 hours, and chemicals loss. Moreover, the waste latex sludge is toxic and has to be treated. In this research, the possibility of using cationic exchange resin to remove Mg^{2+} from the FF-NRL was investigated. The experiment was carried out by comparison the efficiency of difference commercial exchange resin on Mg^{2+} reduction rate after immersing in FF-NRL. The results were found that macroporous cationic exchange resin adsorped Mg^{2+} with highest rate. The Mg^{2+} content of NRL reduced to 100 ppm after immersing macroporous cationic exchange resin in FF-NRL for 6 hours. The performance of cationic exchange resin was increased after regenerate process with acid and can be used for further to reduce Mg^{2+} in FF-NRL. The morphology of cationic exchange resin was investigated using scanning electron microscope (SEM).

Introduction

Natural rubber latex (NRL) contains magnesium ions (Mg^{2+}), which is interrupt the centrifugation process and the quality of concentrated latex. The presence of Mg^{2+} in FF-NRL has been found out to be the major cause of destabilization of natural rubber (NR) latex. Therefore, it is necessary to remove Mg^{2+} from NRL by adding diammonium hydrogen phosphate (DAHP). The reaction of DAHP with Mg^{2+} results in waste solid sludge which is not easily decomposed in soils and leads to pollution. Ion exchange resins are thermoset polymeric materials manufactured using suspension polymerisation from styrene and divinylbenzene (DVB). Cationic exchange resins are well suited for removal positively charged from in water such as calcium and magnesium. This paper revealed with Mg^{2+} removal from fresh field natural rubber latex (FF-NRL) using cationic exchange resin. FF-NRL was characterized before and after Mg^{2+} removal.

Experimental Procedure

FF-NRL was collected from the field. The preservatives had been added in the bulking tanks. Total solid content (TSC) and dry rubber content (DRC), determined according to ISO126. The VFA number and magnesium contents were investigated for the FF-NRL according to the procedure in ISO standard 506-1992 and DIS 17403, respectively. The macroporous cationic resins are polymer bead with diameter 0.5 mm as illustrated in figure 1 was purchased from Behn Meyer Chemical (T) Co., Ltd. The resins 200 grams was immersing in 2 kg FF-NRL for 6 hours after that the resins were removed by filtration. The resins were immersed again in new batch of FF-NRL. FF-NRL after Mg^{2+} removal were characterized for TSC, DRC, VFA number, and Mg^{2+} content.

Figure 1. Macroporous cationic exchange resin

Results and Discussion

The macroporous cationic resin after immersing in FF-NRL was found the rubber covered the resin bead as illustrated in figure 2 resulting in the decay of resin performance in Mg^{2+} removal from FF-NRL as shown in figure 3. The Mg^{2+} was removed from FF-NRL by adsorption process which is depended on surface area of resin. The amount of Mg^{2+} reduction was decreased is not only the performance of resin decay but also the covered rubber on resin surface. This resins need to be cleaned and regenerated with acid after Mg^{2+} removal for more than 8 times.

The properties of FF-NRL before and after the process of Mg^{2+} removal with resin were not changed except Mg^{2+} contents as illustrated in table 1 and table 2, respectively.

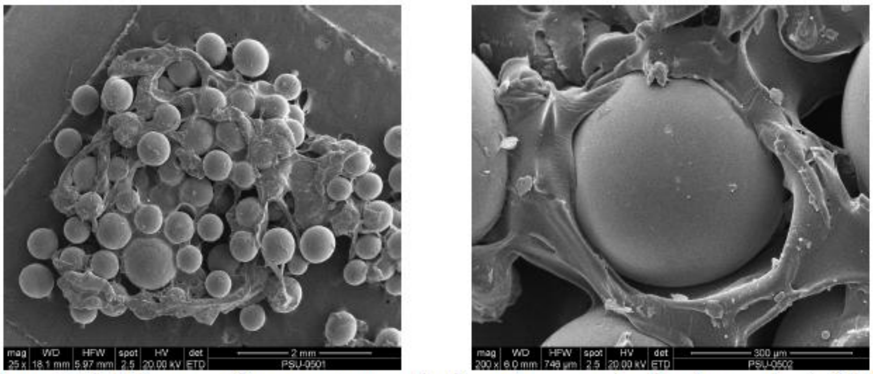

Figure 2. SEM images of macroporous cationic exchange resin after immersing in NRL

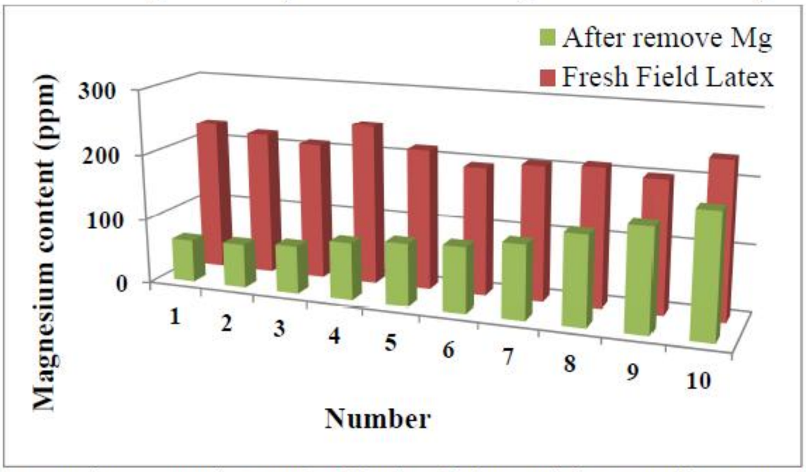

Figure 3. Magnesium content in natural rubber laex before and after removing magnesium using resin

Table 1 Properties of fresh field natural rubber latex

Parameters	Sample batch									
	1	2	3	4	5	6	7	8	9	10
%TSC	37	38	36	35	37	38	37	37	35	34
%DRC	36	36	35	33	35	37	35	36	34	33
VFA number	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Magnesium (ppm)	230	220	210	245	215	195	205	210	200	235

Table 2 Properties of natural rubber latex after removing magnesium using resin

Parameters	Sample batch									
	1	2	3	4	5	6	7	8	9	10
%TSC	37	38	36	35	37	38	37	37	35	34
%DRC	36	37	35	34	36	37	36	36	34	33
VFA number	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Magnesium (ppm)	65	67	73	87	95	99	112	135	155	185

Conclusions

The macroporous cationic exchange resin adsorped Mg^{2+} with high rate resulting in Mg^{2+} content of FF-NRL reduced to 100 ppm after immersing for 6 hours. The performance of the resin reduced with higher amount of NRL and covered rubber on the resin surface. The performance of the resin was increased after regenerate process with acid and can be used for reduction Mg^{2+} content in FF-NRL. It is possible to use adsorption process with macroporous cationic exchange resin to remove Mg^{2+} and improved FF-NRL quality.

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Effect of Tapping Method on Natural Rubber latex Consistency

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Abstract

The quality of latex is important for rubber product, especially, the latex from the tapping process that includes normal tapping and tapping systems that use stimulants. Tapping systems that use stimulants are used to increase the volume of latex from rubber trees. Normally, the latex from the field is tested for many properties before produced as a product at a factory, but for commercial purposes, the cultivators and shops use only the dry rubber content (%DRC) to calculate the price. At the time of tapping and latex collection the level of magnesium can not be determined. However, it is the magnesium which has an effect on the environment. Therefore, the aim of this research is to investigate the magnesium content and total solid content (%TSC) of the latex from normal tapping and ethylene gas tapping methods at the Thepa Research Station in Songkhla Province, Thailand. It was designed as one - tree plot design with 4 tapping methods : T1 was a control without ethylene stimulation while in T2, T3, and T4 ethylene stimulation was applied using the RRIMFLOW, Double Tex, and LET systems, respectively. The results showed that the %TSC in latex from 4 tapping methods were within the normal criteria. Although the average %TSC from the control tapping (T1) was the highest, the %TSC from the ethylene gas tapping in T2, T3, and T4 were lower values. Especially, the average %TSC value of T2 was the lowest in every time. In addition, the quantity of magnesium was high, especially the latex from the ethylene gas tapping in T2, T3, and T4 methods. T2 had the highest value. The T3 and T4 methods were high in magnesium content but varied all the time because sometimes the gas leaked out from the equipment and the injection into bask was not complete. Although the level of magnesium of the control tapping (T1) was high, it was lower than the ethylene gas tapping systems. The latex from the ethylene gas tapping systems was high in magnesium and it led to increased waste in factory and affected the environment over the long term.

Keywords: tapping method, natural rubber latex, ethylene stimulation

1. Introduction

Nowadays, there is an increased demand for natural rubber latex in the rubber industry but the quantity of latex is not enough although the government tries to extend the areas for rubber tree (*Hevea Brasiliensis*) plantations. There are also environmental factors such as global warming and seasonal changes that affect latex production and the cultivators are unable to tap rubber or the tapping is less than normal [3]. These problems affect the quantity of latex produced in the rubber industry. Generally, natural rubber latex production is produced by tapping and with the use of stimulants. The tapping consists of removing a layer of bark in the form of a spiral on the trunk of the tree. The latex is collected and treated to get natural rubber. Ethylene is used as a stimulant to generate chemical substances to increase the productivity from the trees [5]. Ethylene gas stimulation is an attempt to improve the volume of latex that is susceptible to global warming and seasonal changes. In this research, 'stimulant' refers to ethylene gas stimulation.

Ethylene as a stimulant for latex production in *Hevea Brasiliensis* has been used widely in commercial latex production. However, the mechanism of the action of ethylene was not completely elucidated, especially at the in molecular level [10]. In rubber trees, ethylene increased the duration of latex flow after tapping and activated the latex cell metabolism [9] reduced tapping frequency, and increased land and labor productivity [8]. In addition, ethylene reacted at the inner bark and increased the pressure. The internal pressure within the system of latex vessels increased and the pressure of the surrounding tissue on the latex cells increased [1]. Also the elasticity of the laticiferous cells was affected and the coagulation of the latex decreased [8].

The latex from each tapping needs to be thoroughly analyzed. For example, total solids content (%TSC), sucrose content, inorganic phosphorus, and pi and thiol content [2] are measured to determine the quality and suitable tapping methods. After that, the main characteristics of the manufactured product are tested for dry rubber content (%DRC), %TSC, volatile fatty acid number (VFA), mechanical stability (MST), and others. Although, some properties are not major considerations for initial testing, they do affect the manufacturing and environment after the finished process. Therefore, the aims of this research were to investigate the effects of the tapping methods on the natural rubber latex and especially the magnesium content and %TSC from rubber trees that used normal tapping and ethylene gas tapping.

2. Materials and Methods

Plant material and study site: The experiment was carried out at the Thepa Research Station in the Thepa District of Songkhla Province, Thailand. The latex samples were collected from rubber trees (*Hevea brasilliensis*) (RRIM 600 clone). The trees had a mature age of around 20 years old and grew in the same plot with spacing of 3 × 7 meters in sandy loam soil (pH = 5.5).

Statistic design: This experiment design was a one-tree plot design with 4 random treatments which included 3 repetitions per treatment method (12 repetitions in randomization of all the trees).

Treatment or Tapping systems: The rubber trees were tapped in 4 methods: T1 = Control: 1/3s ↑ 2d/3 (One third spiral upward cut at two days tapped by one day rest); T2 = RRIMFLOW : 1/8s ↑ 2d/3 (One eight spiral upward cut at two days tapped one day rest; stimulated with ethylene gas [RRIMFLOW system]); T3 = Double Tex : 1/8s ↑ 2d/3 (One eight spiral upward cut at two days tapped one day rest; stimulated with ethylene gas [Double Tex system]); T4 = LET: 1/8s ↑ 2d/3 (One eight spiral upward cut at two days tapped one day rest; stimulated with ethylene gas [LET system]). The tapping and treatment systems are illustrated in Fig. 1.

Latex analysis: The latex was collected from the rubber trees and the analyses were carried out from January to May 2013. Secondary data from the Pattani Meteorology Station [6] included average rainfall,evaporation, and maximum/minimum temperatures (Fig. 2). In addition, the testing of the magnesium content (ppm) and the %TSC of the latex used the standards of the Rubber Research Institute of Thailand, 2001 [7].

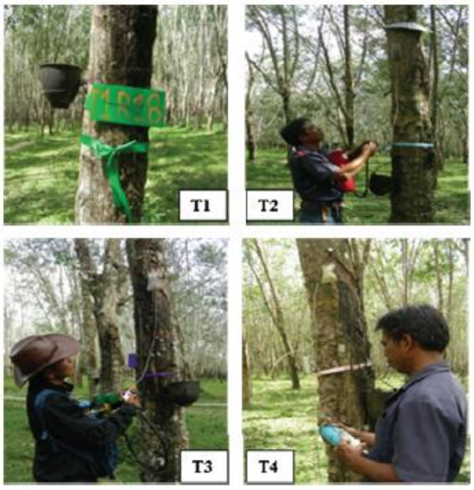

Fig. 1. Tapping and treatment systems: T1 = Control, 1/3s ↑ 2d/3; T2 = RRIMFLOW, 1/8s ↑ 2d/3; T3 = Double Tex, 1/8s ↑ 2d/3; T4 = LET, 1/8s ↑ 2d/3.

3. Results and Discussion

Weather data

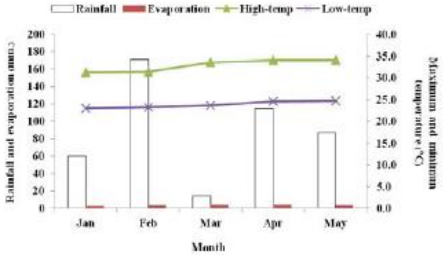

Fig. 2. Weather data: average rainfall; evaporation; and maximum/minimum temperatures from Pattani Meteorology Station.

The weather data in this experiment were collected from January to May 2013 from the Thepa Research Station in the Thepa District of Songkhla Province. The data consisted of the average rainfall, evaporation,and maximum/minimum temperatures.

The peak average rainfall of 171.5 mm occurred in February and fell to the lowest point of 14.6 in March. On the other hand the average evaporation remained stable at around 4 mm and varied with the rainfall while the average maximum temperature leveled off from March to May at 34.1°C and fell gradually from March to January to around 32.1°C. In contrast, the average minimum temperature remained constant at 23.92°C.

Total Solids Content (%TSC)

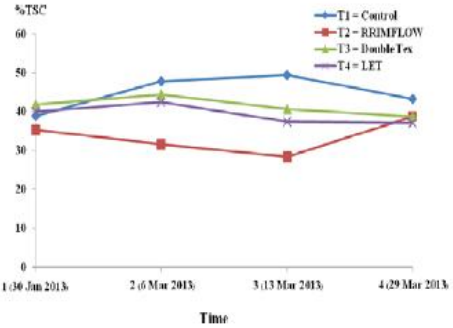

Fig. 3. Trend of total solids content in latex from 4 tapping methods at the Thepa Research Station from January to May 2013.

Fig. 3 shows the %TSC in latex tapped from rubber trees with 4 tapping methods and selected 4 times. According to the data at the first tapping, the %TSC values were homologous data with an average of 38% and the %TSC value of T2 was the lowest at around 35%. The %TSC value of T3 was the highest at 40%. At the second tapping, the %TSC value of T2 dropped gradually but the T1 value increased sharply and was the highest value at this time. The values of T3 and T4 were similar. At the third tapping, the %TSC value of T2 fell to the lowest point to 28% while T4 reached a peak at 49%. The values of T3 and T4 decreased gradually and were similar to the second tapping. At the fourth tapping, the T2 %TSC value increased sharply to 38% which was near the T3 and T4 %TSC values while they dropped slightly from the third tapping. The %TSC value of T1 fell sharply to 43% but this value remained the highest at this tapping.

Magnesium Content

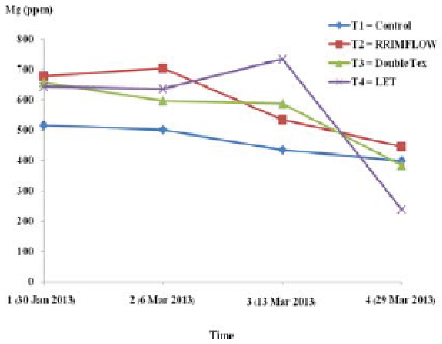

Fig. 4. Trends of magnesium content in latex from 4 tapping methods at the Thepa Research Station from January to May 2013.

Fig. 4 shows the quantity of magnesium content in the latex which was tapped from rubber trees with 4 tapping methods and was collected 4 times. At the first tapping, the magnesium levels were 677, 657, and 644 ppm for T2, T3, and T4, respectively, which used ethylene gas in tapping and they were higher than the control tapping (T1) at 514 ppm. At this time, the value of magnesium content in T2 was the highest and T1 was the lowest. At the second tapping, the level of magnesium for T2 and T4 increased gradually but T1 dropped slightly and T4 fell gradually. The magnesium levels of T2 and T1 remained high and low, respectively. At the third tapping, the T4 magnesium level rose sharply and the T3 level increased slightly while the T2 level dropped sharply and T1 fell slightly. At this time, the value of magnesium of the T1 method was the lowest but T4 reach a peak above all of them at 733 ppm. At the fourth tapping, the values dropped sharply in the T3/T4 methods and gradually in the T1/T2 methods. Although the T2 method was the highest at 444 ppm and the T4 method was the lowest at 238 ppm, all methods had magnesium values less than 500 ppm.

The latex from the four tapping methods consisted of one control tapping (T1 = control) and ethylene gas tapping which included three methods (T2 = RRIMFLOW, T3 = Double Tex, and T4 = LET) which produced different quality results.

Firstly, the %TSC in latex from all methods was within the normal criteria (27–48%). The average %TSC for the control tapping (T1) was the highest while the %TSC from the ethylene gas tapping in T2, T3, and T4 were of low values. Especially, the average value of T2 was the lowest every time. Although, the %TSC values of the latex from ethylene gas tapping were lower than the control tapping, these values were similar to stimulation and latex rheology theory which gave low %TSC values of the latex after tapping [1]

Secondly, the magnesium content in latex from this experiment was high, especially the latex from the ethylene gas tapping in the T2, T3, and T4 methods and the magnesium content in the T2 method was the highest. The T3 and T4 methods were high but varied due to occasional gas leakage from the equipment and the injection into the bark was not complete. Although the level of magnesium of the control tapping (T1) was high, it was generally lower than ethylene gas tapping.

In addition, the magnesium content from all samples dropped at the fourth tapping in March maybe due to high temperatures, low rainfall, and high water evaporation. So, the rubber trees could not uptake water and nutrients for the synthesis of latex. Especially, the ethylene gas could not move the water molecules from the surrounding cells into the synthesis cells for the synthesis of latex [2]. Similarly, the latex from ethylene gas tapping was low in magnesium content due the decreased coagulation of the latex (increased stability of the lutoids) [1] that maybe depended on the weather.

But, in this case, the total magnesium content was different from theory. There was a tendency of the magnesium content in both normal tapping and ethylene gas tapping to be higher than the magnesium standard in concentrated latex [4]. Although the magnesium content decreased or varied sometimes according to the weather, the values were still high. Maybe the ethylene gas moved the magnesium ions in the water and nutrients from the soil for the synthesis of the latex.

4. Conclusions

The difference of tapping methods for mature rubber trees has an effect on the quality of the latex. Especially for the ethylene gas tapping systems, there was a tendency for the %TSC to decrease but the values were within the normal criteria. In contrast, the magnesium content tended to be very high.

Although the magnesium content is not a major concern for improved latex production, it is very important in the concentrated latex process. Magnesium is a major problem when it precipitates out during centrifugation in the concentrated latex process.

The latex from the ethylene gas tapping systems was high in magnesium content and this may lead to increased waste at the factories and affect the environment in the long term.

5. Acknowledgement

The authors were grateful to the financial supports from the Commission on Higher Education (CHE) for supporting her Ph.D. studentship.

6. References

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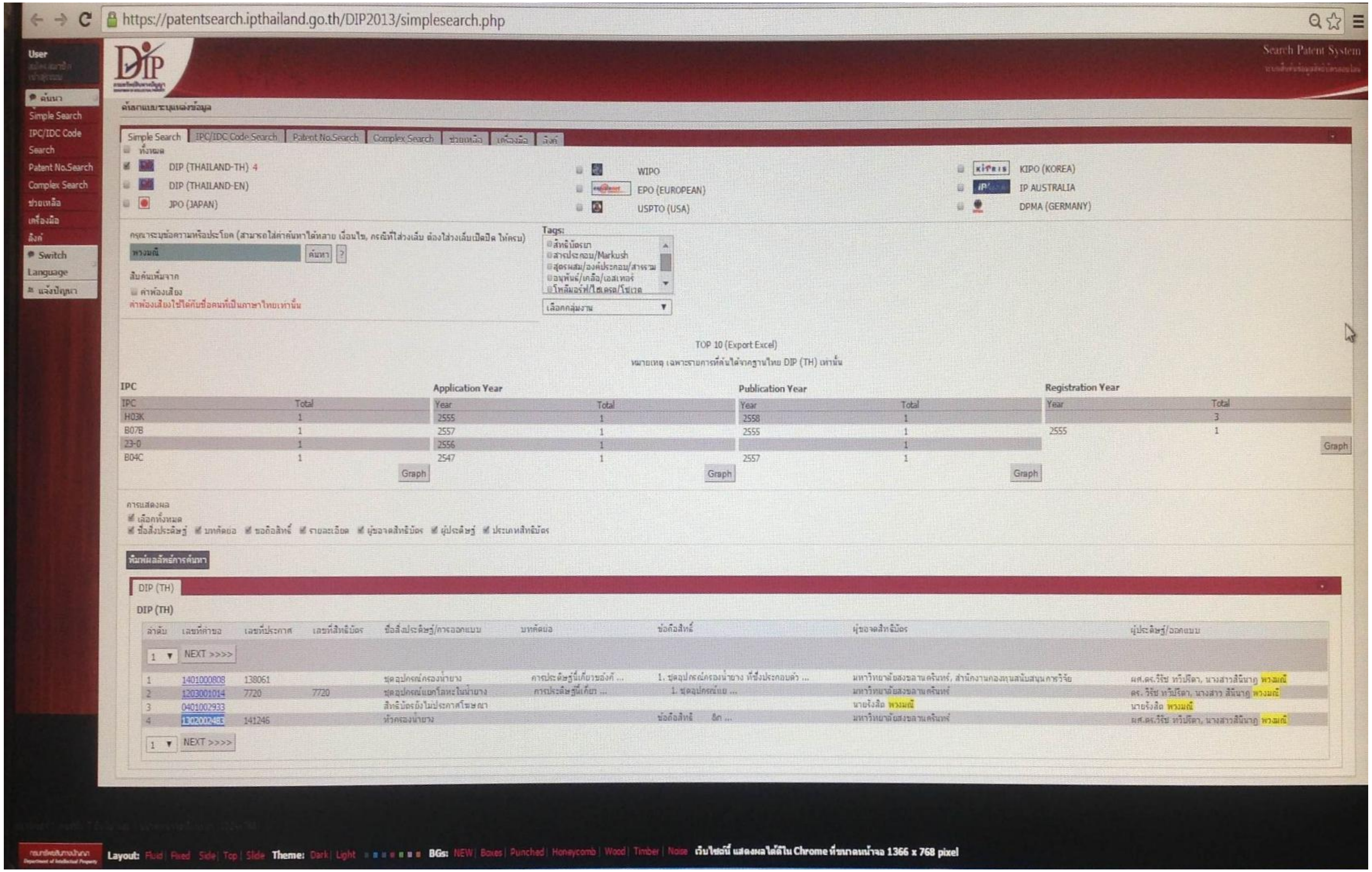
APPENDIX B

Petty patent

Petty patent search



ค้นหาแบบระบุแหล่งข้อมูล

☐ ทั้งหมด
☑ DIP (THAILAND-TH) 4
☐ DIP (THAILAND-EN)
☐ JPO (JAPAN)
☐ WIPO
☐ EPO (EUROPEAN)
☐ USPTO (USA)
☐ KIPO (KOREA)
☐ IP AUSTRALIA
☐ DPMA (GERMANY)

กรุณาระบุข้อความหรือประโยค (สามารถใส่ค่าค้นหาได้หลาย เงื่อนไข, กรณีที่ใส่วงเล็บ ต้องใส่วงเล็บเปิดปิด ให้ครบ)

พวงมณี

สืบค้นเพิ่มจาก
☐ ค่าพ้องเสียง
ค่าพ้องเสียงใช้ได้กับชื่อคนที่เป็นภาษาไทยเท่านั้น

Tags:
☐ สิทธิบัตรยา
☐ สารประกอบ/Markush
☐ สูตรผสม/องค์ประกอบ/สารรวม
☐ อนุพันธ์/เกลือ/เอสเทอร์
☐ โพลีมอร์ฟ/ไฮเดรต/โซเวต

TOP 10 (Export Excel)

หมายเหตุ เฉพาะรายการที่ค้นได้จากฐานไทย DIP (TH) เท่านั้น

IPC

IPC	Total
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B07B	1
23-0	1
B04C	1

Application Year

Year	Total
2555	1
2557	1
2556	1
2547	1

Publication Year

Year	Total
2558	1
2555	1
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2557	1

Registration Year

Year	Total
	3
2555	1

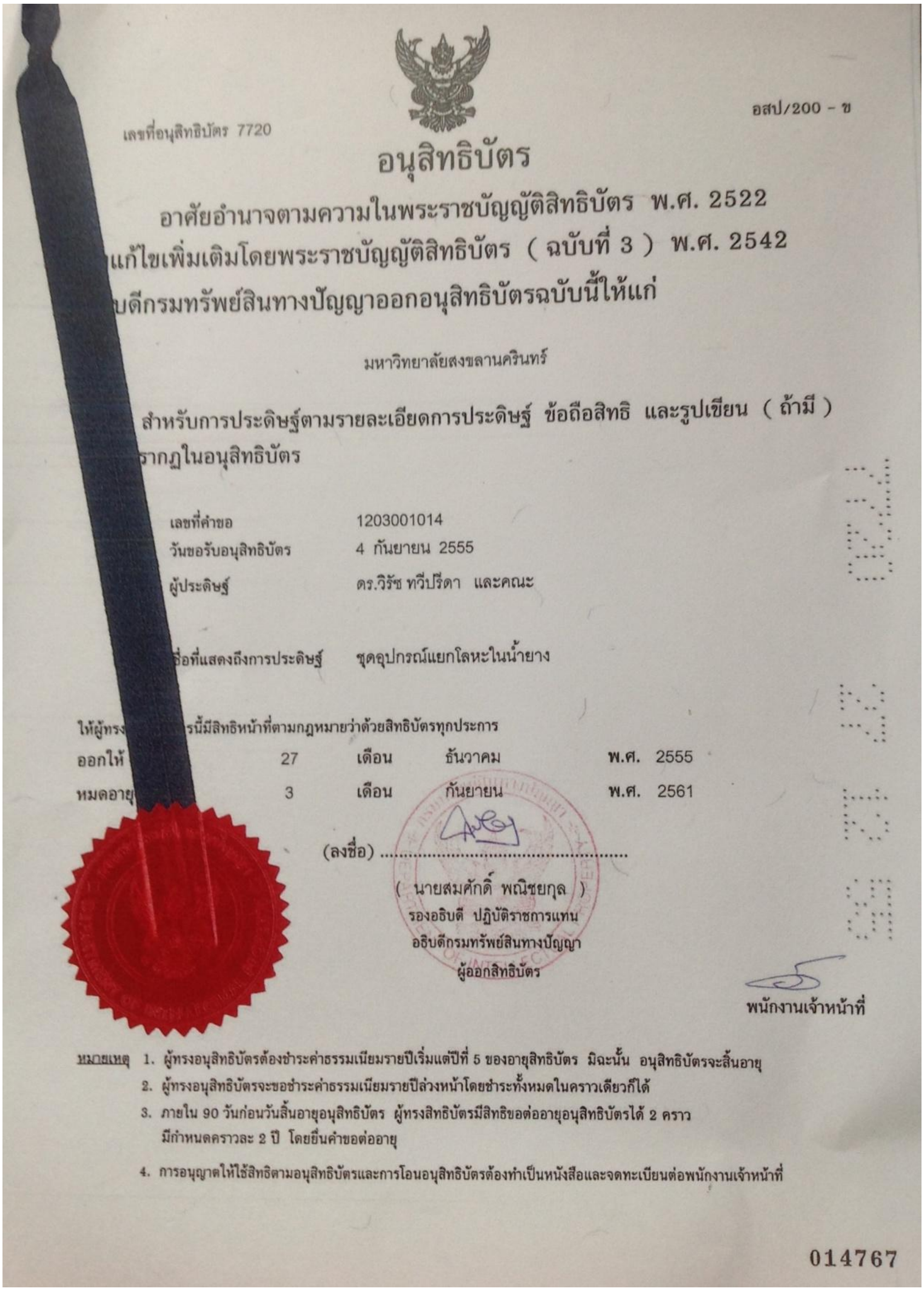
การแสดงผล
☑ เลือกทั้งหมด
☑ ชื่อสิ่งประดิษฐ์ ☑ บทคัดย่อ ☑ ข้อถือสิทธิ์ ☑ รายละเอียด ☑ ผู้ขอรับสิทธิบัตร ☑ ผู้ประดิษฐ์ ☑ ประเภทสิทธิบัตร

DIP (TH)

DIP (TH)

ลำดับ	เลขที่คำขอ	เลขที่ประกาศ	เลขที่สิทธิบัตร	ชื่อสิ่งประดิษฐ์/การออกแบบ	บทคัดย่อ	ข้อถือสิทธิ์	ผู้ขอรับสิทธิบัตร	ผู้ประดิษฐ์/ออกแบบ
1	1401000808	138061		ชุดอุปกรณ์กรองน้ำยาง	การประดิษฐ์นี้เกี่ยวข้องกั ...	1. ชุดอุปกรณ์กรองน้ำยาง ที่ซึ่งประกอบด้ว ...	มหาวิทยาลัยสงขลานครินทร์, สำนักงานกองทุนสนับสนุนการวิจัย	ผศ.ดร.วิรัช ทวีปรีดา, นางสาวสินีนาฏ พวงมณี
2	1203001014	7720	7720	ชุดอุปกรณ์แยกโลหะในน้ำยาง	การประดิษฐ์นี้เกี่ยว ...	1. ชุดอุปกรณ์แย ...	มหาวิทยาลัยสงขลานครินทร์	ดร. วิรัช ทวีปรีดา, นางสาว สินีนาฏ พวงมณี
3	0401002933			สิทธิบัตรยังไม่ประกาศโฆษณา			นายรังสิต พวงมณี	นายรังสิต พวงมณี
4	[illegible]	141246		หัวกรองน้ำยาง		ข้อถือสิทธิ์ อีก ...	มหาวิทยาลัยสงขลานครินทร์	ผศ.ดร.วิรัช ทวีปรีดา, นางสาวสินีนาฏ พวงมณี

Petty patent



เลขที่อนุสิทธิบัตร 7720

อสป/200 - ข

อนุสิทธิบัตร

อาศัยอำนาจตามความในพระราชบัญญัติสิทธิบัตร พ.ศ. 2522
แก้ไขเพิ่มเติมโดยพระราชบัญญัติสิทธิบัตร (ฉบับที่ 3) พ.ศ. 2542
บดีกรมทรัพย์สินทางปัญญาออกอนุสิทธิบัตรฉบับนี้ให้แก่

มหาวิทยาลัยสงขลานครินทร์

สำหรับการประดิษฐ์ตามรายละเอียดการประดิษฐ์ ข้อถือสิทธิ และรูปเขียน (ถ้ามี)
รากฏในอนุสิทธิบัตร

เลขที่คำขอ 1203001014
วันขอรับอนุสิทธิบัตร 4 กันยายน 2555
ผู้ประดิษฐ์ ดร.วิรัช ทวีปรีดา และคณะ

ชื่อที่แสดงถึงการประดิษฐ์ ชุดอุปกรณ์แยกโลหะในน้ำยาง

ให้ผู้ทรง รนี้มีสิทธิหน้าที่ตามกฎหมายว่าด้วยสิทธิบัตรทุกประการ
ออกให้ 27 เดือน ธันวาคม พ.ศ. 2555
หมดอายุ 3 เดือน กันยายน พ.ศ. 2561

(ลงชื่อ) ....

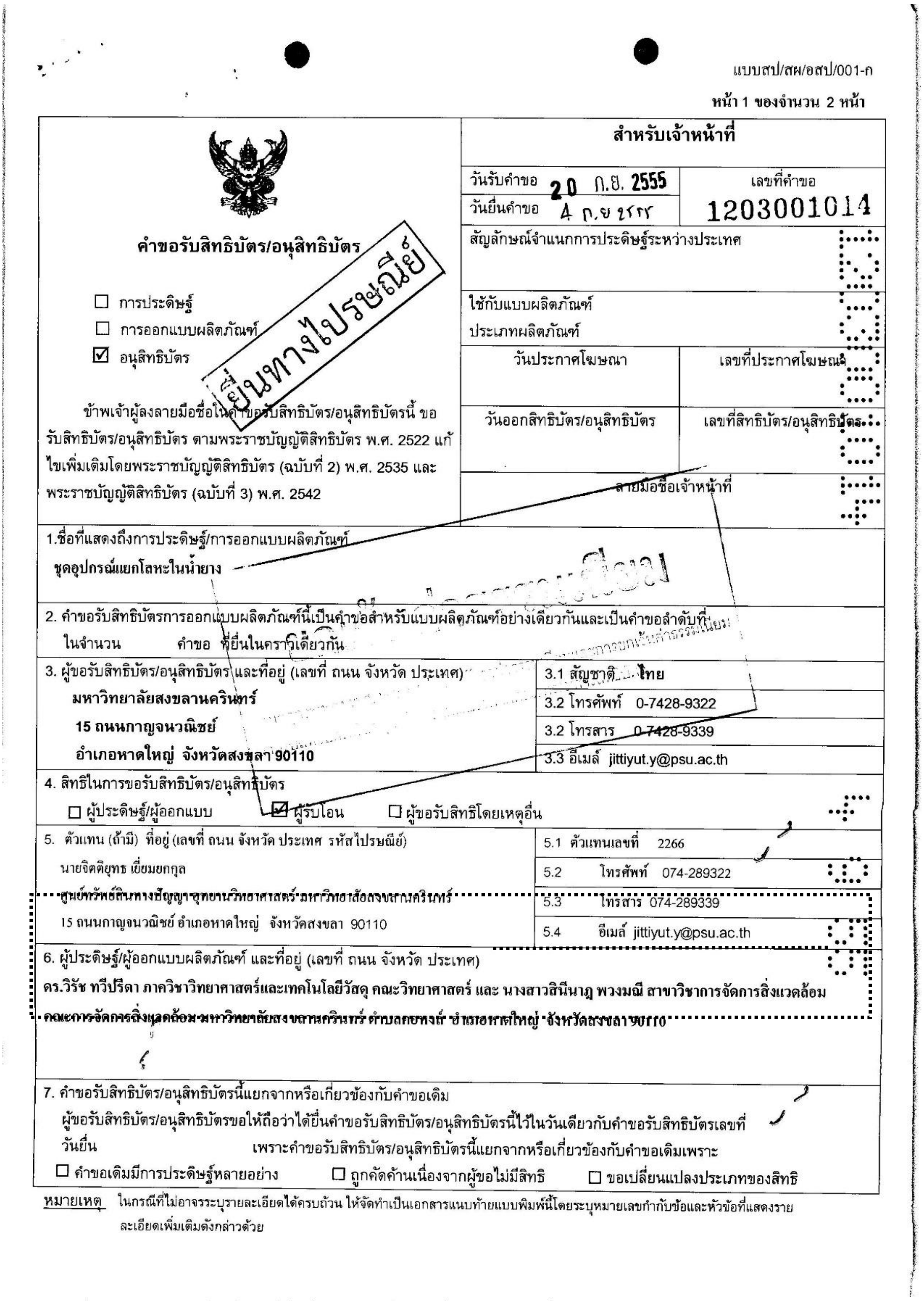
(นายสมศักดิ์ พณิชยกุล)
รองอธิบดี ปฏิบัติราชการแทน
อธิบดีกรมทรัพย์สินทางปัญญา
ผู้ออกสิทธิบัตร

พนักงานเจ้าหน้าที่

<u>หมายเหตุ</u> 1. ผู้ทรงอนุสิทธิบัตรต้องชำระค่าธรรมเนียมรายปีเริ่มแต่ปีที่ 5 ของอายุสิทธิบัตร มิฉะนั้น อนุสิทธิบัตรจะสิ้นอายุ
2. ผู้ทรงอนุสิทธิบัตรจะขอชำระค่าธรรมเนียมรายปีล่วงหน้าโดยชำระทั้งหมดในคราวเดียวก็ได้
3. ภายใน 90 วันก่อนวันสิ้นอายุอนุสิทธิบัตร ผู้ทรงสิทธิบัตรมีสิทธิขอต่ออายุอนุสิทธิบัตรได้ 2 คราว มีกำหนดคราวละ 2 ปี โดยยื่นคำขอต่ออายุ
4. การอนุญาตให้ใช้สิทธิตามอนุสิทธิบัตรและการโอนอนุสิทธิบัตรต้องทำเป็นหนังสือและจดทะเบียนต่อพนักงานเจ้าหน้าที่

014767

Petty patent “Metal Separation Equipment for Latex”



แบบสป/สผ/อสป/001-ก

หน้า 1 ของจำนวน 2 หน้า

คำขอรับสิทธิบัตร/อนุสิทธิบัตร

☐ การประดิษฐ์
☐ การออกแบบผลิตภัณฑ์
☑ อนุสิทธิบัตร

ยื่นทางไปรษณีย์

ข้าพเจ้าผู้ลงลายมือชื่อในคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ ขอรับสิทธิบัตร/อนุสิทธิบัตร ตามพระราชบัญญัติสิทธิบัตร พ.ศ. 2522 แก้ไขเพิ่มเติมโดยพระราชบัญญัติสิทธิบัตร (ฉบับที่ 2) พ.ศ. 2535 และพระราชบัญญัติสิทธิบัตร (ฉบับที่ 3) พ.ศ. 2542

สำหรับเจ้าหน้าที่

วันรับคำขอ 20 ก.ย. 2555 วันยื่นคำขอ 4 ก.ย ๒๕๕๕	เลขที่คำขอ 1203001014
สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ	
ใช้กับแบบผลิตภัณฑ์ ประเภทผลิตภัณฑ์	
วันประกาศโฆษณา	เลขที่ประกาศโฆษณา
วันออกสิทธิบัตร/อนุสิทธิบัตร	เลขที่สิทธิบัตร/อนุสิทธิบัตร
	ลายมือชื่อเจ้าหน้าที่

1.ชื่อที่แสดงถึงการประดิษฐ์/การออกแบบผลิตภัณฑ์

ชุดอุปกรณ์แยกโลหะในน้ำยาง

2. คำขอรับสิทธิบัตรการออกแบบผลิตภัณฑ์นี้เป็นคำขอสำหรับแบบผลิตภัณฑ์อย่างเดียวกันและเป็นคำขอลำดับที่
ในจำนวน คำขอ ที่ยื่นในคราวเดียวกัน

3. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร และที่อยู่ (เลขที่ ถนน จังหวัด ประเทศ)

มหาวิทยาลัยสงขลานครินทร์
15 ถนนกาญจนวณิชย์
อำเภอหาดใหญ่ จังหวัดสงขลา 90110

3.1 สัญชาติ **ไทย**
3.2 โทรศัพท์ 0-7428-9322
3.2 โทรสาร 0-7428-9339
3.3 อีเมล์ jittiyut.y@psu.ac.th

4. สิทธิในการขอรับสิทธิบัตร/อนุสิทธิบัตร

☐ ผู้ประดิษฐ์/ผู้ออกแบบ ☑ ผู้รับโอน ☐ ผู้ขอรับสิทธิโดยเหตุอื่น

5. ตัวแทน (ถ้ามี) ที่อยู่ (เลขที่ ถนน จังหวัด ประเทศ รหัสไปรษณีย์)

นายจิตติยุทธ เยี่ยมยกกุล
ศูนย์ทรัพย์สินทางปัญญาอุทยานวิทยาศาสตร์ มหาวิทยาลัยสงขลานครินทร์
15 ถนนกาญจนวณิชย์ อำเภอหาดใหญ่ จังหวัดสงขลา 90110

5.1 ตัวแทนเลขที่ 2266
5.2 โทรศัพท์ 074-289322
5.3 โทรสาร 074-289339
5.4 อีเมล์ jittiyut.y@psu.ac.th

6. ผู้ประดิษฐ์/ผู้ออกแบบผลิตภัณฑ์ และที่อยู่ (เลขที่ ถนน จังหวัด ประเทศ)

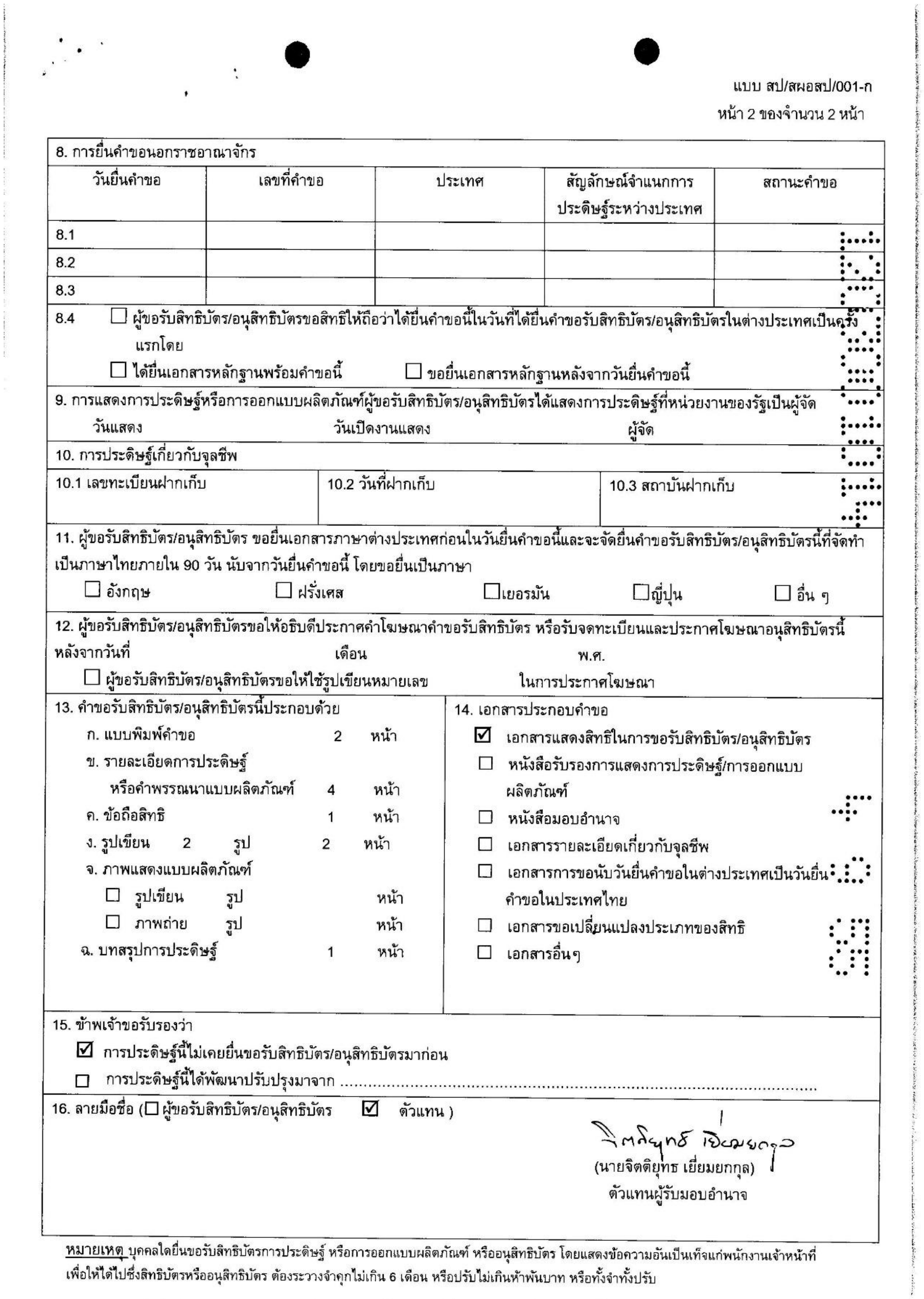
ดร.วิรัช ทวีปรีดา ภาควิชาวิทยาศาสตร์และเทคโนโลยีวัสดุ คณะวิทยาศาสตร์ และ นางสาวสินีนาฏ พวงมณี สาขาวิชาการจัดการสิ่งแวดล้อม คณะการจัดการสิ่งแวดล้อม มหาวิทยาลัยสงขลานครินทร์ ตำบลคอหงส์ อำเภอหาดใหญ่ จังหวัดสงขลา 90110

7. คำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้แยกจากหรือเกี่ยวข้องกับคำขอเดิม

ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอให้ถือว่าได้ยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ไว้ในวันเดียวกับคำขอรับสิทธิบัตรเลขที่
วันยื่น เพราะคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้แยกจากหรือเกี่ยวข้องกับคำขอเดิมเพราะ

☐ คำขอเดิมมีการประดิษฐ์หลายอย่าง ☐ ถูกคัดค้านเนื่องจากผู้ขอไม่มีสิทธิ ☐ ขอเปลี่ยนแปลงประเภทของสิทธิ

<u>หมายเหตุ</u> ในกรณีที่ไม่อาจระบุรายละเอียดได้ครบถ้วน ให้จัดทำเป็นเอกสารแนบท้ายแบบพิมพ์นี้โดยระบุหมายเลขกำกับข้อและหัวข้อที่แสดงรายละเอียดเพิ่มเติมดังกล่าวด้วย



แบบ สป/สผอสป/001-ก
หน้า 2 ของจำนวน 2 หน้า

8. การยื่นคำขอนอกราชอาณาจักร

วันยื่นคำขอ	เลขที่คำขอ	ประเทศ	สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ	สถานะคำขอ
8.1				
8.2				
8.3				

8.4 ☐ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอสิทธิให้ถือว่าได้ยื่นคำขอนี้ในวันที่ได้ยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรในต่างประเทศเป็นครั้งแรกโดย
☐ ได้ยื่นเอกสารหลักฐานพร้อมคำขอนี้ ☐ ขอยื่นเอกสารหลักฐานหลังจากวันยื่นคำขอนี้

9. การแสดงการประดิษฐ์หรือการออกแบบผลิตภัณฑ์ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรได้แสดงการประดิษฐ์ที่หน่วยงานของรัฐเป็นผู้จัด
วันแสดง วันเปิดงานแสดง ผู้จัด

10. การประดิษฐ์เกี่ยวกับจุลชีพ

10.1 เลขทะเบียนฝากเก็บ
10.2 วันที่ฝากเก็บ
10.3 สถาบันฝากเก็บ

11. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร ขอยื่นเอกสารภาษาต่างประเทศก่อนในวันยื่นคำขอนี้และจะจัดยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ที่จัดทำเป็นภาษาไทยภายใน 90 วัน นับจากวันยื่นคำขอนี้ โดยขอยื่นเป็นภาษา
☐ อังกฤษ ☐ ฝรั่งเศส ☐ เยอรมัน ☐ ญี่ปุ่น ☐ อื่น ๆ

12. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอให้อธิบดีประกาศโฆษณาคำขอรับสิทธิบัตร หรือรับจดทะเบียนและประกาศโฆษณาอนุสิทธิบัตรนี้
หลังจากวันที่ เดือน พ.ศ.
☐ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอให้ใช้รูปเขียนหมายเลข ในการประกาศโฆษณา

13. คำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ประกอบด้วย
ก. แบบพิมพ์คำขอ 2 หน้า
ข. รายละเอียดการประดิษฐ์
หรือคำพรรณนาแบบผลิตภัณฑ์ 4 หน้า
ค. ข้อถือสิทธิ 1 หน้า
ง. รูปเขียน 2 รูป 2 หน้า
จ. ภาพแสดงแบบผลิตภัณฑ์
☐ รูปเขียน รูป หน้า
☐ ภาพถ่าย รูป หน้า
ฉ. บทสรุปการประดิษฐ์ 1 หน้า

14. เอกสารประกอบคำขอ
☑ เอกสารแสดงสิทธิในการขอรับสิทธิบัตร/อนุสิทธิบัตร
☐ หนังสือรับรองการแสดงการประดิษฐ์/การออกแบบผลิตภัณฑ์
☐ หนังสือมอบอำนาจ
☐ เอกสารรายละเอียดเกี่ยวกับจุลชีพ
☐ เอกสารการขอนับวันยื่นคำขอในต่างประเทศเป็นวันยื่นคำขอในประเทศไทย
☐ เอกสารขอเปลี่ยนแปลงประเภทของสิทธิ
☐ เอกสารอื่นๆ

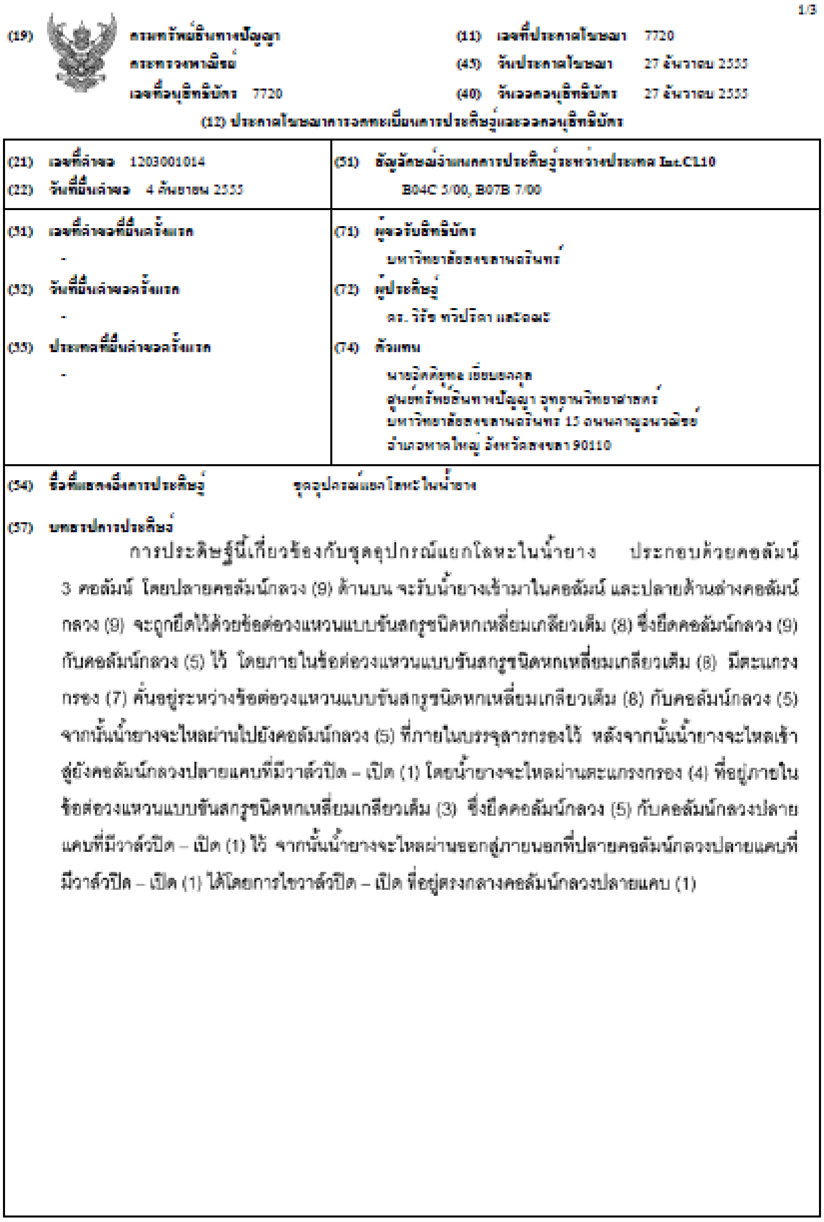
15. ข้าพเจ้าขอรับรองว่า
☑ การประดิษฐ์นี้ไม่เคยยื่นขอรับสิทธิบัตร/อนุสิทธิบัตรมาก่อน
☐ การประดิษฐ์นี้ได้พัฒนาปรับปรุงมาจาก ....

16. ลายมือชื่อ (☐ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร ☑ ตัวแทน)

จิตติยุทธ เยี่ยมยกกุล
(นายจิตติยุทธ เยี่ยมยกกุล)
ตัวแทนผู้รับมอบอำนาจ

<u>หมายเหตุ</u> บุคคลใดยื่นขอรับสิทธิบัตรการประดิษฐ์ หรือการออกแบบผลิตภัณฑ์ หรืออนุสิทธิบัตร โดยแสดงข้อความอันเป็นเท็จแก่พนักงานเจ้าหน้าที่เพื่อให้ได้ไปซึ่งสิทธิบัตรหรืออนุสิทธิบัตร ต้องระวางจำคุกไม่เกิน 6 เดือน หรือปรับไม่เกินห้าพันบาท หรือทั้งจำทั้งปรับ

Advertisement



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(19) กรมทรัพย์สินทางปัญญา
กระทรวงพาณิชย์
เลขที่อนุสิทธิบัตร 7720

(11) เลขที่ประกาศโฆษณา 7720
(45) วันประกาศโฆษณา 27 ธันวาคม 2555
(40) วันออกอนุสิทธิบัตร 27 ธันวาคม 2555

(12) ประกาศโฆษณาการจดทะเบียนการประดิษฐ์และออกอนุสิทธิบัตร

(21) เลขที่คำขอ 1203001014
(22) วันที่ยื่นคำขอ 4 กันยายน 2555

(51) สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ Int.CL10
B04C 5/00, B07B 7/00

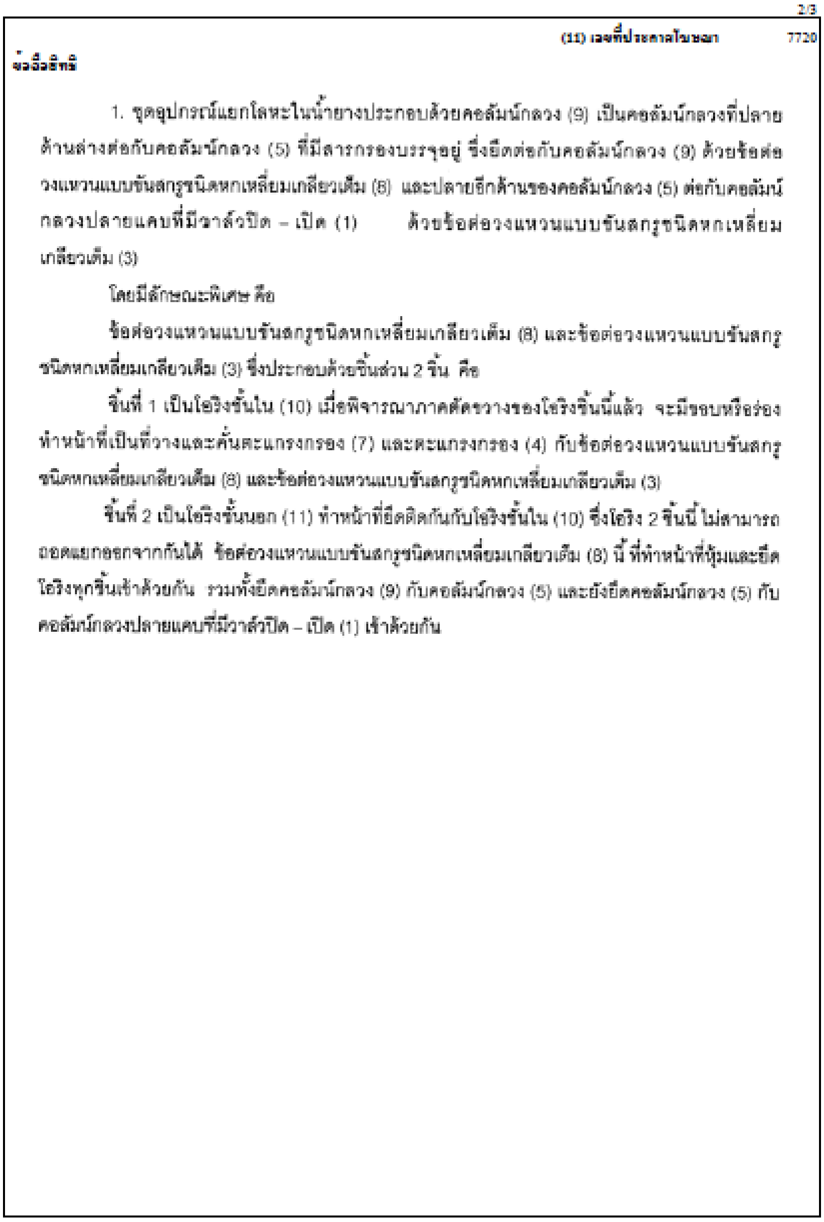
(31) เลขที่คำขอที่ยื่นครั้งแรก
-
(32) วันที่ยื่นคำขอครั้งแรก
-
(33) ประเทศที่ยื่นคำขอครั้งแรก
-

(71) ผู้ขอรับสิทธิบัตร
มหาวิทยาลัยสงขลานครินทร์
(72) ผู้ประดิษฐ์
ดร. วิรัช ทวีปรีดา และคณะ
(74) ตัวแทน
นายอิทธิยุทธ เอี่ยมสกุล
ศูนย์ทรัพย์สินทางปัญญา อุทยานวิทยาศาสตร์
มหาวิทยาลัยสงขลานครินทร์ 15 ถนนกาญจนวณิชย์
อำเภอหาดใหญ่ จังหวัดสงขลา 90110

(54) ชื่อที่แสดงถึงการประดิษฐ์ ชุดอุปกรณ์แยกโลหะในน้ำยาง

(57) บทสรุปการประดิษฐ์

การประดิษฐ์นี้เกี่ยวข้องกับชุดอุปกรณ์แยกโลหะในน้ำยาง ประกอบด้วยคอลัมน์ 3 คอลัมน์ โดยปลายคอลัมน์กลวง (9) ด้านบน จะรับน้ำยางเข้ามาในคอลัมน์ และปลายด้านล่างคอลัมน์กลวง (9) จะถูกยึดไว้ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) ซึ่งยึดคอลัมน์กลวง (9) กับคอลัมน์กลวง (5) ไว้ โดยภายในข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) มีตะแกรงกรอง (7) คั่นอยู่ระหว่างข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) กับคอลัมน์กลวง (5) จากนั้นน้ำยางจะไหลผ่านไปยังคอลัมน์กลวง (5) ที่ภายในบรรจุสารกรองไว้ หลังจากนั้นน้ำยางจะไหลเข้าสู่ยังคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) โดยน้ำยางจะไหลผ่านตะแกรงกรอง (4) ที่อยู่ภายในข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ซึ่งยึดคอลัมน์กลวง (5) กับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ไว้ จากนั้นน้ำยางจะไหลผ่านออกสู่ภายนอกที่ปลายคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ได้โดยการไขวาล์วปิด – เปิด ที่อยู่ตรงกลางคอลัมน์กลวงปลายแคบ (1)



(11) เลขที่ประกาศโฆษณา 7720

ข้อถือสิทธิ

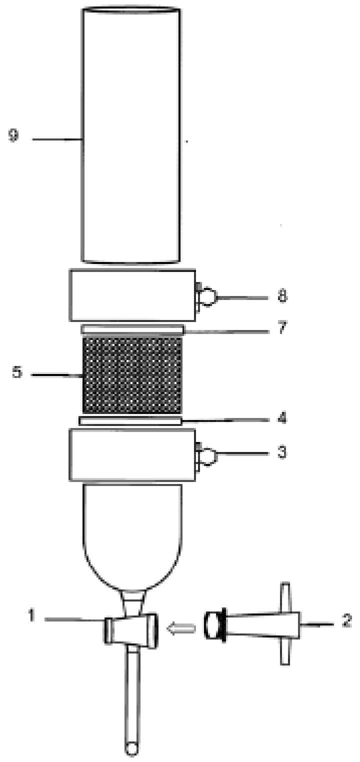
1. ชุดอุปกรณ์แยกโลหะในน้ำยางประกอบด้วยคอลัมน์กลวง (9) เป็นคอลัมน์กลวงที่ปลายด้านล่างต่อกับคอลัมน์กลวง (5) ที่มีสารกรองบรรจุอยู่ ซึ่งยึดต่อกับคอลัมน์กลวง (9) ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และปลายอีกด้านของคอลัมน์กลวง (5) ต่อกับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3)

โดยมีลักษณะพิเศษ คือ

ข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ซึ่งประกอบด้วยชิ้นส่วน 2 ชิ้น คือ

ชิ้นที่ 1 เป็นโอริงชั้นใน (10) เมื่อพิจารณาภาคตัดขวางของโอริงชิ้นนี้แล้ว จะมีขอบหรือร่องทำหน้าที่เป็นที่วางและคั่นตะแกรงกรอง (7) และตะแกรงกรอง (4) กับข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3)

ชิ้นที่ 2 เป็นโอริงชั้นนอก (11) ทำหน้าที่ยึดติดกันกับโอริงชั้นใน (10) ซึ่งโอริง 2 ชิ้นนี้ ไม่สามารถถอดแยกออกจากกันได้ ข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) นี้ ที่ทำหน้าที่หุ้มและยึดโอริงทุกชิ้นเข้าด้วยกัน รวมทั้งยึดคอลัมน์กลวง (9) กับคอลัมน์กลวง (5) และยังยึดคอลัมน์กลวง (5) กับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) เข้าด้วยกัน


9
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บทสรุปการประดิษฐ์

การประดิษฐ์นี้เกี่ยวข้องกับชุดอุปกรณ์แยกโลหะในน้ำยาง ประกอบด้วยคอลัมน์ 3 คอลัมน์ โดยปลายคอลัมน์กลวง (9) ด้านบน จะรับน้ำยางเข้ามาในคอลัมน์ และปลายด้านล่างคอลัมน์กลวง (9) จะถูกยึดไว้ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) ซึ่งยึดคอลัมน์กลวง (9) กับคอลัมน์กลวง (5) ไว้ โดยภายในข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) มีตะแกรงกรอง (7) คั่นอยู่ระหว่างข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) กับคอลัมน์กลวง (5) จากนั้นน้ำยางจะไหลผ่านไปยังคอลัมน์กลวง (5) ที่ภายในบรรจุสารกรองไว้ หลังจากนั้นน้ำยางจะไหลเข้าสู่ยังคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) โดยน้ำยางจะไหลผ่านตะแกรงกรอง (4) ที่อยู่ภายในข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ซึ่งยึดคอลัมน์กลวง (5) กับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ไว้ จากนั้นน้ำยางจะไหลผ่านออกสู่ภายนอกที่ปลายคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ได้โดยการไขวาล์วปิด – เปิด ที่อยู่ตรงกลางคอลัมน์กลวงปลายแคบ (1)

รายละเอียดการประดิษฐ์

ชื่อที่แสดงถึงการประดิษฐ์

ชุดอุปกรณ์แยกโลหะในน้ำยาง

สาขาวิทยาการที่เกี่ยวข้องกับการประดิษฐ์

วิศวกรรม ในส่วนที่เกี่ยวข้องกับชุดอุปกรณ์แยกโลหะในน้ำยาง

ภูมิหลังของศิลปะหรือวิทยาการที่เกี่ยวข้อง

ประเทศไทยเป็นประเทศผู้ผลิตและส่งออกน้ำยางข้นอันดับหนึ่งของโลก และมีสัดส่วนการส่งออกเป็นอันดับ 3 ของโลก รองจากยางแท่ง และยางรมควัน การผลิตน้ำยางข้นของประเทศไทยมีการขยายตัวเพิ่มสูงขึ้นอย่างรวดเร็วตลอดระยะเวลา 5 ปีที่ผ่านมา (2543 - 2547) จาก 0.29 ล้านตัน ในปี 2543 เป็น 0.50 ล้านตัน ในปี 2547 หรือเพิ่มขึ้นถึง 72.41% เนื่องจากการขยายการผลิตของอุตสาหกรรมถุงมือยาง และอุตสาหกรรมถุงยางอนามัย ที่เข้ามาใช้ประเทศไทยเป็นฐานการผลิตของโลก (รักษ์ พฤกษชาติ, 2552)

โดยน้ำยางข้นผลิตขึ้นจากน้ำยางสด ซึ่งประกอบด้วยปริมาณเนื้อยาง (Dry Rubber Content) เฉลี่ยประมาณ 35% สารละลายที่ไม่ใช่ยาง (Non – Rubber Solid) 5% และน้ำ (Watery) มาผ่านกระบวนการแปรรูปให้อยู่ในรูปของน้ำยางข้น ที่มีเนื้อยางแห้งอย่างน้อย 60% กับหางน้ำยาง โดยใช้วิธีการปั่นแยกด้วยเครื่องปั่นความเร็วสูง น้ำยางที่ได้จะเรียกว่า น้ำยางข้น (Concentrated Latex) ซึ่งมีน้ำยางข้น 60% กับหางน้ำยาง จากนั้นจะทำการรักษาสภาพด้วยการเติมแอมโมเนีย เพื่อป้องกันการจับตัว

น้ำยางข้นที่ผลิตในประเทศไทยจะต้องผลิตภายใต้มาตรฐานคุณภาพตามข้อกำหนดมาตรฐานน้ำยางข้นไทย (มอก. 980 – 2533) ซึ่งเป็นไปตามมาตรฐาน ISO : 1997 (E) ที่กำหนดมาตรฐานคุณภาพและวิธีการตรวจสอบคุณภาพไว้อย่างชัดเจน และในปัจจุบันได้ปรับปรุงมาตรฐานน้ำยางข้นไทยจาก มอก. 980 – 2533 เป็น มอก. 980 – 2552 (ประกาศกระทรวงอุตสาหกรรม, 2552) โดยได้เพิ่มเติมคุณลักษณะเรื่องปริมาณแมกนีเซียมในน้ำยางข้นเข้ามา ซึ่งทางสมาคมน้ำยางข้นนั้น ได้กำหนดมาตรฐานคุณภาพ น้ำยางข้นที่มีคุณสมบัติสูงกว่ามาตรฐาน ISO เพื่อยกระดับมาตรฐานน้ำยางข้นของไทยให้เป็นที่ยอมรับในทั่วโลก ซึ่งได้รับการรับรองจากสถาบันวิจัยยางให้ใช้เป็นมาตรฐานสำหรับการซื้อขายในตลาดสินค้าเกษตรล่วงหน้าได้ (รักษ์ พฤกษชาติ, 2552) ซึ่งเป็นข้อกำหนดมาตรฐานที่อ้างอิงมาจาก มอก. 980 – 2552

จากการที่เพิ่มเติมคุณลักษณะของปริมาณแมกนีเซียมเข้าไปในมอก. 980 – 2552 ซึ่งจากเดิมที่ไม่เคยระบุไว้ใน มอก. 980 – 2533 เนื่องจากในกระบวนการผลิตน้ำยางข้นชนิดปั่นแยก ได้ประสบปัญหาในการปั่นแยกน้ำยาง คือ เกิดการอุดตันของกากขี้แป้งในระหว่างการปั่นน้ำยาง ทำให้ต้องล้างเครื่องปั่นแยกทุกๆ 2 – 3 ชั่วโมง และเสียเวลาในการล้างประมาณ 8 – 20 นาที ต่อการล้างแต่ละครั้ง

แม้ว่าก่อนการปั่นแยกจะมีการตกตะกอนกากขี้แป้งออกไปก่อนหน้าแล้วก็ตาม แต่ในความเป็นจริงการเกิดกากขี้แป้งจะเกิดขึ้นได้ตั้งแต่ขั้นตอนการรวบรวมน้ำยางสดและการขนส่งน้ำยางสดมายังโรงงาน ซึ่งมีการรักษาสภาพน้ำยางด้วยสารละลายแอมโมเนีย โดยที่แอมโมเนียนั้นจะทำปฏิกิริยากับโปรตีนที่ถูกดูดซับที่ผิวของอนุภาคยาง และยังเกิดปฏิกิริยาได้กับประจุโลหะมัลติวาเลนท์ (Multivalent metal ions) เช่น Mg^{2+} ทำให้ได้แมกนีเซียมแอมโมเนียมฟอสเฟต (Magnesium ammonium phosphate) ซึ่งจะตกตะกอนแยกออกจากน้ำยางเป็นกากขี้แป้ง ส่งผลให้อนุภาคเม็ดยางมีความเสถียรและคงสภาพเป็นน้ำยางสดอยู่ได้จนถึงโรงงาน และเมื่อน้ำยางเข้าสู่กระบวนการผลิตน้ำยางข้น น้ำยางสดจะถูกเติมสารเคมีรักษาสภาพและเติมสารไดแอมโมเนียมฟอสเฟต (DAP) ก่อนกระบวนการปั่นแยกในถังพักน้ำยางสด ซึ่งสามารถเกิดกากขี้แป้งได้เช่นกัน นอกจากนี้ยังพบกากขี้แป้งในกระบวนการปั่นแยกจากการอุดตันของกากขี้แป้งบริเวณจานแยกและพบกากขี้แป้งได้อีกในบ่อตกตะกอนหางน้ำยาง รวมไปถึงในบ่อรักษาสภาพน้ำยางข้นที่มีการเติมแอมโมเนียเพื่อรอการบรรจุและจำหน่ายและสุดท้ายที่จุดเทรวมกากขี้แป้งในโรงงาน

โดยกากขี้แป้งจะถูกกำจัดด้วยวิธีการเทกอง นำไปถมที่ การเผาทำลายซึ่งก่อให้เกิดกลิ่นเหม็นรบกวนกลายเป็นปัญหามลพิษสิ่งแวดล้อมตามมา นอกจากนี้ยังพบการชะละลายธาตุอาหารจากกากขี้แป้ง ถึงแม้ไม่มีความเป็นพิษแต่มีความเข้มข้นสูงอย่างต่อเนื่อง มีโอกาสที่จะเกิดผลกระทบสิ่งแวดล้อมได้ หากมีการชะละลายแล้วไหลลงสู่แหล่งน้ำธรรมชาติ (ธันวดี เตชะภัททวรกุล สุขสาโรจน์, 2554)

แม้ว่าจะมีการค้นคว้าวิจัยในการที่จะลดปริมาณกากขี้แป้ง โดยการนำกากขี้แป้งไปใช้ประโยชน์ เช่น การนำไปทำเป็นปุ๋ย/วัสดุบำรุงดิน การแยกเนื้อยางออกจากกากขี้แป้งทั้งทางกายภาพและเคมี ซึ่งบางส่วนยังเป็นเพียงต้นแบบที่ยังมีการใช้งานไม่แพร่หลายมากนักในเชิงพาณิชย์ ทำให้การลดปริมาณกากขี้แป้งเป็นไปได้ในระดับหนึ่ง

จากปัญหาดังกล่าวทำให้เกิดแนวความคิดในการลดปริมาณโลหะในน้ำยาง โดยเฉพาะแมกนีเซียมซึ่งเป็นสารตั้งต้นของการเกิดกากขี้แป้งในกระบวนการผลิตน้ำยางข้น โดยปกติในการแยกโลหะด้วยวิธีการกรองจะใช้คอลัมน์แก้วที่เป็นคอลัมน์แก้วชิ้นเดียวและมีความยาวเท่ากันตลอดทั้งคอลัมน์ โดยปราศจากข้อต่อใดๆ และยังไม่สามารถประกอบเข้ากับแผ่นกรองที่เป็นโลหะได้ซึ่งส่วนใหญ่แผ่นกรองที่ใช้จะทำจากวัสดุอ่อนนุ่ม เช่น สำลี กระดาษกรอง หรือวัสดุอื่นใดที่ไม่ใช่โลหะ ซึ่งหากนำมาใช้กับน้ำยางจะทำให้เกิดการอุดตันและไม่ทนทานต่อจำนวนครั้งของการทดสอบ ดังนั้นจึงประดิษฐ์คอลัมน์แก้วขึ้นมาใหม่

ลักษณะและความมุ่งหมายของการประดิษฐ์

การประดิษฐ์นี้เกี่ยวข้องกับชุดอุปกรณ์แยกโลหะในน้ำยาง ประกอบด้วยคอลัมน์ 3 คอลัมน์ โดยปลายคอลัมน์กลวง (9) ด้านบน จะรับน้ำยางเข้ามาในคอลัมน์ และปลายด้านล่างคอลัมน์กลวง (9) จะถูกยึดไว้ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) ซึ่งยึดคอลัมน์กลวง (9) กับคอลัมน์กลวง (5) ไว้ โดยภายในข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8)

มีตะแกรงกรอง (7) คั่นอยู่ระหว่างข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) กับคอลัมน์กลวง (5) จากนั้นน้ำยางจะไหลผ่านไปยังคอลัมน์กลวง (5) ที่ภายในบรรจุสารกรองไว้ หลังจากนั้นน้ำยางจะไหลเข้าสู่ยังคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) โดยน้ำยางจะไหลผ่านตะแกรงกรอง (4) ที่อยู่ภายในข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ซึ่งยึดคอลัมน์กลวง (5) กับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ไว้ จากนั้นน้ำยางจะไหลผ่านออกสู่ภายนอกที่ปลายคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ได้โดยการไขวาล์วปิด – เปิด ที่อยู่ตรงกลางคอลัมน์กลวงปลายแคบ (1)

ความมุ่งหมายของการประดิษฐ์นี้ เพื่อใช้เป็นอุปกรณ์ในการแยกโลหะออกจากน้ำยาง โดยเฉพาะแมกนีเซียม ซึ่งเป็นสารตั้งต้นที่ทำให้เกิดตะกอนกากขี้แป้งในกระบวนการผลิตน้ำยางข้น ที่ทำให้เกิดเป็นปัญหากากของเสียอุตสาหกรรม นอกจากนี้การใช้ชุดอุปกรณ์แยกโลหะในน้ำยางจะช่วยลดต้นทุนการผลิตในส่วนของการซื้อสารเคมีเพื่อนำมาตกตะกอนเคมีแมกนีเซียมตามวิธีดั้งเดิมแล้ว ยังช่วยร่นระยะเวลาในการแยกแมกนีเซียมออกจากน้ำยางให้สั้นลงกว่าวิธีเดิม และไม่เกิดเป็นตะกอนกากขี้แป้งในระหว่างการใช้ชุดอุปกรณ์ชุดนี้อีกด้วย จึงทำให้น้ำยางที่ได้มีปริมาณโลหะ โดยเฉพาะแมกนีเซียมต่ำ ซึ่งมีความเหมาะสมที่จะนำเข้าสู่กระบวนการผลิตเป็นน้ำยางข้น

การเปิดเผยการประดิษฐ์โดยสมบูรณ์

การประดิษฐ์นี้เป็นการประดิษฐ์ที่เกี่ยวข้องกับชุดอุปกรณ์แยกโลหะในน้ำยาง ชุดอุปกรณ์นี้เป็นคอลัมน์ประกอบด้วยคอลัมน์ทำจากวัสดุที่ทนต่อสารเคมี 3 คอลัมน์ โดยในการใช้งานจะให้น้ำยางไหลผ่านเข้าปลายคอลัมน์กลวง (9) ด้านบน ซึ่งทำหน้าที่รับน้ำยางเข้ามาในคอลัมน์ และส่วนปลายด้านล่างคอลัมน์กลวง (9) จะถูกยึดไว้ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) ซึ่งยึดคอลัมน์กลวง (9) กับคอลัมน์กลวง(5)ไว้ โดยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) ประกอบด้วยชิ้นส่วน 2 ชิ้น คือ ชิ้นที่ 1 เป็นโอริงชั้นใน (10) เมื่อพิจารณาภาคตัดขวางของโอริงชิ้นนี้แล้วจะมีขอบหรือร่อง ทำหน้าที่เป็นที่วางและคั่นตะแกรงกรอง (7) และตะแกรงกรอง (4) กับข้อต่อวงแหวนแบบ ขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ส่วนชิ้นที่ 2 เป็นโอริงชั้นนอก (11) ทำหน้าที่ยึดติดกันกับโอริงชั้นใน (10) ซึ่งโอริง 2 ชิ้นนี้ ไม่สามารถถอดแยกออกจากกันได้ ข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) นี้ ที่ทำหน้าที่หุ้มและยึดโอริงทุกชิ้นเข้าด้วยกัน รวมทั้งยึดคอลัมน์กลวง (9) กับคอลัมน์กลวง (5) และยังยึดคอลัมน์กลวง (5) กับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) เข้าด้วยกันอีกด้วย นอกจากนี้ยังทำหน้าที่รับแรงกดจากการขันสกรูเข้า - ออก ในขณะถอดและประกอบคอลัมน์กลวงทั้ง 2 ชิ้น

เมื่อน้ำยางไหลเข้ามายังคอลัมน์กลวง (9) แล้ว ก่อนจะไหลเข้าสู่คอลัมน์กลวง (5) จะไหลผ่านตะแกรงกรอง (7) โดยที่ตะแกรงกรอง (7) จะวางอยู่บนโอริงชั้นใน (10) ของข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) ซึ่งตะแกรงกรอง (7) จะทำหน้าที่แยกสิ่งเจือปนออกจากน้ำยางและป้องกันการไหลของสารกรองปนไปกับน้ำยางในขณะกรอง จากนั้นน้ำยางไหลไปยังคอลัมน์กลวง (5) ซึ่งภายในบรรจุ

สารกรอง โดยที่สารกรองนี้เป็นสารกรองกลุ่มแคทไอออนและ/หรือแอนไอออน ที่ทำหน้าที่แลกเปลี่ยนประจุระหว่างประจุของโลหะในน้ำยางกับประจุที่ผิวสารกรอง

หลังจากนั้นน้ำยางจะไหลจากคอลัมน์กลวง (5) เข้าสู่คอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) โดยน้ำยางจะไหลผ่านตะแกรงกรอง (4) ซึ่งทำหน้าที่ป้องกันการไหลของสารกรองปนไปกับน้ำยางในขณะกรองเช่นเดียวกับตะแกรงกรอง (7) โดยที่ตะแกรงกรอง (4) จะถูกวางอยู่บนโอริงชั้นใน (10) ของข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ซึ่งเป็นข้อต่อแบบเดียวกันกับข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) ซึ่งทำหน้าที่ยึดคอลัมน์กลวง (5) กับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) จากนั้นน้ำยางจะไหลผ่านคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ออกสู่ภายนอกได้โดยการไขวาล์วปิด – เปิด ที่อยู่ตรงกลางคอลัมน์กลวงปลายแคบ (1)

การประกอบคอลัมน์ทั้ง 3 ส่วนเข้าด้วยกัน ดังนี้

1. นำคอลัมน์กลวงปลายแคบที่มีช่องใส่วาล์วปิด – เปิด (1) มาประกอบเข้ากับวาล์วปิด – เปิด (2) จากนั้นประกอบเข้ากับข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) แล้วปิดทับด้วยตะแกรงกรอง (4) จากนั้นนำคอลัมน์กลวง (5) มาประกอบเข้ากับข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) แล้วขันสกรูจนแน่น

2. เติมสารกรองกลุ่มแคทไอออนและ/หรือแอนไอออน ลงในคอลัมน์กลวง (5) จนเต็ม จากนั้นปิดทับด้วยตะแกรงกรอง (7) แล้วนำมาประกอบเข้ากับข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และคอลัมน์กลวง (9) จากนั้นขันสกรูให้แน่น

คำอธิบายรูปเขียนโดยย่อ

รูปที่ 1 ส่วนประกอบของชุดอุปกรณ์แยกโลหะในน้ำยาง

รูปที่ 2 ภาพด้านบนของข้อต่อแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม

วิธีการในการประดิษฐ์ที่ดีที่สุด

เหมือนกับที่ได้กล่าวไว้แล้วในหัวข้อการเปิดเผยการประดิษฐ์โดยสมบูรณ์

ข้อถือสิทธิ

1. ชุดอุปกรณ์แยกโลหะในน้ำยางประกอบด้วยคอลัมน์กลวง (9) เป็นคอลัมน์กลวงที่ปลายด้านล่างต่อกับคอลัมน์กลวง (5) ที่มีสารกรองบรรจุอยู่ ซึ่งยึดต่อกับคอลัมน์กลวง (9) ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และปลายอีกด้านของคอลัมน์กลวง (5) ต่อกับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) ด้วยข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3)

โดยมีลักษณะพิเศษ คือ

ข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ซึ่งประกอบด้วยชิ้นส่วน 2 ชิ้น คือ

ชิ้นที่ 1 เป็นโอริงชั้นใน (10) เมื่อพิจารณาภาคตัดขวางของโอริงชิ้นนี้แล้ว จะมีขอบหรือร่องทำหน้าที่เป็นที่วางและคั่นตะแกรงกรอง (7) และตะแกรงกรอง (4) กับข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3)

ชิ้นที่ 2 เป็นโอริงชั้นนอก (11) ทำหน้าที่ยึดติดกันกับโอริงชั้นใน (10) ซึ่งโอริง 2 ชิ้นนี้ ไม่สามารถถอดแยกออกจากกันได้ ข้อต่อวงแหวนแบบขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) นี้ ที่ทำหน้าที่หุ้มและยึดโอริงทุกชิ้นเข้าด้วยกัน รวมทั้งยึดคอลัมน์กลวง (9) กับคอลัมน์กลวง (5) และยังยึดคอลัมน์กลวง (5) กับคอลัมน์กลวงปลายแคบที่มีวาล์วปิด – เปิด (1) เข้าด้วยกัน

2. ชุดอุปกรณ์แยกโลหะในน้ำยางตามข้อถือสิทธิ 1 ที่ซึ่งภายในข้อต่อวงแหวนขันสกรูชนิดหกเหลี่ยมเกลียวเต็ม (8) และข้อต่อวงแหวนสกรูชนิดหกเหลี่ยมเกลียวเต็ม (3) ดังกล่าวยังประกอบเพิ่มเติมด้วยตะแกรงกรอง (7) และตะแกรงกรอง (4) ตามลำดับ โดยจะถูกวางอยู่บนขอบหรือร่องของโอริงชั้นใน (10)

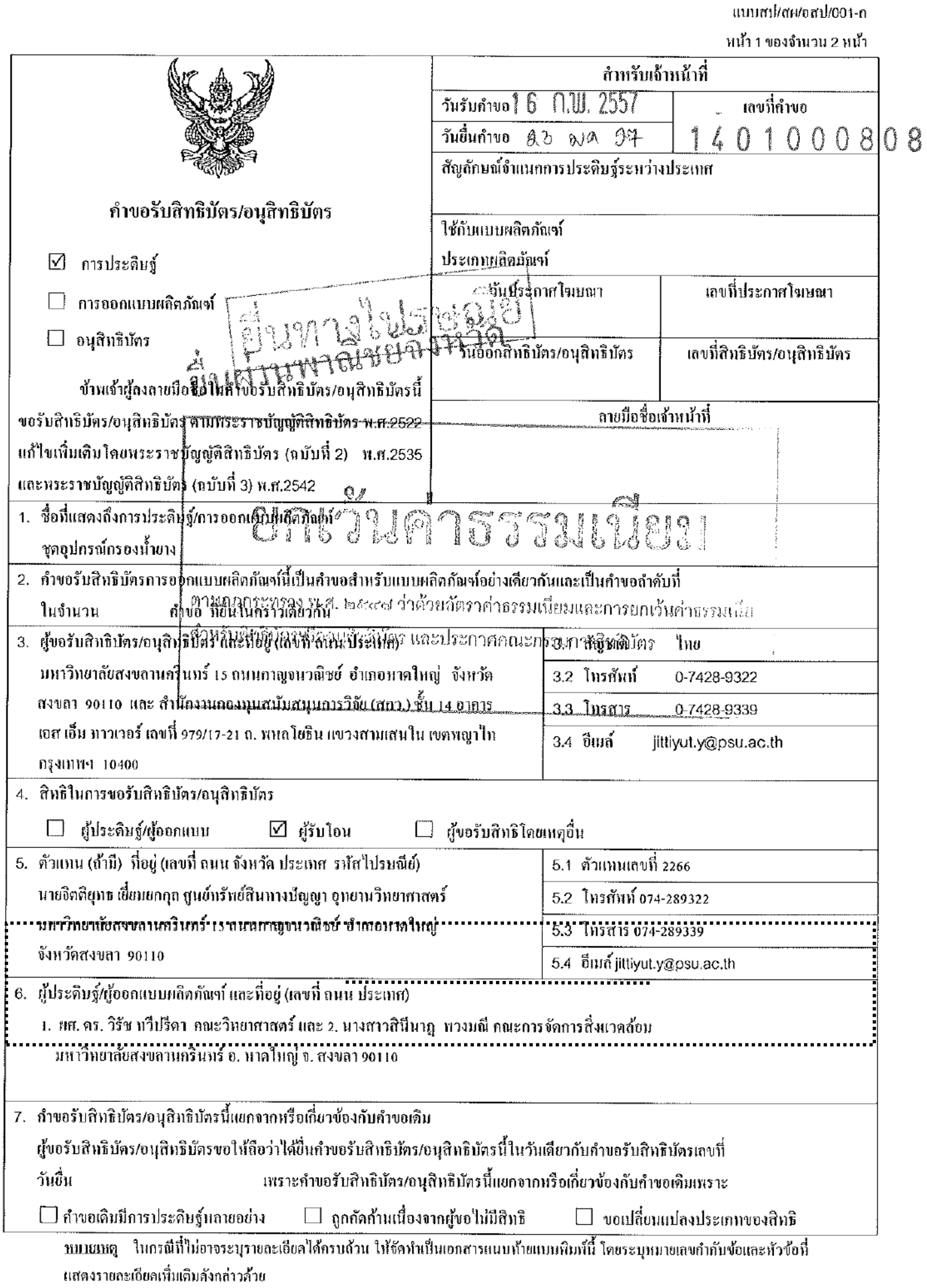
3. ชุดอุปกรณ์แยกโลหะในน้ำยางตามข้อถือสิทธิ 1 หรือ 2 ที่ซึ่งเป็นคอลัมน์กลวงทำจากวัสดุที่ทนต่อสารเคมี

4. ชุดอุปกรณ์แยกโลหะในน้ำยางตามข้อถือสิทธิ 1 - 3 ข้อใดข้อหนึ่งที่ซึ่งเป็นคอลัมน์กลวง (5) ภายในบรรจุสารกรองกลุ่มแคทไอออนและ/หรือกลุ่มแอนไอออน

Appendix C

Patents

Patent 2 “Latex Filter Equipment”



แบบสป/สผ/อสป/001-ก

หน้า 1 ของจำนวน 2 หน้า

คำขอรับสิทธิบัตร/อนุสิทธิบัตร

☑ การประดิษฐ์

☐ การออกแบบผลิตภัณฑ์

☐ อนุสิทธิบัตร

ข้าพเจ้าผู้ลงลายมือชื่อในคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ ขอรับสิทธิบัตร/อนุสิทธิบัตร ตามพระราชบัญญัติสิทธิบัตร พ.ศ.2522 แก้ไขเพิ่มเติมโดยพระราชบัญญัติสิทธิบัตร (ฉบับที่ 2) พ.ศ.2535 และพระราชบัญญัติสิทธิบัตร (ฉบับที่ 3) พ.ศ.2542

สำหรับเจ้าหน้าที่

วันรับคำขอ 16 ก.พ. 2557

วันยื่นคำขอ ๑๖ มค ๕๗

เลขที่คำขอ 1401000808

สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ

ใช้กับแบบผลิตภัณฑ์

ประเภทผลิตภัณฑ์

วันประกาศโฆษณา	เลขที่ประกาศโฆษณา
วันออกสิทธิบัตร/อนุสิทธิบัตร	**เลขที่สิทธิบัตร/อนุสิทธิบัตร**

ลายมือชื่อเจ้าหน้าที่

ยื่นทางไปรษณีย์

ยื่นผ่านพาณิชย์จังหวัด

ยกเว้นค่าธรรมเนียม

ตามกฎกระทรวง พ.ศ. ๒๕๔๗ ว่าด้วยอัตราค่าธรรมเนียมและการยกเว้นค่าธรรมเนียม สำหรับสถาบันอุดมศึกษาตามพระราชบัญญัติสิทธิบัตร และประกาศคณะกรรมการสิทธิบัตร

1. ชื่อที่แสดงถึงการประดิษฐ์/การออกแบบผลิตภัณฑ์
   ชุดอุปกรณ์กรองน้ำยาง

2. คำขอรับสิทธิบัตรการออกแบบผลิตภัณฑ์นี้เป็นคำขอสำหรับแบบผลิตภัณฑ์อย่างเดียวกันและเป็นคำขอลำดับที่
   ในจำนวน คำขอ ที่ยื่นในคราวเดียวกัน

3. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร และที่อยู่ (เลขที่ ถนน ประเทศ)
   มหาวิทยาลัยสงขลานครินทร์ 15 ถนนกาญจนวณิชย์ อำเภอหาดใหญ่ จังหวัดสงขลา 90110 และ สำนักงานกองทุนสนับสนุนการวิจัย (สกว.) ชั้น 14 อาคาร เอส เอ็ม ทาวเวอร์ เลขที่ 979/17-21 ถ. พหลโยธิน แขวงสามเสนใน เขตพญาไท กรุงเทพฯ 10400

3.1 สัญชาติ ไทย

3.2 โทรศัพท์ 0-7428-9322

3.3 โทรสาร 0-7428-9339

3.4 อีเมล์ jittiyut.y@psu.ac.th

4. สิทธิในการขอรับสิทธิบัตร/อนุสิทธิบัตร
   ☐ ผู้ประดิษฐ์/ผู้ออกแบบ ☑ ผู้รับโอน ☐ ผู้ขอรับสิทธิโดยเหตุอื่น

5. ตัวแทน (ถ้ามี) ที่อยู่ (เลขที่ ถนน จังหวัด ประเทศ รหัสไปรษณีย์)
   นายจิตติยุทธ เยี่ยมยกกุล ศูนย์ทรัพย์สินทางปัญญา อุทยานวิทยาศาสตร์ มหาวิทยาลัยสงขลานครินทร์ 15 ถนนกาญจนวณิชย์ อำเภอหาดใหญ่ จังหวัดสงขลา 90110

5.1 ตัวแทนเลขที่ 2266

5.2 โทรศัพท์ 074-289322

5.3 โทรสาร 074-289339

5.4 อีเมล์ jittiyut.y@psu.ac.th

6. ผู้ประดิษฐ์/ผู้ออกแบบผลิตภัณฑ์ และที่อยู่ (เลขที่ ถนน ประเทศ)
   1. ผศ. ดร. วิรัช ทวีปรีดา คณะวิทยาศาสตร์ และ 2. นางสาวสินีนาฎ พวงมณี คณะการจัดการสิ่งแวดล้อม มหาวิทยาลัยสงขลานครินทร์ อ. หาดใหญ่ จ. สงขลา 90110

7. คำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้แยกจากหรือเกี่ยวข้องกับคำขอเดิม
   ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอให้ถือว่าได้ยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ในวันเดียวกับคำขอรับสิทธิบัตรเลขที่
   วันยื่น เพราะคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้แยกจากหรือเกี่ยวข้องกับคำขอเดิมเพราะ
   ☐ คำขอเดิมมีการประดิษฐ์หลายอย่าง ☐ ถูกคัดค้านเนื่องจากผู้ขอไม่มีสิทธิ ☐ ขอเปลี่ยนแปลงประเภทของสิทธิ

<u>หมายเหตุ</u> ในกรณีที่ไม่อาจระบุรายละเอียดได้ครบถ้วน ให้จัดทำเป็นเอกสารแนบท้ายแบบพิมพ์นี้ โดยระบุหมายเลขกำกับข้อและหัวข้อที่แสดงรายละเอียดเพิ่มเติมดังกล่าวด้วย

แบบสป/สผ/อสป/001-ก

หน้า 2 ของจำนวน 2 หน้า

8. การยื่นคำขอนอกราชอาณาจักร

วันยื่นคำขอ	เลขที่คำขอ	ประเทศ	สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ	สถานะคำขอ
8.1				
8.2				
8.3				

8.4 ☐ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอสิทธิให้ถือว่าได้ยื่นคำขอนี้ในวันที่ได้ยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรในต่างประเทศเป็นครั้งแรกโดย

☐ ได้ยื่นเอกสารหลักฐานพร้อมคำขอนี้ ☐ ขอยื่นเอกสารหลักฐานหลังจากวันยื่นคำขอนี้

9. การแสดงการประดิษฐ์ หรือการออกแบบผลิตภัณฑ์ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรได้แสดงการประดิษฐ์ที่หน่วยงานของรัฐเป็นผู้จัด

วันแสดง วันเปิดงานแสดง ผู้จัด

10. การประดิษฐ์เกี่ยวกับจุลชีพ

10.1 เลขทะเบียนฝากเก็บ	10.2 วันที่ฝากเก็บ	10.3 สถาบันฝากเก็บ/ประเทศ

11. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร ขอยื่นเอกสารภาษาต่างประเทศก่อนในวันยื่นคำขอนี้ และจะจัดยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ที่จัดทำเป็นภาษาไทยภายใน 90 วัน นับจากวันยื่นคำขอนี้ โดยขอยื่นเป็นภาษา

☐ อังกฤษ ☐ ฝรั่งเศส ☐ เยอรมัน ☐ ญี่ปุ่น ☐ อื่น ๆ

12. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร ขอให้อธิบดีประกาศโฆษณาคำขอรับสิทธิบัตร หรือรับจดทะเบียน และประกาศโฆษณาอนุสิทธิบัตรนี้

หลังจากวันที่ เดือน พ.ศ.

☐ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอให้ใช้รูปเขียนหมายเลข ในการประกาศโฆษณา

13. คำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ประกอบด้วย

ก. แบบพิมพ์คำขอ 2 หน้า

ข. รายละเอียดการประดิษฐ์
หรือคำพรรณนาแบบผลิตภัณฑ์ 5 หน้า

ค. ข้อถือสิทธิ 1 หน้า

ง. รูปเขียน 3 รูป 3 หน้า

จ. ภาพแสดงแบบผลิตภัณฑ์

☐ รูปเขียน รูป หน้า

☐ ภาพถ่าย รูป หน้า

ฉ. บทสรุปการประดิษฐ์ 1 หน้า

14. เอกสารประกอบคำขอ

☑ เอกสารแสดงสิทธิในการขอรับสิทธิบัตร/อนุสิทธิบัตร

☐ หนังสือรับรองการแสดงการประดิษฐ์/การออกแบบผลิตภัณฑ์

☐ หนังสือมอบอำนาจ

☐ เอกสารรายละเอียดเกี่ยวกับจุลชีพ

☐ เอกสารการขอนับวันยื่นคำขอในต่างประเทศเป็นวันยื่นคำขอในประเทศไทย

☐ เอกสารขอเปลี่ยนแปลงประเภทของสิทธิ

☐ เอกสารอื่น ๆ

15. ข้าพเจ้าขอรับรองว่า

☑ การประดิษฐ์นี้ไม่เคยยื่นขอรับสิทธิบัตร/อนุสิทธิบัตรมาก่อน

☐ การประดิษฐ์นี้ได้พัฒนาปรับปรุงมาจาก..

16. ลายมือชื่อ (☐ ผู้ขอรับสิทธิบัตร / อนุสิทธิบัตร; ☑ ตัวแทน)

จิตติยุทธ เยี่ยมยกกุล

(นายจิตติยุทธ เยี่ยมยกกุล)
ตัวแทนผู้รับมอบอำนาจ

<u>หมายเหตุ</u> บุคคลใดยื่นคำขอรับสิทธิบัตรการประดิษฐ์หรือการออกแบบผลิตภัณฑ์ หรืออนุสิทธิบัตร โดยการแสดงข้อความอันเป็นเท็จแก่พนักงานเจ้าหน้าที่ เพื่อให้ได้ไปซึ่งสิทธิบัตรหรืออนุสิทธิบัตร ต้องระวางโทษจำคุกไม่เกินหกเดือน หรือปรับไม่เกินห้าพันบาท หรือทั้งจำทั้งปรับ

Advertisement

1/2

(19) กรมทรัพย์สินทางปัญญา
กระทรวงพาณิชย์

(11) **เลขที่ประกาศโฆษณา** 138061
(43) **วันประกาศโฆษณา** 18 พฤศจิกายน 2557

(12) ประกาศโฆษณาคำขอรับสิทธิบัตรการประดิษฐ์

(21) **เลขที่คำขอ** 1401000808
(22) **วันที่ยื่นคำขอ** 23 มกราคม 2557

(51) **สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ Int.Cl.10**
B07B 7/00

(31) **เลขที่คำขอที่ยื่นครั้งแรก**
-

(32) **วันที่ยื่นคำขอครั้งแรก**
-

(33) **ประเทศที่ยื่นคำขอครั้งแรก**
-

(71) **ผู้ขอรับสิทธิบัตร**
มหาวิทยาลัยสงขลานครินทร์
สำนักงานกองทุนสนับสนุนการวิจัย

(72) **ผู้ประดิษฐ์**
ผศ.ดร.วิรัช ทวีปรีดา
นางสาวสินีนาฏ พวงมณี

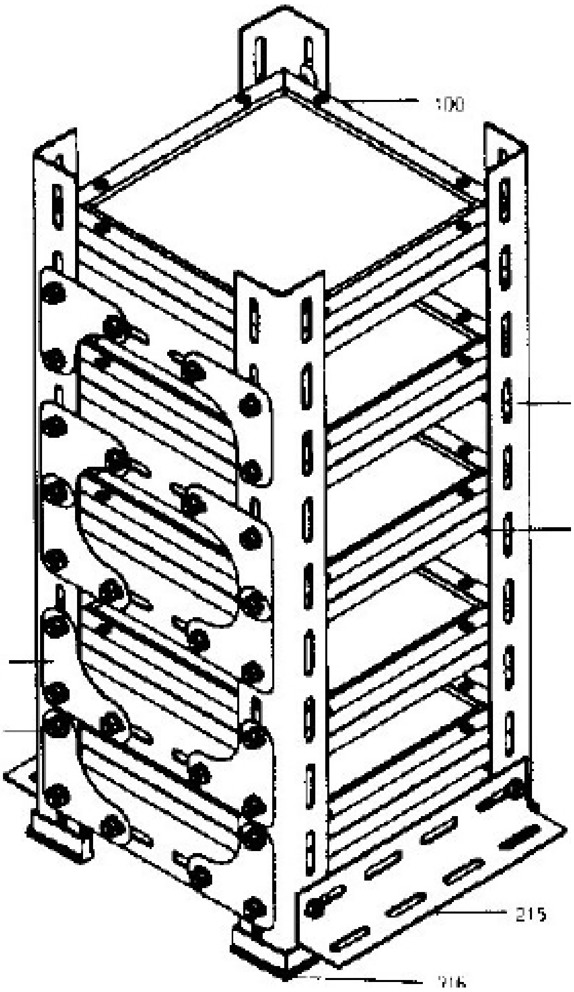
(74) **ตัวแทน**
นายจิตติยุทธ เยี่ยมยกกุล
ศูนย์ทรัพย์สินทางปัญญา อุทยานวิทยาศาสตร์
มหาวิทยาลัยสงขลานครินทร์ 15 ถ.กาญจนวณิชย์
อำเภอหาดใหญ่จังหวัดสงขลา 90110

(54) **ชื่อที่แสดงถึงการประดิษฐ์** ชุดอุปกรณ์กรองน้ำยาง

(57) **บทสรุปการประดิษฐ์**

การประดิษฐ์นี้เกี่ยวข้องกับชุดอุปกรณ์กรองน้ำยาง ที่ประกอบด้วยชุดตะแกรงกรอง (100) โดยที่มีชุดย่อยเป็นชุดตะแกรงหยาบ (110) ยางรองกันซึม (120) ชุดตะแกรงละเอียด (130) และนอตยึดตะแกรง (140) ประกอบเข้าด้วยกัน โดยที่มุมทั้ง 4 ของชุดตะแกรงกรองจะถูกวางอยู่บนบ่าของชุดขาตั้ง (200) ที่มีฐานค้ำยันโครงขาตั้ง (215) คอยรับน้ำหนักและค้ำยัน

(11) เลขที่ประกาศโฆษณา 138061



(ข้อถือสิทธิ 10 ข้อ, รูปเขียน 3 รูป)

Summary of the invention

บทสรุปการประดิษฐ์

การประดิษฐ์นี้เกี่ยวข้องกับชุดอุปกรณ์กรองน้ำยาง ที่ประกอบด้วยชุดตะแกรงกรอง (100) โดยที่มีชุดย่อยเป็นชุดตะแกรงหยาบ (110) ยางรองกันซึม (120) ชุดตะแกรงละเอียด (130) และนอตยึดตะแกรง (140) ประกอบเข้าด้วยกัน โดยที่มุมทั้ง 4 ของชุดตะแกรงกรองจะถูกวางอยู่บนบ่าของชุดขาตั้ง (200) ที่มีฐานค้ำยันโครงขาตั้ง (215) คอยรับน้ำหนักและค้ำยัน

Patent 1 “A Filter Head”

แบบสป/สผ/อสป/001-ก
หน้า 1 ของจำนวน 2 หน้า

คำขอรับสิทธิบัตร/อนุสิทธิบัตร

ยื่นทางไปรษณีย์

☐ การประดิษฐ์
☑ การออกแบบผลิตภัณฑ์
☐ อนุสิทธิบัตร

ข้าพเจ้าผู้ลงลายมือชื่อในคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ ขอรับสิทธิบัตร/อนุสิทธิบัตร ตามพระราชบัญญัติสิทธิบัตร พ.ศ.2522 แก้ไขเพิ่มเติมโดยพระราชบัญญัติสิทธิบัตร (ฉบับที่ 2) พ.ศ.2535 และพระราชบัญญัติสิทธิบัตร (ฉบับที่ 3) พ.ศ.2542

สำหรับเจ้าหน้าที่

วันรับคำขอ -5 ก.ย. 2556
วันยื่นคำขอ ๒๘ ส.ค. 56
เลขที่คำขอ 1302002483
สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ
ใช้กับแบบผลิตภัณฑ์
ประเภทผลิตภัณฑ์
วันประกาศโฆษณา
เลขที่ประกาศโฆษณา
วันออกสิทธิบัตร/อนุสิทธิบัตร
เลขที่สิทธิบัตร/อนุสิทธิบัตร
ลายมือชื่อเจ้าหน้าที่

1. ชื่อที่แสดงถึงการประดิษฐ์/การออกแบบผลิตภัณฑ์
หัวกรองน้ำยาง

2. คำขอรับสิทธิบัตรการออกแบบผลิตภัณฑ์นี้เป็นคำขอสำหรับแบบผลิตภัณฑ์อย่างเดียวกันและเป็นคำขอลำดับที่
ในจำนวน คำขอ ที่ยื่นในคราวเดียวกัน

3. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร และที่อยู่ (เลขที่ ถนน ประเทศ)
มหาวิทยาลัยสงขลานครินทร์ 15 ถนนกาญจนวณิชย์ อำเภอหาดใหญ่ จังหวัดสงขลา 90110
3.1 สัญชาติ ไทย
3.2 โทรศัพท์ 0-7428-9322
3.3 โทรสาร 0-7428-9339
3.4 อีเมล์ jittiyut.y@psu.ac.th

4. สิทธิในการขอรับสิทธิบัตร/อนุสิทธิบัตร
☐ ผู้ประดิษฐ์/ผู้ออกแบบ ☑ ผู้รับโอน ☐ ผู้ขอรับสิทธิโดยเหตุอื่น

5. ตัวแทน (ถ้ามี) ที่อยู่ (เลขที่ ถนน จังหวัด ประเทศ รหัสไปรษณีย์)
นายจิตติยุทธ เยี่ยมยกกุล ศูนย์ทรัพย์สินทางปัญญา อุทยานวิทยาศาสตร์ มหาวิทยาลัยสงขลานครินทร์ 15 ถนนกาญจนวณิชย์ อำเภอหาดใหญ่ จังหวัดสงขลา 90110
5.1 ตัวแทนเลขที่ 2266
5.2 โทรศัพท์ 074-289322
5.3 โทรสาร 074-289339
5.4 อีเมล์ jittiyut.y@psu.ac.th

6. ผู้ประดิษฐ์/ผู้ออกแบบผลิตภัณฑ์ และที่อยู่ (เลขที่ ถนน ประเทศ)
1. ผศ. ดร. วิรัช ทวีปรีดา คณะวิทยาศาสตร์ 2. นางสาวสินีนาฏ พวงมณี คณะการจัดการสิ่งแวดล้อม
มหาวิทยาลัยสงขลานครินทร์ อ. หาดใหญ่ จ. สงขลา 90110

7. คำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้แยกจากหรือเกี่ยวข้องกับคำขอเดิม
ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอให้ถือว่าได้ยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ในวันเดียวกับคำขอรับสิทธิบัตรเลขที่
วันยื่น เพราะคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้แยกจากหรือเกี่ยวข้องกับคำขอเดิมเพราะ
☐ คำขอเดิมมีการประดิษฐ์หลายอย่าง ☐ ถูกคัดค้านเนื่องจากผู้ขอไม่มีสิทธิ ☐ ขอเปลี่ยนแปลงประเภทของสิทธิ

<u>หมายเหตุ</u> ในกรณีที่ไม่อาจระบุรายละเอียดได้ครบถ้วน ให้จัดทำเป็นเอกสารแนบท้ายแบบพิมพ์นี้ โดยระบุหมายเลขกำกับข้อและหัวข้อที่แสดงรายละเอียดเพิ่มเติมดังกล่าวด้วย

แบบสป/สผ/อสป/001-ก

8. การยื่นคำขอนอกราชอาณาจักร

วันยื่นคำขอ	เลขที่คำขอ	ประเทศ	สัญลักษณ์จำแนกการประดิษฐ์ระหว่างประเทศ	สถานะคำขอ
8.1				
8.2				
8.3				

8.4 ☐ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอสิทธิให้ถือว่าได้ยื่นคำขอนี้ในวันที่ได้ยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรในต่างประเทศเป็นครั้งแรกโดย

☐ ได้ยื่นเอกสารหลักฐานพร้อมคำขอนี้ ☐ ขอยื่นเอกสารหลักฐานหลังจากวันยื่นคำขอนี้

9. การแสดงการประดิษฐ์ หรือการออกแบบผลิตภัณฑ์ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรได้แสดงการประดิษฐ์ที่หน่วยงานของรัฐเป็นผู้จัด

วันแสดง วันเปิดงานแสดง ผู้จัด

10. การประดิษฐ์เกี่ยวกับจุลชีพ

10.1 เลขทะเบียนฝากเก็บ

10.2 วันที่ฝากเก็บ

10.3 สถาบันฝากเก็บ/ประเทศ

11. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร ขอยื่นเอกสารภาษาต่างประเทศก่อนในวันยื่นคำขอนี้ และจะจัดยื่นคำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ที่จัดทำเป็นภาษาไทยภายใน 90 วัน นับจากวันยื่นคำขอนี้ โดยขอยื่นเป็นภาษา

☐ อังกฤษ ☐ ฝรั่งเศส ☐ เยอรมัน ☐ ญี่ปุ่น ☐ อื่น ๆ

12. ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตร ขอให้อธิบดีประกาศโฆษณาคำขอรับสิทธิบัตร หรือรับจดทะเบียน และประกาศโฆษณาอนุสิทธิบัตรนี้ หลังจากวันที่ เดือน พ.ศ.

☐ ผู้ขอรับสิทธิบัตร/อนุสิทธิบัตรขอให้ใช้รูปเขียนหมายเลข ในการประกาศโฆษณา

13. คำขอรับสิทธิบัตร/อนุสิทธิบัตรนี้ประกอบด้วย

ก. แบบพิมพ์คำขอ 2 หน้า

ข. รายละเอียดการประดิษฐ์
หรือคำพรรณนาแบบผลิตภัณฑ์ 1 หน้า

ค. ข้อถือสิทธิ 1 หน้า

ง. รูปเขียน 4 รูป 2 หน้า

จ. ภาพแสดงแบบผลิตภัณฑ์

☐ รูปเขียน รูป หน้า

☐ ภาพถ่าย รูป หน้า

ฉ. บทสรุปการประดิษฐ์ หน้า

14. เอกสารประกอบคำขอ

☑ เอกสารแสดงสิทธิในการขอรับสิทธิบัตร/อนุสิทธิบัตร

☐ หนังสือรับรองการแสดงการประดิษฐ์/การออกแบบผลิตภัณฑ์

☐ หนังสือมอบอำนาจ

☐ เอกสารรายละเอียดเกี่ยวกับจุลชีพ

☐ เอกสารการขอนับวันยื่นคำขอในต่างประเทศเป็นวันยื่นคำขอในประเทศไทย

☐ เอกสารขอเปลี่ยนแปลงประเภทของสิทธิ

☐ เอกสารอื่น ๆ

15. ข้าพเจ้าขอรับรองว่า

☑ การประดิษฐ์นี้ไม่เคยยื่นขอรับสิทธิบัตร/อนุสิทธิบัตรมาก่อน

☐ การประดิษฐ์นี้ได้พัฒนาปรับปรุงมาจาก..

16. ลายมือชื่อ (☐ ผู้ขอรับสิทธิบัตร / อนุสิทธิบัตร; ☑ ตัวแทน)

(นายจิตติยุทธ เยี่ยมยกกุล)

ตัวแทนผู้รับมอบอำนาจ

หมายเหตุ บุคคลใดยื่นคำขอรับสิทธิบัตรการประดิษฐ์หรือการออกแบบผลิตภัณฑ์ หรืออนุสิทธิบัตร โดยการแสดงข้อความอันเป็นเท็จแก่พนักงานเจ้าหน้าที่ เพื่อให้ได้ไปซึ่งสิทธิบัตรหรืออนุสิทธิบัตร ต้องระวางโทษจำคุกไม่เกินหกเดือน หรือปรับไม่เกินห้าพันบาท หรือทั้งจำทั้งปรับ

Advertisetment

1/1

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(43) **วันประกาศโฆษณา** 19 มิถุนายน 2558

(12) ประกาศโฆษณาคำขอรับสิทธิบัตรการออกแบบผลิตภัณฑ์

(21) **เลขที่คำขอ** 1302002483 (22) **วันที่ยื่นคำขอ** 28 สิงหาคม 2556	(51) **สัญลักษณ์จำแนกการออกแบบผลิตภัณฑ์ระหว่างประเทศ** 23-01
(31) **เลขที่คำขอที่ยื่นครั้งแรก** - (32) **วันที่ยื่นคำขอครั้งแรก** - (33) **ประเทศที่ยื่นคำขอครั้งแรก** -	(71) **ผู้ขอรับสิทธิบัตร** มหาวิทยาลัยสงขลานครินทร์ (72) **ผู้ประดิษฐ์** ผศ.ดร.วิรัช ทวีปรีดา และ นางสาวสินีนาฏ พวงมณี (74) **ตัวแทน** นายจิตติยุทธ เอี่ยมอกกุล

(54) **ชื่อที่แสดงถึงการออกแบบผลิตภัณฑ์** หัวกรองน้ำยาง

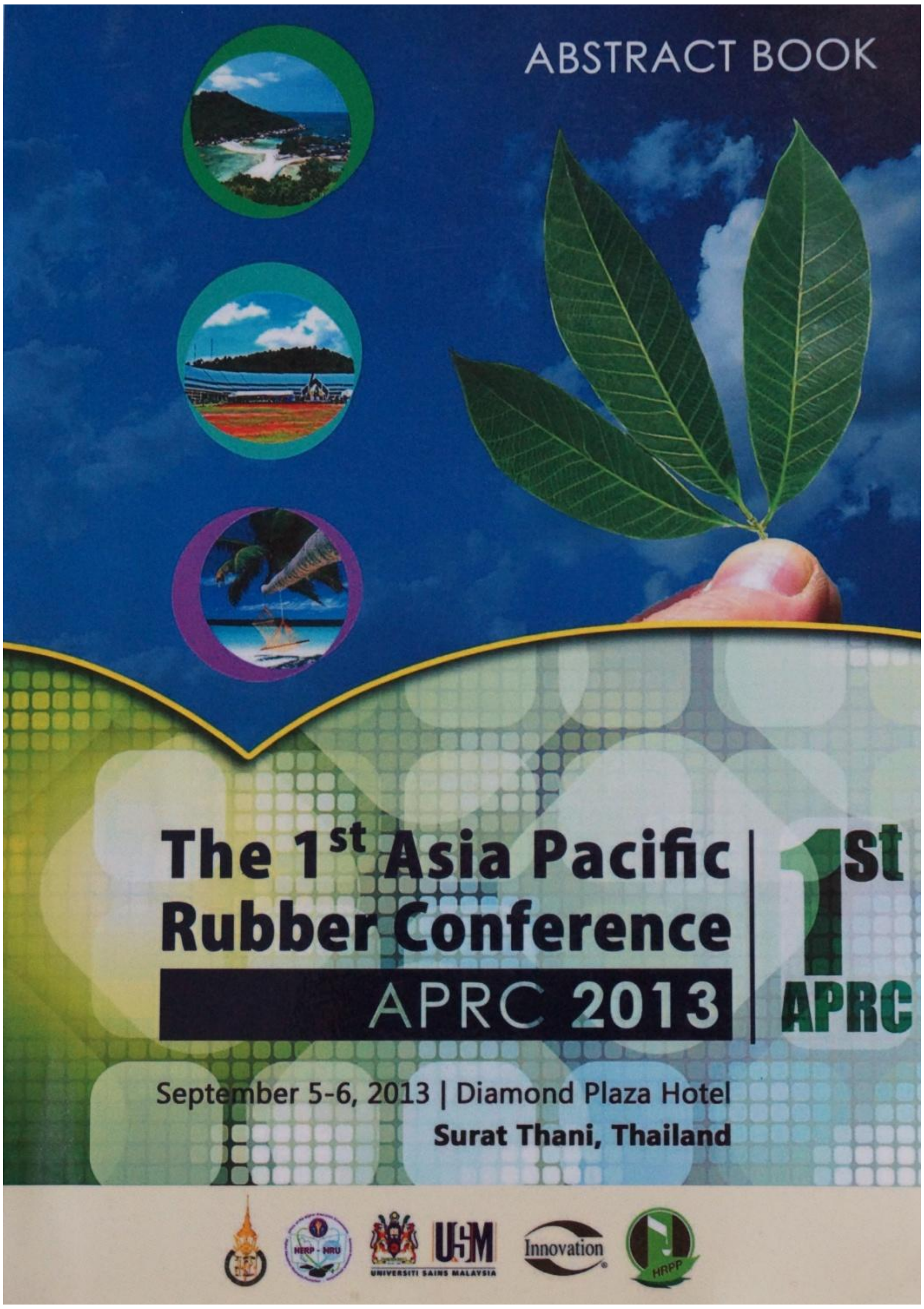
Appendix D

Conferences

Conference 1 (Oral presentation)

The 1st Asia Pacific Rubber Conference APRC 2013

5 – 6 September 2013, Diamond Plaza Hotel, Surat Thani, Thailand



ABSTRACT BOOK

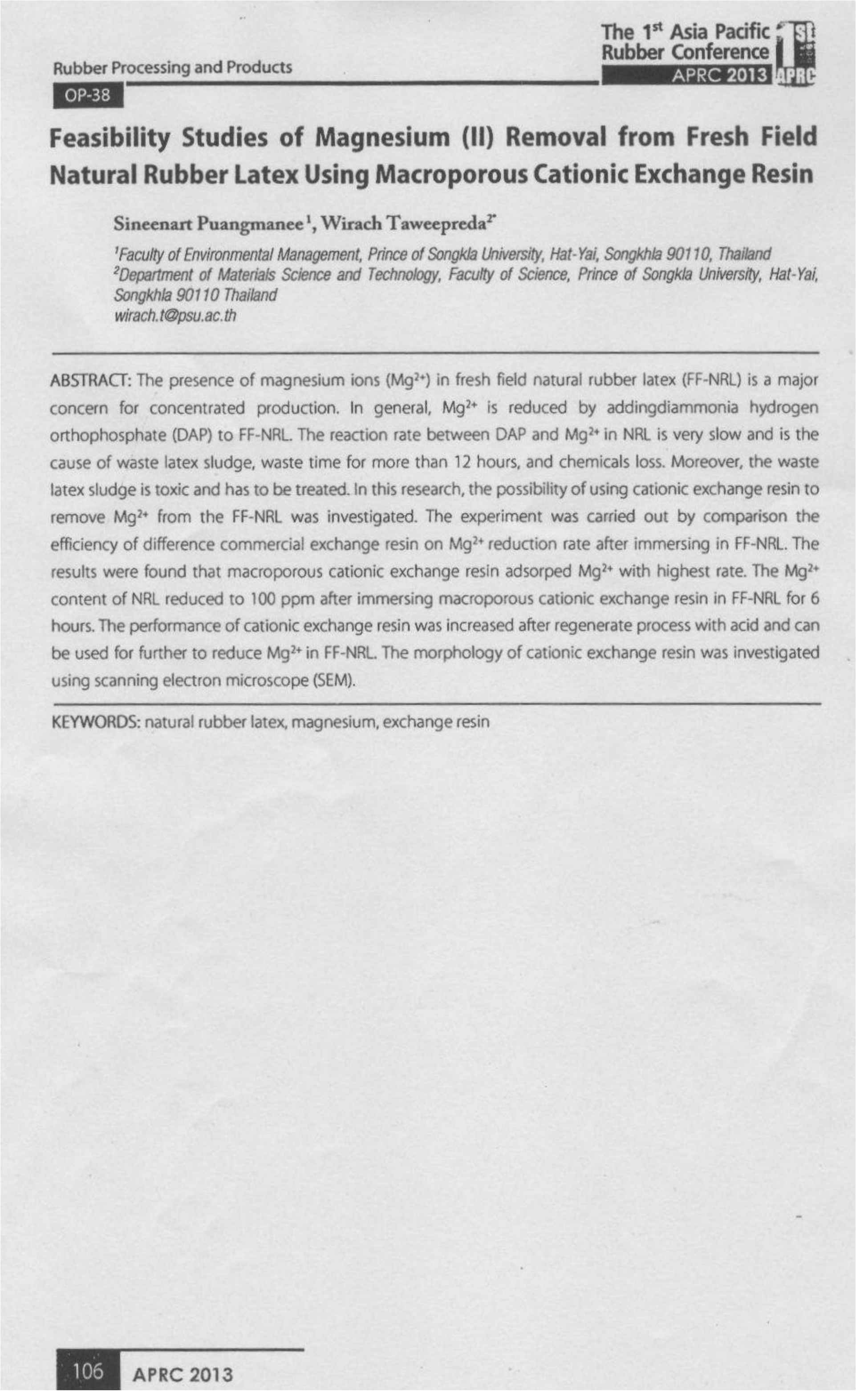
The 1st Asia Pacific Rubber Conference

APRC 2013

1st APRC

September 5-6, 2013 | Diamond Plaza Hotel
Surat Thani, Thailand

Abstract



Feasibility Studies of Magnesium (II) Removal from Fresh Field Natural Rubber Latex Using Macroporous Cationic Exchange Resin

Sineenart Puangmanee[1], **Wirach Taweepreda**[2*]

[1]Faculty of Environmental Management, Prince of Songkla University, Hat-Yai, Songkhla 90110, Thailand
[2]Department of Materials Science and Technology, Faculty of Science, Prince of Songkla University, Hat-Yai, Songkhla 90110 Thailand
wirach.t@psu.ac.th

ABSTRACT: The presence of magnesium ions (Mg^{2+}) in fresh field natural rubber latex (FF-NRL) is a major concern for concentrated production. In general, Mg^{2+} is reduced by addingdiammonia hydrogen orthophosphate (DAP) to FF-NRL. The reaction rate between DAP and Mg^{2+} in NRL is very slow and is the cause of waste latex sludge, waste time for more than 12 hours, and chemicals loss. Moreover, the waste latex sludge is toxic and has to be treated. In this research, the possibility of using cationic exchange resin to remove Mg^{2+} from the FF-NRL was investigated. The experiment was carried out by comparison the efficiency of difference commercial exchange resin on Mg^{2+} reduction rate after immersing in FF-NRL. The results were found that macroporous cationic exchange resin adsorped Mg^{2+} with highest rate. The Mg^{2+} content of NRL reduced to 100 ppm after immersing macroporous cationic exchange resin in FF-NRL for 6 hours. The performance of cationic exchange resin was increased after regenerate process with acid and can be used for further to reduce Mg^{2+} in FF-NRL. The morphology of cationic exchange resin was investigated using scanning electron microscope (SEM).

KEYWORDS: natural rubber latex, magnesium, exchange resin

Conference 2 (Oral presentation)

The sixth International Conference on Science, Technology and Innovation for Sustainable
Well-Being
28-30 August 2014, Apsara Angkor Resort & Conference, Siem Reap,
Kingdom of Cambodia

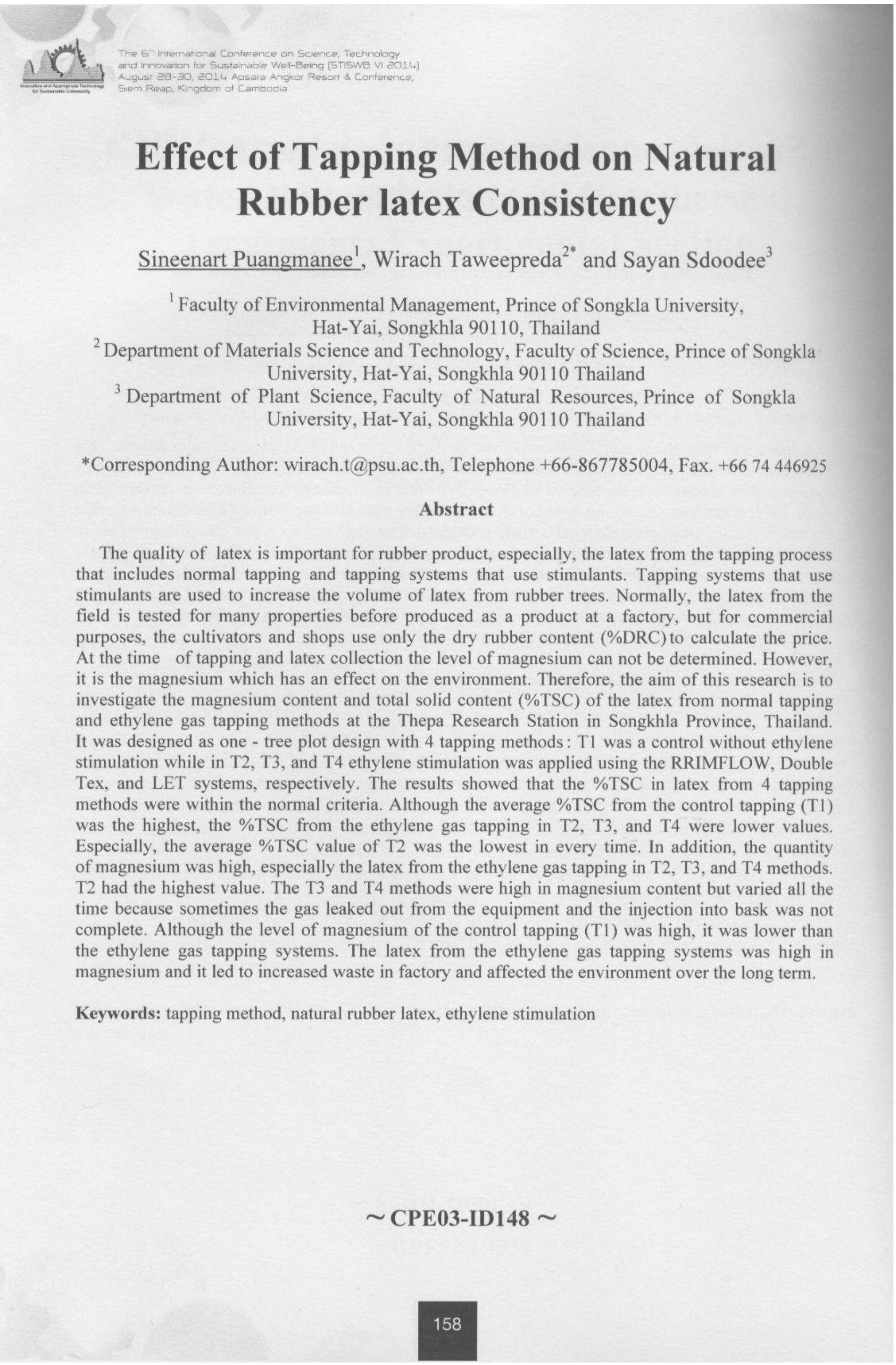
The Sixth
International Conference on
Science, Technology
and Innovation for
Sustainable Well-Being

STISWB VI
AUG 28-30, 2014
Innovative & Appropriate
Technology for Sustainable
Community

August 28-30, 2014
Apsara Angkor Resort & Conference,
Siem Reap, Kingdom of Cambodia

Faculty of Engineering,
Rajamangala University
of Technology Isan,
Khonkaen Campus

Abstract



The 6th International Conference on Science, Technology
and Innovation for Sustainable Well-Being (STISWB VI 2014)
August 28-30, 2014 Apsara Angkor Resort & Conference,
Siem Reap, Kingdom of Cambodia

Effect of Tapping Method on Natural Rubber latex Consistency

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Hat-Yai, Songkhla 90110, Thailand
[2] Department of Materials Science and Technology, Faculty of Science, Prince of Songkla
University, Hat-Yai, Songkhla 90110 Thailand
[3] Department of Plant Science, Faculty of Natural Resources, Prince of Songkla
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Abstract

The quality of latex is important for rubber product, especially, the latex from the tapping process that includes normal tapping and tapping systems that use stimulants. Tapping systems that use stimulants are used to increase the volume of latex from rubber trees. Normally, the latex from the field is tested for many properties before produced as a product at a factory, but for commercial purposes, the cultivators and shops use only the dry rubber content (%DRC) to calculate the price. At the time of tapping and latex collection the level of magnesium can not be determined. However, it is the magnesium which has an effect on the environment. Therefore, the aim of this research is to investigate the magnesium content and total solid content (%TSC) of the latex from normal tapping and ethylene gas tapping methods at the Thepa Research Station in Songkhla Province, Thailand. It was designed as one - tree plot design with 4 tapping methods: T1 was a control without ethylene stimulation while in T2, T3, and T4 ethylene stimulation was applied using the RRIMFLOW, Double Tex, and LET systems, respectively. The results showed that the %TSC in latex from 4 tapping methods were within the normal criteria. Although the average %TSC from the control tapping (T1) was the highest, the %TSC from the ethylene gas tapping in T2, T3, and T4 were lower values. Especially, the average %TSC value of T2 was the lowest in every time. In addition, the quantity of magnesium was high, especially the latex from the ethylene gas tapping in T2, T3, and T4 methods. T2 had the highest value. The T3 and T4 methods were high in magnesium content but varied all the time because sometimes the gas leaked out from the equipment and the injection into bask was not complete. Although the level of magnesium of the control tapping (T1) was high, it was lower than the ethylene gas tapping systems. The latex from the ethylene gas tapping systems was high in magnesium and it led to increased waste in factory and affected the environment over the long term.

Keywords: tapping method, natural rubber latex, ethylene stimulation

~ CPE03-ID148 ~

Conference 3 (Oral presentation)

NANOMATA 2014 International Symposium on Nano-Material,
Technology and Applications
15-17 October 2014, the campus of Vietnam National Unversity, Hanoi, Vietnam

NANOMATA2014
International Symposium
on Nano - Materials, Technology and Applications
15-17 October 2014, Hanoi, Vietnam

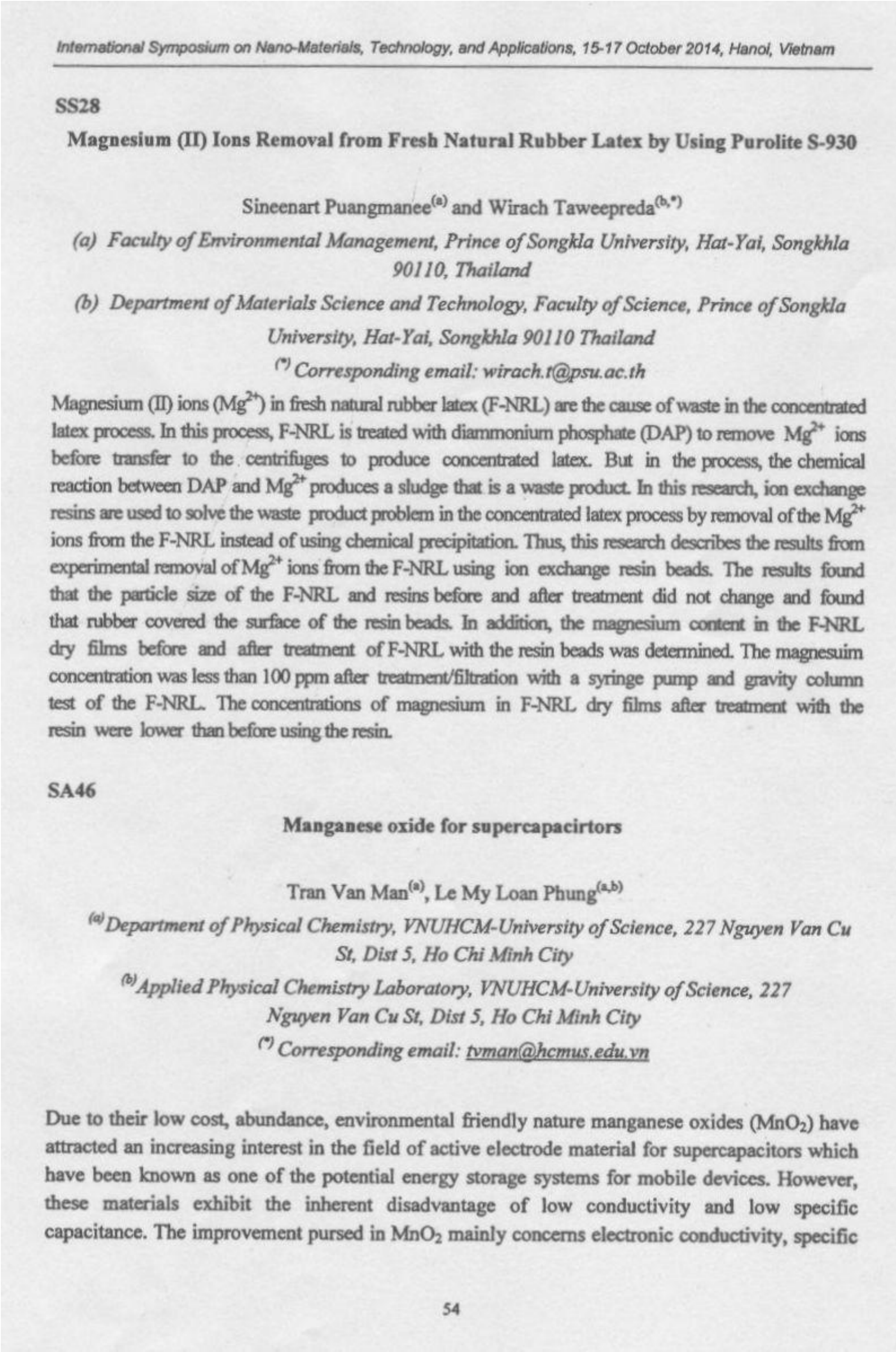
The Japan Institute of Metals and Materials

VNU-Journal of Science

10 ANNIVERSARY

Website: www.uet.vnu.edu.vn/nanomata2014

Abstract



SS28

Magnesium (II) Ions Removal from Fresh Natural Rubber Latex by Using Purolite S-930

Sineenart Puangmanee[(a)] and Wirach Taweepreda[(b,*)]
(a) Faculty of Environmental Management, Prince of Songkla University, Hat-Yai, Songkhla 90110, Thailand
(b) Department of Materials Science and Technology, Faculty of Science, Prince of Songkla University, Hat-Yai, Songkhla 90110 Thailand
(*) Corresponding email: wirach.t@psu.ac.th

Magnesium (II) ions (Mg^{2+}) in fresh natural rubber latex (F-NRL) are the cause of waste in the concentrated latex process. In this process, F-NRL is treated with diammonium phosphate (DAP) to remove Mg^{2+} ions before transfer to the centrifuges to produce concentrated latex. But in the process, the chemical reaction between DAP and Mg^{2+} produces a sludge that is a waste product. In this research, ion exchange resins are used to solve the waste product problem in the concentrated latex process by removal of the Mg^{2+} ions from the F-NRL instead of using chemical precipitation. Thus, this research describes the results from experimental removal of Mg^{2+} ions from the F-NRL using ion exchange resin beads. The results found that the particle size of the F-NRL and resins before and after treatment did not change and found that rubber covered the surface of the resin beads. In addition, the magnesium content in the F-NRL dry films before and after treatment of F-NRL with the resin beads was determined. The magnesuim concentration was less than 100 ppm after treatment/filtration with a syringe pump and gravity column test of the F-NRL. The concentrations of magnesium in F-NRL dry films after treatment with the resin were lower than before using the resin.

SA46

Manganese oxide for supercapacirtors

Tran Van Man[(a)], Le My Loan Phung[(a,b)]
[(a)]Department of Physical Chemistry, VNUHCM-University of Science, 227 Nguyen Van Cu St, Dist 5, Ho Chi Minh City
[(b)]Applied Physical Chemistry Laboratory, VNUHCM-University of Science, 227 Nguyen Van Cu St, Dist 5, Ho Chi Minh City
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Due to their low cost, abundance, environmental friendly nature manganese oxides (MnO_2) have attracted an increasing interest in the field of active electrode material for supercapacitors which have been known as one of the potential energy storage systems for mobile devices. However, these materials exhibit the inherent disadvantage of low conductivity and low specific capacitance. The improvement pursed in MnO_2 mainly concerns electronic conductivity, specific

Appendix E

Innovation Award

Innovation Award

Received Innovation Awards from National Research Council of Thailand and Rajamangala University of Technology Srivijaya and Good Award for Agro-Industry innovation type (Southern Region) 2013 in Green innovation for magnesium reduction of fresh field natural rubber latex.

วช.
NRCT

สำนักงานคณะกรรมการวิจัยแห่งชาติ
มอบประกาศนียบัตรนี้ เพื่อประกาศเกียรติคุณ
แก่
นางสาวสินีนาฏ พวงมณี
ในฐานะที่ได้รับ รางวัลระดับดี
ประเภท : การประกวดผลงานประดิษฐ์คิดค้น
กลุ่มเรื่อง : เพื่อการพัฒนาอุตสาหกรรมการเกษตร
ผลงานเรื่อง "นวัตกรรมสีเขียวเพื่อการลดแมกนีเซียมในน้ำยางสด"
โครงการส่งเสริมการวิจัยสิ่งประดิษฐ์ และเครือข่ายนวัตกรรมอุดมศึกษา (ภาคใต้)
ให้ไว้ ณ วันที่ ๑๔ กรกฎาคม พุทธศักราช ๒๕๕๖

(ศาสตราจารย์ นายแพทย์สุทธิพร จิตต์มิตรภาพ)
เลขาธิการคณะกรรมการวิจัยแห่งชาติ

VITAE

Name	Sineenart Puangmanee
Student ID	5310930012

Educational Attainment

Degree	**Name of Institution**	**Year of Graduation**
B.Sc.	Rajabhat Institute Phuket	2000
M.Sc.	Prince of Songkla University	2004

Scholarship Awards during Enrolment

Graduate School Research Support Funding for Thesis.

Office of The Higher Education Commission under a faculty development scholarship.

Thai-ASEAN Student Exchange Program Scholarships 2013 (Phase II) at the Faculty of Engineering, Physics and Technology, University of Engineering and Technology, Vietnam National University, Hanoi, Vietnam.

Received Innovation Awards from National Research Council of Thailand and Rajamangala University of Technology Srivijaya and Good Award for Agro-Industry innovation type (Southern Region) 2013 in Green innovation for magnesium reduction of fresh field natural rubber latex.

List of Publications and Proceedings

Publication

Puangmanee, S. and Taweepreda, W. 2014. Feasibility studies of magnesium (II) removal from fresh field natural rubber latex macroporous cation exchange resin. Advanced Material Research, 844 (2014) pp 198-200.

Proceeding

Puangmanee, S., Taweepreda, W., Sdoodee, S. 2014. Effect of tapping method on natural rubber latex consistency. Proceeding of The Sixth International Conference on Science, Technology and Innovation for Sustainable Well-Being (STISWB VI 2014), 158-162.

Petty patent and patent

Taweepreda, W. and Puangmanee, S. Petty Patent "Metal Separation Equipment for Latex " Petty patent application No. 1203001014, Petty patent No. 7720.

Taweepreda, W. and Puangmanee, S. Invention Patent "Latex Filter Equipment" Patent Application No. 1401000808.

Taweepreda, W. and Puangmanee, S. Production Patent "A Filter Head" Application No.1302002483.