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Situation of wastewater treatment of natural rubber latex processing in the Southeastern region, Vietnam

Tình hình xử lý nước thải sơ chế mủ cao su thiên nhiên ở vùng Đông Nam Bộ, Việt Nam

Review paper

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Rubber tree is one of the main plants which play an important role in the economy of Southeastern region, Vietnam. Approximately 90% of Vietnamese natural rubber latex is exported as raw products. The preliminary process of natural rubber latex discharges a large amount of wastewater to the environment. In Vietnam, there are many available technologies set up and operated for treatment wastewater of rubber latex processing. However, the effluent quality is still poor and the concentration of pollutants is higher than the required national technical regulation on the effluent of the natural rubber processing industry (QCVN 01:2008/BTNMT). Thus, this paper summarizes various technologies and methods currently applied for the treatment of latex processing wastewater in Vietnam. Additionally, the new effective methods being researched and applied in Thailand and Malaysia are also mentioned (countries with the highest production of natural rubber in the world). This paper also provides a screening of treatment technologies for reducing environmental pollution and contributing to high-quality effluent for meeting the required standard.

Cao su là một trong những cây trồng chính và đóng vai trò quan trọng trong nền kinh tế của miền Đông Nam Bộ, Việt Nam. Sản phẩm từ cây cao su thiên nhiên tại Việt Nam chủ yếu là xuất khẩu (khoảng 90%), tuy nhiên chỉ mới là dạng cao su thiên nhiên sơ chế. Quá trình sơ chế mủ cao su thiên nhiên thải bỏ một lượng lớn nước thải vào môi trường. Ở Việt Nam, hiện tại có rất nhiều công nghệ xử lý nước thải sơ chế mủ cao su đã được thiết lập và vận hành. Tuy nhiên, nồng độ ô nhiễm trong nước thải sau quá trình xử lý còn cao so với tiêu chuẩn yêu cầu (QCVN 01:2008/BTNMT). Vì vậy, bài báo này tóm tắt những công nghệ và phương pháp khác nhau được sử dụng để xử lý nước thải sơ chế mủ cao su tại Việt Nam gần đây. Thêm vào đó, những phương pháp mới và hiệu quả đang được nghiên cứu và áp dụng tại Malaysia và Thái Lan, những quốc gia có sản lượng sản xuất mủ cao su cao nhất trên thế giới cũng được giới thiệu. Bài báo này cũng cung cấp sự đa dạng của những phương pháp xử lý nhằm giảm thiểu ô nhiễm môi trường và góp phần đảm bảo chất lượng nước đầu ra đạt tiêu chuẩn cho phép.

Keywords: rubber processing, natural rubber latex wastewater, wastewater treatment, biological treatment, Vietnam

1. Introduction

According to the report of rubber industry in 2010, Vietnam was one of the world's biggest in growing area and productivity of natural rubber products, following Thailand, Indonesia, Malaysia and India (Le, 2010). In Vietnam, the rubber tree has been grown mostly in the South East region such as Binh Phuoc, Binh Duong, Tay Ninh, Dong Nai provinces etc. due to their favourable climate and suitable land for the optimum growth of rubber tree. Despite the great profits of natural rubber latex production, its processing releases a large amount of wastewater into the water bodies from such several processing steps such as coagulation, centrifugation, lamination, washing, drying etc.

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On average, the production of 1 ton of rubber products including Standard Vietnamese Rubber (SVR) or Ribbed Smoked Sheet (RSS) (dry weight) from the fresh latex discharges around 25 m^3 wastewater, while that from the miscellaneous rubber is around 35 m^3. However, 1 ton of natural rubber concentrated latex produced discharges just approximately 18 m^3 wastewater (Nguyen, 2003). Wastewater from the natural rubber latex processing is heavily polluted, pollution expressed in high suspended solids (the remaining latex), high organic matter and nitrogen-containing pollutants (N-organic, N-NH_3), high acidity and strong smell (the typical characteristics of wastewater from concentrated latex processing are displayed in Table 1).

Table 1. Characteristics of influent and effluent of the concentrated latex processing factories in South East region

No.	Items		Loc Hiep		Quan Loi		Tan Lap		Tan Bien	
	Name	Unit	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
1	pH	-	9.2	6.83	9.1	8.39	8.55	8.23	8.23	7.39
2	COD	mg/L	18,885	123	26,914	567	19,029	466	14,466	107
3	BOD	mg/L	10,780	57	8,750	40	7,830	70	9,200	92
4	TSS	mg/L	900	70	740	74	2,220	300	850	60
5	T-N	mg/L	611	35.3	766	160	713	40.6	450	65
6	NH_3	mg/L	341	30.8	361	37	302	34.5	350	47

Table 1. (cont)

No.	Items		Ven Ven		Bo La		Xuan Lap		QCVN 01:2008/BTNMT	
	Name	Unit	Influent	Effluent	Influent	Effluent	Influent	Effluent	A	B
1	pH	-	9.42	8.14	8.09	7.88	8.56	6.59	6 - 9	6 - 9
2	COD	mg/L	26,436	120	13,981	127	11,935	130	50	250
3	BOD	mg/L	13,820	85	7,590	61	8,780	60	30	50
4	TSS	mg/L	1,690	60	468	30	1,164	94	50	100
5	T-N	mg/L	651	74.9	972	120	1,306	67	15	60
6	NH_3	mg/L	285	33	686	30.3	1,043	50	5	40

Note: The above factories do not have the processing of skim latex. The data represent average values analysed during November 2011 at the processing factories Loc Hiep, Quan Loi, Tan Lap, Tan Bien, Ven Ven, Bo La and Xuan Lap.

Table 2. The average capacity of influent and the technical processes for wastewater treatment system of some rubber processing factories in South East region, Vietnam

No.	Factory	Company	Average volume capacity of influent (m^3/day) *		Technical process for wastewater treatment of the processing of concentrated latex rubber **
			Concentrated latex wastewater	Other kinds of wastewater (miscellaneous latex, SVR3L, SVR 10)	
1	Loc Hiep	Loc Ninh One Member Co., Ltd	450	550	Decantation - UASB – aeration tank – settling and filter
2	Quan Loi	Binh Long Rubber Company	500	-	Decantation – oxidation ditch – settling and filter
3	Tan Lap	Dong Phu Rubber Joint Stock Company	300	-	Decantation – oxidation ditch – settling and filter
4	Tan Bien	Tan Bien One Member Co., Ltd	300	700	Decantation – oxidation ditch – settling and filter
5	Ven Ven	Tay Ninh Rubber Joint Stock Company	550	950	Decantation – flotation – oxidation ditch – settling and filter
6	Bo La	Phuoc Hoa Rubber Joint Stock Company	400	-	Decantation – flotation – UASB – aeration tank – settling and filter
7	Xuan Lap	Dong Nai Rubber Coporation	700	1,000	Decantation – oxidation ditch – settling and filter

* The average data were calculated during November, 2011

** Source: Conference of the summarization of mechatronics, processing and environment of Vietnam Rubber Group, 2009

The discharge of wastewater directly into the environment without appropriate treatment will have a serious impact to the ecological balance. The wastewater of the concentrated latex processing from fresh latex rubber is the most polluted source compared to the processing of block rubber and miscellaneous rubber because of the high concentration of uncoagulated rubber particles and organic matters. If this process includes the processing of skim latex , the characteristic of wastewater is highly acidic and highly sulphated. However, the wastewater generated by the rubber block processing from the miscellaneous rubber is the less polluted because it originates mainly from the soaking and washing process of miscellaneous rubber. This wastewater just contains less-harmful matter such as leaves, sand, gravel, soil etc. and its pH value is neutral. In the processing of block rubber (SVR and RSS) from fresh rubber latex, the wastewater is discharged at various processing steps such as mixing, coagulation and mechanical manufacturing. This wastewater shows high acidity because of the residual amount of acid used for the coagulation latex as well as high concentration of uncoagulated latex particles.

2. Current situation and limitations of the wastewater treatment of natural rubber latex processing in Vietnam

There are many technologies applied for the treatment of rubber latex wastewater in many factories in South East region (Table 2), however, several limitations still exist, such as:

- The greatest difficulty of wastewater treatment of rubber processing factories in South East region is the low efficiency of the technologies. For example, the conventional decantation process is usually overloaded, thus the concentration of uncoagulated rubber particles in wastewater is very high, which causes difficulties for the following treatment. Additionally, the technologies including UASB, activated sludge, oxidation ditch etc. do not have enough ability to remove completely of Nitrogen-containing pollutants. Generally, rubber processing factories have not made good investments in new technologies in order to get the better effluent quality.

- Almost none of the total-nitrogen and ammonia in the rubber processing wastewater have not been treated completely yet.

- In biological treatment, the maintenance of microorganisms community is difficult and they usually die because of the high organic loads of rubber processing wastewater.

- The costs of chemicals and electricity at the stage of latex coagulation are very high (approximately 500,000 VND/ton of rubber product).

- The effluent quality of rubber processing wastewater used to be required to meet the national technical regulation (QCVN 01:2008/BTNMT), category B, but now it must be upgraded to category A (see Table 1), which has caused many difficulties for wastewater treatment plants.

- The effluent concentration of COD, BOD, Nitrogen (total N, N-NH_3) and SS (suspended solids) are still higher than the actual standard.

- Generally, the practical treatment capacity of natural rubber processing wastewater at almost all factories exceeds the initial designed capacity. Thus, the start-up stage is prolonged and the effluent does not meet the national technical regulations.

- Operation and periodic maintenance of the treatment stages have not been properly considered yet, thus, the efficiency of the whole wastewater treatment system is rather low.

Generally, the technologies of wastewater treatment of natural rubber processing in South East region are based on conventional biological processes, for example: pond system, oxidation ditch, anaerobic digestion and activated sludge. So far there is no implementation of a full combination of the biological, physical and chemical processes for the removal of the major pollutants in rubber processing wastewater. Therefore, they are not able to properly treat the natural rubber wastewater in order to meet the national technical standard. The advantages and disadvantages of the available technologies are as follows:

- The pond system costs least especially due to the missing operation costs. However, this process requires a large construction area, has strong smell and is harmful to the ground water without carefully revetting and waterproofing the pond. This process is suitable for less polluted wastewater and it should not be applied near residential areas. The method can be applied successfully for the treatment of wastewater from the miscellaneous rubber processing.

- Oxidation ditch process is stable, highly efficient for the removal of Nitrogen-containing pollutants and organic matter in rubber processing wastewater. This process is applied to treat wastewater containing high concentration of pollutants, especially wastewater with high ammonia concentration. However, applying and operating this process needs some conditions such as high qualified labor, it has high operation costs and needs periodic maintenance. Therefore, the oxidation ditch can be applied for the wastewater treatment of the processing of concentrated rubber latex and RSS.

- Anaerobic digestion and activated sludge processes are widely applied in factories because of their high efficiency in treating organic matter and the low operation cost. This method is suitable for highly polluted wastewater from the processing of RSS and SVR. However, anaerobic process is usually affected by ammonia level in rubber processing wastewater therefore spillway is applied to reduce the amount of acid used for coagulation stage as well as the concentration of ammonia in wastewater. The spillway is usually located outdoors to utilize sunlight for heating the skim latex and enable a quick evaporation of NH_3 (Vietnam Rubber Group, 2011).

3. Technologies for wastewater treatment from natural rubber latex processing in Vietnam

Generally, the wastewater of natural rubber latex processing is heavy polluted although most of the pollutants consist of biodegradable organic matter (95%) such as: volatile organic acid (acetic/formic acid), sugar, protein, lipids and mineral salts (Nguyen, 1999). Additionally, other components include suspended solids (in the remaining latex), organic matters (sugar, protein, lipid etc. in remaining latex), nitrogen-containing pollutants and others (sulphate, heavy metals etc). The removal of these compounds would permit unrestricted discharge of treated wastewater into the water bodies. The conventional methods for the treatment of such wastewater components released by the factories in South East region are summarized and analysed in this paper. Furthermore, the most effective technologies currently applied worldwide are also mentioned in order to provide a comprehensive understanding of the wastewater treatment of natural rubber latex in South East region, in particular, and in Vietnam, in general.

3.1 Removal of remaining latex

3.1.1 Decantation tank

Decantation tank is usually used to remove the remaining latex in wastewater system of almost all the processing factories because of the following advantages: low construction costs and low operating costs, unchanged properties of the obtaining latex after decantation and especially its reproduction together with miscellaneous rubber for new products. However, there is little research on optimal hydraulic retention time (HRT) of decantation tank and its removal efficiency is still low. Nguyen (2008) reported the use of two models consisting of decantation tanks equipped with coconut shell fibres (one containing 1 g/L cow dung and the other without dung) for the removal of the remaining latex in wastewater. The results showed that the highest efficiency and optimal HRT of the model without cow dung were 64.58% and 16 hours, respectively. The efficiency of this model is two times higher than the conventional decantation tanks used in processing factories in Vietnam (efficiency of the conventional decantation tank is usually between 10 and 30%). The research also showed that the addition of cow dung reduced the efficiency of decantation tank. However, the stability of coconut shell fibres used in decantation tank has not been studied completely yet. Thus, more research is needed on the life of coconut shell fibres in decantation tank as well as their proper disposal.

3.1.2 Decantation + stabilization + dissolved air flotation + coagulation and flocculation

The combination of processes such as decantation, stabilization, dissolved air flotation (DAF), coagulation and flocculation brings high removal efficiency of suspended solid (around 70%) but the costs of these processes are so high that it is difficult to apply widely (Ba Ria Rubber Company, 2006). Removal of remaining latex in the wastewater of natural rubber latex processing plays an important role in whole wastewater treatment system because it can reduce pollution load and the congestion of follow-up treatment. Therefore, the economy and efficiency of the removal of remaining latex should be considered thoroughly.

Generally, the physical treatment step in almost all the processing factories represents a rubber trap to recover the uncoagulated latex and other solid particles from the wastewater before the discharge to the secondary treatment units. However, the removal efficiency of the conventional rubber traps was observed to be rather slow. Therefore, the flotation technique has been researched in order to improve the treatment efficiency of conventional rubber traps in the concentrated latex industry (Somtip et al., 2009). The results implied that the pH adjustment the mixed wastewater from concentrated latex and skim rubber process lines to be 4.5 gave the highest coagulation efficiency. Additionally, the removal efficiency for SS, turbidity, COD and BOD was determined to be 98%, 99%, 80% and 81%, respectively. From this study, it can be concluded that air flotation could promote a higher treatment efficiency and rubber recovery from the rubber trap. The method should be considered as an alternative solution to be applied to wastewater management in the concentrated latex industry.

3.2 Removal of organic matter

3.2.1 Anaerobic and aerobic processes

The anaerobic and aerobic processes are conventional biological treatment methods applied for the removal of organic matter in wastewater due to their low operating costs, high removal efficiency and large amounts of biogas generated (anaerobic process). Anaerobic and aerobic processes are usually applied to treat the wastewater of natural rubber latex processing in some countries such as Malaysia, Thailand, Sri Lanka etc. (Mitra et al, 2010). The wastewater of concentrated latex processing contains high amount of sulphate because of the sulphuric acid (H_2SO_4) used in the latex coagulation. Therefore, one of the disadvantages of anaerobic process is the H_2S generated by sulphate reducing bacteria. The H_2S in gas form is toxic, has the smell of rotten eggs and it restrains the activities of methanogen bacteria in UASB process (Kantachote et al, 2005). Moreover, sulphur compounds in high concentration also reduce the COD removal efficiency of UASB systems. Thus, the reduction of sulphur concentration plays an important role for the treatment of rubber processing wastewater before the beginning of biogas production in UASB.

The anaerobic and aerobic models researched successfully by Nguyen (1990) were found suitable for the treatment of the wastewater of natural rubber latex processing. The results showed that UASB could be applied to treat wastewater with an organic load of 28.5 kg COD/m^3xd while the removal efficiency of COD was around 79.8% –

87.9%. Granular sludge was formed in UASB tank after 10 – 21 days of operation. This study also investigated four types of seed sludge such as fresh pig manure (FPM), digested pig manure sludge (DPMS), city polluted canal sludge (CS) and septic tank sludge (STS) for assessing the specific methanogen activity (SMA) of the start-up procedure in UASB process. The results showed that DPMS was strongly recommended as seed sludge for full-scale UASB reactor start-up while the SMA of DPMS amounts were the highest (0.13 – 0.26 g COD/g VSSxd). However, the remaining rubber particles affect the anaerobic biological process quite adversely. Thus, it is essential to develop an effective method for achieving a sufficient removal efficiency of suspended solids in order to achieve a high treatment efficiency of organic matters. Additionally, the work of Nguyen (2003) also indicated that anaerobic tank equipped with coconut shell fibres could treat almost all the organic matters in wastewater with a removal efficiency of 94.13% COD and 95% BOD.

3.2.2 Biological pond (lagoon system)

The biological ponds are generally used to remove organic matter in the wastewater of natural rubber latex due to their lowest operation cost and construction costs. They are very effective at removing disease-causing organisms (pathogens) from wastewater. The effluent released from the system can be suitable for irrigation (where appropriate) due to its high nutrient and low pathogen content. The biological pond system uses natural and energy-efficient processes to provide low-cost wastewater treatment. However, they show some difficulties for the application on large scale, including: large construction area, long HRT (over 30 days), low removal efficiency of organic matters and nitrogen compounds. Additionally, they are not effective at removing heavy metals from wastewater and they provide a breeding area for mosquitoes and other insects. According to Pham (2008), the application of pond systems (including decantation, stabilization, anaerobic ponds, three facultative ponds and sedimentation ponds) were used for the wastewater treatment at Thuan Phu processing factory. However, the treated wastewater does not meet the national technical regulations on effluent from natural rubber processing industry (QCVN 01:2008/BTNMT). The main reason for failure was considered to be the inefficient functionality of decantation step which created the formation of a thick layer of uncoagulated rubber particles in the following ponds. This limitation leads to a obstruction of sunlight to the surface of ponds, the poor growth of algae and other plants.

3.3 Removal of nitrogen-containing compounds

3.3.1 Oxidation ditch

The oxidation ditch is an advanced process based on biological activated sludge with long sludge retention time (SRT). The long SRT creates favorable conditions for the occurrence of nitrification and the elimination of biological organic matters. The oxidation ditch is equipped with an air supply system to provide oxygen for the microbial activities and fully mix wastewater and activated sludge. In the aerobic area of the oxidation ditch, autotrophic microorganisms (nitrifier bacteria) can oxidize ammonia ($N\text{-}NH_3$) into nitrite ($N\text{-}NO_2^-$) and then nitrate ($N\text{-}NO_3^-$). In anoxic area, the heterotrophic microorganisms can transfer nitrate and then return to nitrogen gas (N_2) discharged to the atmosphere. The sludge liquor in the anoxic zone is recycled in order to provide sufficient nitrate concentration for aerobic area. According to Pham (2008), the oxidation ditch is the most appropriate solution for nitrogen removal in the wastewater of natural rubber latex processing. The concentration of dissolved oxygen in channel is required to be kept over 3 mg/L. Moreover, the application of oxidation ditch to remove the nitrogen compounds in rubber processing wastewater was also researched by Ibrahim (1980). The results showed that removal efficiency of nitrogen compounds was very high (93.5 – 99%) with organic loading rates of 0.108 – 0.158 mg BOD/mg MLVSSxd^{-1}. The author also reported that the nitrification and de-nitrification processes occurred simultaneously in the ditch, followed by the release of nitrogen gas into atmosphere.

3.3.2 Algal pond

The algal pond was investigated from September 1999 to October 2002 by Nguyen (2003) at the Rubber Research Institute of Vietnam (Binh Duong province) for the wastewater treatment of natural rubber sheet processing. The results indicated that the removal efficiency of organic matter was very low (around 11% COD) at the HRT of 7 days. However, the assimilated ammoniac of the algal pond was very high, with a NH3 removal efficiency of nearly 99%. The research also showed that the algal pond could also partly oxidize the sulphate present in the wastewater.

3.4 Tertiary treatment for rubber latex processing wastewater

3.4.1 Filtration & polishing pond

The filtration with material such as sand, activated coal, gravel etc. is generally used to separate the remaining suspended solids in wastewater before discharging them into the water bodies. Additionally, polishing pond can also be applied to improve the effluent quality of wastewater treatment system. Plant species such as water hyacinth and water fern are usually cultivated in polishing ponds since they can assimilate organic compounds in low concentrations. The research of Nguyen (2008) was done by using a polishing pond cultivated with water hyacinth for the additional wastewater treatment. After the biological treatment step, the wastewater was transferred into the polishing pond containing water hyacinths. The plants were then responsible for the continuous removal of the remaining pollutants using the mechanism of nutrient assimilation. Moreover, the suspended solids could be removed by the root system of the plants after their settlement in the bottom of the tank. The water hyacinths were cultivated in the tank with the average density of 7 kg/m^2 surface and were maintained for about three months in order to obtain the density of 24 kg/m^2, then harvested and disposed properly. The results showed that the tank containing water hyacinth had low stability so the maintenance of the plants for having stable biomass was not easy to realise.

4. Advanced technologies for the treatment of wastewater from rubber processing industries in the world

Beside the conventional processes, there are many advanced technologies being researched worldwide for the wastewater treatment from natural rubber latex processing industry. These new technologies can overcome the existing disadvantage of conventional processes used in Vietnam therefore the following chapter will shortly introduce the most common ones.

4.1 In-situ methods (electrolysis, electrocoagulation, electroflotation)

The biological methods used for the treatment of rubber processing wastewater leads to long HRT and high shock load capacity. Nowadays, electrochemical method received a lot of consideration for wastewater treatment because of its cost, easy control, short HRT and high efficiency (Vijayaraghavan et al, 2008; Chopra et al, 2011). This method was developed based on in-situ hypochlorous acid (HOCl) generation. The hypochlorous acid was generated in an undivided electrolytic cell consisting of two sets of graphite, as anode, and stainless sheets, as cathode. The HOCl acid served as an oxidizing agent to destroy the organic compounds present in the latex wastewater. The results showed that in-situ generation of HOCl acid was effective towards the treatment of latex wastewater. The optimum operating conditions were found to be at an initial pH 4.5, the sodium chloride content was 3% and the current density 74.5 mA/cm^2. The results showed that at the end of a 90-min electrolysis period, the treated wastewater had the following characteristics: pH 7.3, COD 98%, BOD5 97%. The energy requirement for the setup above was 35 Wh/L at a current density of 74.5 mA/cm^2 with an electrolyte concentration 3% and treating 24 litres of latex-containing wastewater.

The electrochemical treatment requires only 30 – 45 min compared to the conventional biological treatment (such as activated sludge process) and the other aerobic oxidation methods (Vimalamma et al, 2009). Another advantage of electrochemical process is emulsion breaking and bleaching by oxygen ions produced in the reaction chamber oxidizes bacteria, viruses, sulphides and other biohazards. One of the main attractions of electrochemical treatment is the use of solar energy for electrolysis, which can be of great help for rural areas in order to reduce the running costs of the treatment processes.

4.2 Advanced treatment technologies

4.2.1 Advanced oxidation processes

Novel advanced oxidation processes (AOPs) show great promise for applications in many wastewater treatment areas. These AOPs utilize the very strong oxidizing power of hydroxyl radicals to oxidize organic compounds to the preferred end products of carbon dioxide and water. AOPs have many benefits in wastewater treatment because they can be applied for overall organic content reduction, specific pollutant destruction, sludge treatment, increasing bioavailability of recalcitrant organics and colour & odour reduction (John and James, 2009). The ozonation method can destroy the large molecular weight materials (non-biological organic materials) into small molecular ones. Ozone is one of the most active, readily available oxidizing agents, which can transfer ammonia into the nitrate. Moreover, ozonation process can eliminate odours, reduces oxygen demanding matter, turbidity and surfactants; increases dissolved oxygen and increases suspended solids reduction. The disadvantages of ozonation include high capital costs, high electricity consumption and is highly corrosive. A major limitation of the ozonation process is the relatively high cost of ozone generation, process coupled with a very short half-life period of ozone. Thus, ozone needs to be generated always at site. Moreover, the process efficiency is severely dependent on the efficient gas liquid mass transfer, which is quite difficult to achieve due to the low solubility of ozone in the aqueous solution. Therefore, new designs of contactors (for example static mixers) should be tackled with more studies to enable the use of ozonation in large-scale operation with lower treatment costs. And one solution to overcome the disadvantages mentioned above is to use ozone in combination with other techniques such as ultrasonic/ultraviolet irradiation, hydrogen peroxide etc (Gogate and Pandit, 2004). Generally, the non-biological matter is difficult to remove by conventional treatment methods as a result of their affinity for the liquid phase. Thus, ozonation process is considered as an advanced method for treatment of rubber latex processing. Rungruang and Babel (2008) studied the removal of biological matter and ammonia by ozonation process combined with batch activated sludge process (BAS) and their results showed that the optimal conditions for the removal of pollutants are 66.44 mg O_3/LO_2 of ozone concentration, pH 9 and the contact time of 30 minutes.

4.2.2 Membrane technology

The biological processes such as anaerobic-cum-facultative lagoons, anaerobic-cum-aerated lagoons, aerated lagoons and oxidation ditches have as main shortcomings the large land area requirement, high energy consumption for aerators and long period of the treatment, odour problem, high operation costs and high maintenance costs. Generally, the technology of membrane bioreactor (MBR) can overcome the disadvantages of biological methods. Currently, this technology had been researched for the treatment of rubber latex processing wastewater. This technology has many benefits such as small space requirement, high ability of disinfection and high loading rate capability; high removal solid and organic compounds that can enhance the biodegradation process (Le-Clech et al., 2003). The results of the research done by Nik et al. (2010) showed that the optimum flux of process was obtained at 0.009 m^3/m^{2}xh and at this flux rate, the process could be continuously operated more than one month without the chemical cleaning of membranes. The removal efficiency of COD 96.99% at the initial concentration of 3,500 mg/L COD, BOD 96.78%, total-N 65.17% and N-NH_3 61.35%.

5. Conclusions

Generally, the following three major pollutants originating from the natural rubber latex processing are found in the resulting wastewater: latex, organic matter and nitrogen-containing compounds. The typical biological treatment include anaerobic digestion, activated sludge and biological pond and is widely used for the treatment of wastewater from natural rubber processing. However, these processes do not have sufficient ability to meet the quality requirement for the effluent of natural rubber processing industry (QCVN 01:2008/BTNMT). Therefore, many advanced technologies are being investigated to obtain better effluent quality such as: coagulation-flocculation, flotation, membrane, ozonation etc. In conclusion, it is absolutely necessary to properly combine the biological, physical and chemical treatment processes in order to provide cost-effective solutions and high removal efficiency.

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