# Eco-Efficiency of Smart Reclaimed water management system: A case study of wastewater treatment from natural rubber processing (Condom Production)

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## Abstract.

The reuse of wastewater reuse has been hailed as a possible alternative solution to cope with the global water scarcity. Reclaimed wastewater may be used to restore the natural water bodies, maintaining the water quality while being environmentally friendly. Industries are demanding a higher quantity of water, which at the same time produces waste. Thailand is a major exporter in the world natural rubber latex production, it has been ability for rubber industries to seek appropriate measures for producing environmentally friendly rubber products. This research aims to study the possibility of reusing the wastewater from production and process in the condom factory through a wastewater treatment system and recycle the water using an IoT with a reverse osmosis method for zero discharge. The result of the study showed promise by lessening the environmental impact and decreasing the operation cost for water treatment. The financial analysis of the RO system was calculated to have a discount rate of 20.99% with a NPV of 679,759 THB/annum while having a discount payback period of 27 months, indicating that the project was feasible to invest. The ecoefficiency of the project was measured to be 1.47.

This can be a promising strategy but inherently associated operation and maintenance costs need to be considered to fully assess their potential cost-effectiveness.

**Keywords**. wastewater, IoT, Condom Production, RO system, Reclaimed water

## 1. INTRODUCTION

The Eastern Economic Corridor (EEC) development project is an extension of the success of the Eastern Seaboard under the Thailand 4.0 strategic plan. Thailand's great leap forward in the industrialization of new s-curve. Clean water and sanitation is the sixth item listed in United Nations Sustainable Development Goals with implementation of circular economic principles within the water sector a widely regarded approach to achieve this goal [1]. Goal 6. 3 specifically addresses the target to increase wastewater recycling and safe reuse. The 3Rs (reduce, reuse, recycle) of waste management are apprehensively analyzed for obtain recommendations and successful implementation of Circular Economy (CE) in the water sector.

Water reuse has become an effective economic solution to tackle the environmental issues for industries. Reusing effluents improves the industry' s image in terms of environmental impact and also reduces cost for the company as less treated water is purchased and there is less reliance on local water sanitation companies. Industrial water reuse and recycling is the process by which wastewater produced from one source is treated to be reused in the same process or recycled for another difference is effective in permeation through a membrane [2]. Opportunities for wastewater reuse and recycling in a natural rubber latex condom manufacturer plant includes a water management system to treat the effluent waste water. It has been demonstrated that a transmembrane pressure difference is effective in permeation through a membrane [3]. For a highly porous membrane with large pore size, the pressure required is lower than for a nanoporous or dense membrane such as the following structure (1) Reverse Osmosis) (2) Nanofiltration (3) Ultrafiltration and (4) Microfiltration [4].

Thailand is currently the world's largest natural rubber producer in the world. As the global leader in natural rubber latex production, it has been a challenge for rubber industries to implement appropriate measures to manufacture environmentally friendly rubber products. Condoms manufactured in Thailand are exported worldwide to many international markets such as China, United States, and Europe. Majority of condoms are made from natural rubber latex (NR condom), with some alternative non-latex synthetic condoms for people allergic to the natural latex protein [5]. The process for manufacturing both NR condom and synthetic condom are similar and follows the steps below; (Fig. 1.) [6].

*Incoming materials:* the primary raw material used in the production is rubber, which the company employs 60% latex as the main ingredient.

*Compound latex:* The latex will be homogenized with chemicals into a prevulcanized compound latex and allowed to mature to the appropriate swelling index to obtain a proportionate latex used to produce each type of condom.

*Dipping:* Starch and dried in a dryer.

*Visual inspection:* Primarily, our well-trained staff will visually screen the products by checking the condition of the condoms, such as leaks, the edges of the condom, unmatched color, etc.

*Electronic testing:* Arrange a capacitive hole tester forour testing to meet international standards.

*Foil & Packing:* The condom is foiled into individual package and packed into consumer boxes as per customer.

*Quality Assurance, Quality Control (QA/QC):* focused on identifying quality issues in manufactured products.


**Figure 1** Process of condom production.

Reclaiming water is an effective option for reducing environmental impact on the world by saving scarce water resources available through reuse of water treatment effluent.

Nowadays, research and practice in the digitalization of the water sector to create a smart water system: IoT (Internet of Things) is a flexible solution designed for the water utility industry, allowing for smarter decisions while optimizing the use of existing resources and investments. Interoperability is one of the key aspects of the IoT that contribute to its growing popularity. Connected or “smart” devices — as “things” in the IoT are often called —have the ability to gather and share data from their environments with other devices and networks. Thus, they need a special method to classify and recycle. In order to address these issues, we implemented the IoT for a wastewater managing system, which detects pollutants mixed in water using IoT and processed in the wastewater treatment into recycled water for reuse. The aim of this research is to study the possibility of reuse of the wastewater after processing the natural rubber processing (condom production) through the wastewater treatment system.

Many industries are concerned over the cost to comply with the stringent regulations set by industrialized nations over water quality. In order to tackle this issue, effective water treatment methods through the use of the latest trends, treatment technique, and alternative treatment technology is required to drive cost down for water treatment while providing quality water.

The activities to provide water and wastewater services result which harm to the health of people and the environment. Therefore, reducing water costs and moving to a sustainable water cycle, is a priority for water utilities. This study used ecoefficiency to analyze the effectiveness of the water utilities. Eco-efficiency is defined as the creation of more goods (outputs) and services with fewer resources (inputs) and a smaller environmental impact.

## 2. METHOD

There are steps, as follows (Fig 2): 1) as a first step to finding the design, 2) Installation process 3) Implementary of research, and 4) evaluation of research that has developed and analyze methods. The wastewater reuse system is presented in Figs. 3 and 4. Fig. 3 shows the process flow chart of the condom production wastewater reuse system, and Fig. 4 shows the point of sensor and meter controlled by IoT.


**Figure 2** Step of case study method.

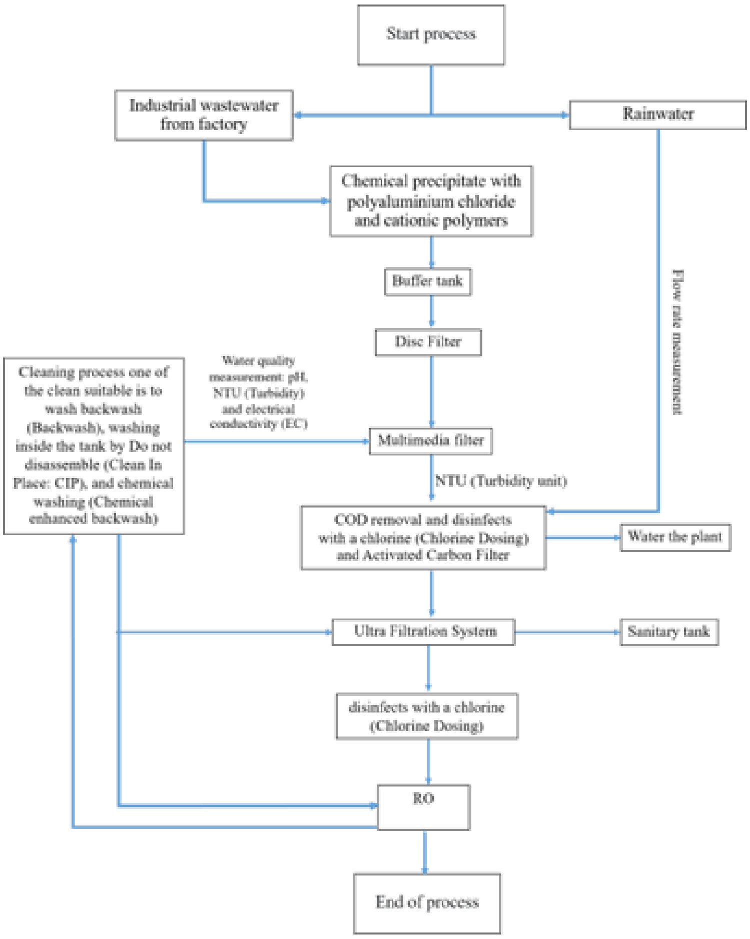


**Figure 3** Process Flow Chart – Wastewater treatment

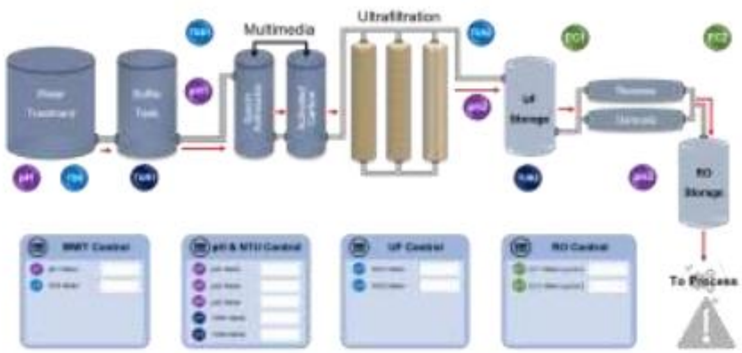


**Figure 4** Point of sensor and meter for measuring water quality with IoT real-time monitoring

2.1 *Ultrafiltration (UF) System*

A pretreatment system is a pre- filtration system designed to remove turbidity, sediment, suspended solids and other compounds such as Chlorine and organic substances that are harmful to the UF system or can result in the UF system not working properly.

It is a tube- type membrane filter cartridge that combines several tubes to trap sediment before use. It has the structure of the rewinding tank made of plastic There are pipes to use on 3 sides, with the top being the bile duct or Permeate, and the sides will have two sides. On one side is the water pipe into the system. On the other side is a water pipe or sewage. There is a filter that used a membrane with a size of 0.1-0.3 microns inside the cylinder. To filter sediment and impurities in the water. (Fig. 5)

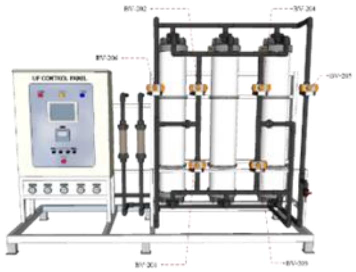

**Figure 5** Ultrafiltration (UF) System

2.2 *Reverse Osmosis System*

The feed water will be pumped from the water storage tank into the system through a series of filters starting with the 5µm sediment filter. Afterward, the water is filtered through a membrane filter, which separated the clean water into the RO tank and concentrated water which is directed to the waste collection tank for recycling. The feed water value is measured using the feed conductivity meter and the permeated conductivity smart meter with IoT device gets real-time water consumption (Fig. 6-7).


**Figure 6** Reverse Osmosis System

CIP for RO system will be done in case of high Concentrate Flow and low permeate flow or in case of inlet-outlet pressure of 5 microns filters having unequal pressure.

**Figure 7** Ultrafiltration and Reverse Osmosis System

2.3 *Eco-efficiency analysis*

Eco-efficiency refers to the ability of firms, industries, regions, or economies to produce more goods and services with fewer impacts on the environment and less consumption of natural resources. It is measured as a ratio of useful outputs (products and services) to environmental inputs (e.g., water consumption and energy consumption) or undesirable environmental outputs. For our study, eco-efficiency was defined as follows: [7]

$$\text{Eco-efficiency} = \frac{\text{Economic performance}}{\text{Environmental impacts}}$$

2.4 *Discounted Payback Period: DPB*

The discounted payback period (DPB) is calculated from the conversion of accumulated future cash flows received in the future to the present value before calculating from the equation [8].

5DPB = Amount before the payback period + (Unrefunded portion/ Cash flow incurred in the year of payback)

## 3. RESULT AND DISCUSSION

3.1 *Control of the wastewater treatment system, chemical quantity, and origin of wastewater.*

Wastewater from the production process has a total flow rate of 100 cubic meters per day. The wastewater is contaminated with natural latex, chemicals used in the latex mixing process, chemicals in the cleaning of latex tanks, various machines and containers. The wastewater is treated by a combination of sedimentation and chemical treatment through the coagulation-flocculation method with aluminum sulfate and cationic polymers. At the end of the wastewater treatment, the treated water is analyzed to ensure that the pH is within the range of 7 ± 0.5, the COD value not greater than 300 mg/ L and the total dissolved solid value (TDS) not exceeding 2,000 mg/L. The treated water conformed to the specification with the TDS value measuring to be 200 mg/L.

3.2 *Production Processes and Water Balance*

General water balance of the factory is illustrated in Figure 8. Annually 113,983 $m^3$ /day of water input is required, approximately 64,175.23 $m^3$/day of production processes, 49,807.77 $m^3$ /day water resource for consumption, 6,060.98 $m^3$/day of condensate for water reuse. 22,797.00 $m^3$ /day (20%) of water in production processes. The water source is well water which have been subjected to softening. Part of the softened water (102,755 $m^3$ /year) is directly used in the processes while the other portion (142,075 $m^3$ /year) is passed through a reverse osmosis unit to obtain the required water quality for certain production processes.

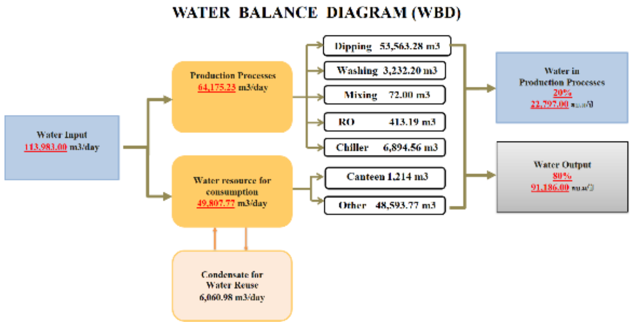


**Figure 8** Water balance diagram

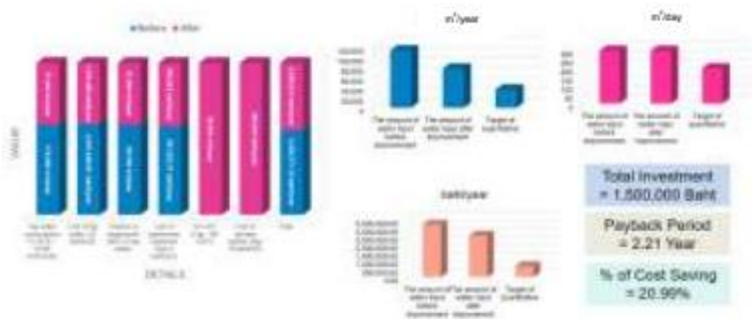


**Figure 9** Financial analysis of smart reclaimed water management system

3.3 *Financial analysis*

A preliminary financial analysis showed the feasibility of the proposed system. The discount rate was calculated to be 20.99% with a NPV of 679,759 baht per year. The discount payback period is 2 years and 3 months, indicating that the project is feasible to invest. (Fig. 9.). This concept's utility is illustrated in the article.

The capital costs for recently completed smart reclaimed water were also reviewed to validate the cost curve. Water is also used in many large scale industrial processes, hotspot of water consumption in the factory as presented in Fig. 10.

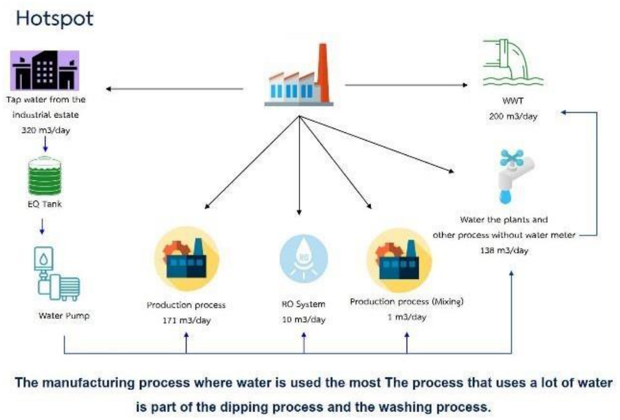


**Figure 10** Hotspot: water consumption in condom production

3.4 *Eco-efficiency*

In this study, we analyzed eco- efficiency trends by analyzing the environmental pressure and economic growth from 2019 to 2021 while aiming to find efficient ways of achieving sustainability.

We used clustering and regression techniques to help us understand the eco-efficiency drivers. Our study result showed that we were able to improve the eco-efficiency of our water treatment process in comparison to 2019 with the eco-efficiency value for 2021 being 1.47 (Fig. 11).

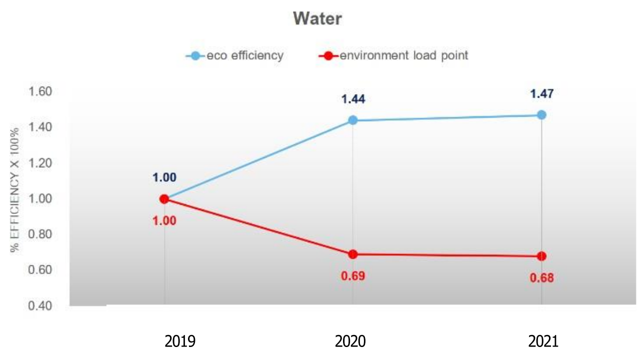


**Figure 11** Eco-Efficiency of water reclaimed water

Industrial water quality issues have been addressed in this study through water treatment methods by studying the use of the latest trends, treatment technique, and alternative treatment technology is required to drive cost down for water treatment while providing quality water.

This study analyzes the 2019 – 2021 eco-efficiency trends with the aim to contribute to the sustainable development of the Eco-factory. While eco-efficiency of all of the indicators that we analyzed showed improvements during the study period, a gap remained in comparison to the more advanced eco-efficiency observed both domestically and internationally. Decoupling indices were introduced in order to examine the decoupling relationship between environmental pressure and economic growth. This analysis demonstrated that some progress occurred during the study period resulting from the implementation of existing policies and measures entailing resource conservation and reduction in the emission of pollutants.

## 4. Conclusion

The present work examined and confirmed the possibility of using membrane technology for effluent treatment from an industrial wastewater treatment plant with the goal for reuse of the treated water through a combination of ultrafiltration followed by reverse osmosis. The study demonstrated the effectiveness of the treatment technologies of the reclaimed water system. The results of the study shows that the proposed smart reclaimed water treatment system is effective for our condom manufacturing plant and has the potential to be applicable for similar industries with similar volume and wastewater contaminants types [9].

## 5. Acknowledgment

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