EFFICIENT WATER MANAGEMENT SYSTEM IN PHARMACEUTICAL MANUFACTURING PREMISES

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RESEARCH PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (SAFETY, HEALTH AND ENVIRONMENT)

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ABSTRACT

Main source of drinking water suply in Malaysia is surface water stored in reservoirs. High operation and maintenance cost as well as environmental impacts are identified due to lack of sustainable sewage industry. Past studies have shown that water consumption in pharmaceutical industry is high due to high quality treated water requirement for the processes involved in the industry which led to high waste water generation and difficulty in treating the waste water. This study aimed to understand the water requirement for consumption in pharmaceutical manufacturing premises and identify possible solutions for reduction of water usage as well as reduce waste water generation from the processes involved. This study was carried out in a pharmaceutical manufacturing plant located in Peninsular Malaysia. Reverse Osmosis (RO) is one of the common water purififcation system in pharmaceutical industry which utilizes natural water osmosis phenomenon in reverse in order to produce purified water. Energy recovery devices are devices to recover the pressure energy from the reject stream and reuse it back in the process as the reject stream has a signifiant amount of energy resulted from high pressure and low recovery characteristic of Reverse Osmosis system. The Energy Recovery Device chosen was the Pressure Exchanger which was found was found to recover 28% of the high-pressure pump work, achieving annual savings of approximately 9800 kWh for the site at assumed 98% efficiency. Water recycling is reusing water for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin (referred to as ground water recharge) which offers resource and financial savings. The common water recycling is recycling of treated wastewater as the discharge is controlled at pharmaceutical industry. Overall high water consumption identified at site and average about 50 m^3/day of treated water being discharged daily to the perimeter drain found to be useful if reused for

other that drinking water usage which could save water consumption and the cost involved. Treated water can be used for purposes such as gardening, external area cleaning, toilet flushing, Chiller make up water, and cooling of ambient temperature of chiller units. Reusing treated water can reduce water consumption at site and treated water discharge could be recycled which will reduce the discharge to the surrounding. Hence, less impact to the environment and better management of natural resources at site. This research can be extended in more depth in terms of the process optimisation as in the manufacturing processes as this current research is about reducing and controlling the existing system energy consumption which does not impact the manufacturing processes.

ABSTRAK

Sumber utama air minuman di Malaysia adalah air permukaan yang disimpan di dalam takungan. Kos pengendalian dan penyelenggaraan yang tinggi serta kesan alam sekitar dikenal pasti kerana kekurangan industri kumbahan yang mapan. Kajian lepas menunjukkan bahawa penggunaan air dalam industri farmaseutikal adalah tinggi kerana keperluan air yang berkualiti tinggi untuk proses yang terlibat dalam industri yang membawa kepada penjanaan air sisa yang tinggi dan kesukaran untuk merawat air sisa. Kajian ini bertujuan untuk memahami keperluan air untuk kegunaan premis pembuatan farmaseutikal dan mengenal pasti penyelesaian yang berpotensi untuk pengurangan penggunaan air serta mengurangkan penjanaan air buangan daripada proses yang terlibat. Kajian ini dijalankan di loji pembuatan farmaseutikal yang terletak di Semenanjung Malaysia. Reverse Osmosis sebagai salah satu sistem pembersihan air yang terkenal dalam induktri farmaseutikal menggunakan fenomena osmosis air semula jadi dalam bentuk terbalik untuk menghasilkan air yang telah dibersihkan. Peranti pemulihan tenaga adalah peranti untuk memulihkan tenaga tekanan dari aliran penolakan dan menggunakannya semula dalam proses sebagai aliran penolakan mempunyai jumlah tenaga yang besar yang dihasilkan daripada tekanan tinggi dan ciri pemulihan yang rendah dalam sistem Reverse Osmosis. Peranti Pemulihan Tenaga yang dipilih adalah Penukar Tekanan yang didapati dijumpai untuk pulih 28% daripada kerja pam tekanan tinggi, mencapai penjimatan sebanyak 9811 kWh bagi sistem tersebut dengan andaian kecekapan 98%. Kitar semula air adalah menggunakan semula air untuk tujuan yang bermanfaat seperti pengairan pertanian dan lanskap, proses perindustrian, pembersihan tandas, dan penambahan semula air tanah (dirujuk sebagai cas semula air) yang menawarkan penjimatan sumber dan kewangan. Kitar semula air terkenal adalah kitar semula air buangan dirawat disebabkan oleh

pelepasan dikawal untuk industri farmaseutikal. Keseluruhan penggunaan air yang tinggi yang dikenal pasti di tapak dan purata kira-kira 50 m3 / hari air dirawat dilepaskan setiap hari ke longkang perimeter yang didapati berguna jika digunakan semula untuk penggunaan air selain sebagai minuman yang dapat menjimatkan penggunaan air dan kos yang terlibat. Air yang dirawat boleh digunakan untuk tujuan seperti berkebun, pembersihan kawasan luaran, pembersihan tandas, air untuk sistem pendingin angin dan penyejukan suhu ambien unit penyejuk. Penggunaan semula air yang dirawat dapat mengurangkan penggunaan air di tapak dan pelepasan air terawat boleh dikitar semula yang akan mengurangkan pelepasan ke sekitar. Oleh itu, kesan kepada alam sekitar dapat dikurangkan dan pengurusan sumber alam semula jadi yang lebih baik di tapak. Penyelidikan ini boleh menjadi lebih mendalam dari segi pengoptimuman proses seperti dalam proses pembuatan kerana penyelidikan semasa ini adalah mengenai mengurangkan dan mengawal penggunaan tenaga sistem yang sedia ada yang tidak memberi kesan kepada proses pembuatan.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

NLT	: NOT LESS THAN
NMT	: NOT MORE THAN

CHAPTER 1: INTRODUCTION

1.1 Background of Study

Main source of drinking water supply in Malaysia is surface water stored in reservoirs. Sources of ground water are limited and only available in certain states such as Kelantan as one of the state with the largest groundwater source. Access to water source is better in urban areas compared to rural areas. There are alternative souces available in rural areas such as tube wells and underground sources. High facilities cost led by geographical and other factors have caused low coverage for rural areas.

Per capita Water consumption in Malaysia is unsustainable as average household water consumption of 211 litres per day. This issue is alarming and have been worsening due to recent weather events such as “El Nino phenomenon” in 2016 causing water levels in many of the reservoirs to be at very low level as water had dried out. Besides that, water rationing was carried out in Selangor in 2014 affecting more than 60,000 households. Water supply is also affected by lack of good facilities causing water loss and later to water shortage.

Wastewater and sewerage treatment in Malaysia is similar to drinking water supply in terms of development. High operation and maintenance cost as well as enevironmental impacts are identified due to lack of sustainable sewage industry (Kim, C.T, 2013). The Indah Water Konsortium, Malaysia’s main sewerage operator, highlights that sustainable treatment capabilities is lacking in Malaysia and primarily depend on primary and secondary treatment. Tertiary treament is seen as future development removal of agricultural waste proved to be a challenge for current treatment systems. Furthermore, wastewater treatment plant is serving only about 56 percent of the population while the remaining of the population relies on septic tanks and flush systems. This is due to limited connectivity to sewerage networks and limited coverage of those networks.

Malaysia has been rebuilding its water sector as initiative to improvise the current services of water utilities in the past few years. The Malaysian Government's focuses on generation and supply of clean consumable water. The government has put resources into enhanced water infrastructure and restoring and growing of existing drinking water treatment plants and distribution networks. The government is currently looking to enhance water productivity and saving funds through incorporated water management at infrasturctures, water usage monitoring, decreasing loses and non-revenue consumption, and boosting general water accessibility and sustainability. This move is increasing investments in water efficient products, for example, as rainwater harvesting systems, smart monitoring and metering equipment, advanced leak detection equipment, non-revenue water control software, low-loss distribution equipment and storage equipment.

The technologies in treatment or existing and expected wastewater plants is mainly focussed in mechanical treatment methods such as Extended Aeration (EA), Oxidation Ditch (OD), Rotating Biological Contactors (RBC), Sequenced Batch Reactors (SBR) and Trickling Filters. Malaysian utilities favor build-transfer (BT) models for project development where capital investment, operations and maintenance is key element in management of the systems. Besides that, other demanding technologies include engineering, procurement and construction (EPC) services, advanced filtration, anaerobic digestion, nitrification, biological denitrification, monitoring, and testing equipment.

1.2 Problem Statement

Past studies have shown that water consumption in pharmaceutical industry is high due to high quality treated water requirement for the processes involved in the industry. High water consumption in processes involved have led to high waste water generation and difficulty in treating the waste water. This study aimed to understand the water requirement for consumption in pharmaceutical manufacturing premises and identify the possible solutions for reduction of water usage as well as reduce waste water generation from the processes involved. Appropriate systems and processes as tools to evaluate and implement reduction in water consumption efficently without compromising the quality of pharmaceutical products. The areas of focus would be areas with highest water consumption and wastages such as water purification system and manufacturing areas as well as cleaning processes involved. The solutions proposed would be generally on the overall reduction of water consumption respect to the system and processes involved at areas of focus in order to ensure significant water reduction in water consumption and wastages. This will in return reduce the likelihood of complications in treating the waste water generated and ensure compliance to the local regulatory requirements. Ultimately, the processes and system can be utilised to be cost efficient as well as environmental friendly. Previous reports have indicated that significant amount of water can be reduced if appropriate systems and processes are implemented in the premises.

The questions that arises from this research work are:

a. What are the possible sources of water usages in pharmaceutical industries?
b. How are the waste water generated in pharmaceutical industries?
c. What are the implication of high water consumption and wastages in treating the waste water in pharmaceutical industries?
d. Are there any means to reduce these wastages as well as treating the waste water generated efficiently?

1.3 Aim and Objective

The aim of the study is to reduce water consumption by pharmaceutical industries and have better control of treating the wastewater generated. To achieve this aim, the following objectives are defined:

a. To identify water consumption and sources of water wastages in a selected pharmaceutical premise.

b. To propose and evaluate possible water reducing strategies and techniques in the selected premise.

1.4 Scope of Study

This study was carried out in a pharmaceutical manufacturing plant located in Peninsular Malaysia. The selected plant has secondary pharmaceutical manufacturing facilities from raw material finished products to be transported. In order to achieve the objectives, several detailed scope as below was carried out:

a. Plant general process and process flow chart from selected premise to understand the overall water consumption on site.

b. Data collection on plant processes involved and its relevant departments such as environmental and engineering departments.

1.5 Report Layout

This research report consists of five main chapters. The chapters involves are as following:

Chapter 1: Introduction

This chapter covers introduction to pharmaceutical industry and also the aim of the study. In this chapter, the objectives are shown and scope of the study is defined.

Chapter 2: Literature Review

More detailed information on topics related to pharmaceutical industry, water consumption and other general information is discussed in this chapter. Water quality requirement had also been discussed in this section.

Chapter 3: Methodology

Methods were constructed to be carried out at the selected pharmaceutical plant. This chapter enable identification of water sources, water consumption and prevention of water wastages. Methods identified will ensure the achievements of the objectives of research.

Chapter 4: Results and Discussion

Results obtained from the pharmaceutical plant based on the methodology were then obtained and discussed in the form of tables and calculations.

Chapter 5: Conclusion and Recommendation

In this chapter, conclusions are made from the results obtained. Then, recommendations for future work were made to ease or improve future studies.

CHAPTER 2: LITERATURE REVIEW

2.1 Water Consumption in Industrial Sector

The largest energy as well as water consumption is consumed by the sector of of industries compared to other usages which is about 54% of total energy available. Pharmaceutical sector have high demand on sustainable, high quality water supply for production and advanced wastewater treatment systems needed to meet the regulatory discharge limits. Companies keep carrying out initiative to improve themselves from conventional thinking and typical approaches and explore new technologies and solutions to meet these challenges.

Water and energy are inter-related, and this increased focus on water and energy. Companies are looking into new technologies and integrated solutions to reduce water consumption and increase energy efficiency without compromising the availibility and reliability of the water and energy systems to meet the demands by the marketplace. Hence, there is a need for efficient water solutions and product safety in the pharmaceutical industry.

Pharmaceuticals as well as other industries taking effort in reduction of its operating costs in order to operate efficiently. Cost of ownership on a water systems is an important aspect of system design. New methods to reduce the cost of treating water, wastewater discharge, and infrastructure challenges legacy system designs are being explored. Most of the cost savings techniques offer enhanced reliability and performance of conventional water systems, while lowering cost of ownership.

Conservation of natural resources in the pharmaceutical industry is important as negative public perception and ratings from regulatory bodies as well as shareholders, can be present if not operating at an optimal level. Many more companies taking initiative on efficient use of natural resources and a sustainable global footprint. On top of that, companies experience increased demand and pressure from various entities including the public, regarding concerns about pharmaceuticals in drinking water. So, ensuring sustainable management of water supply is crutial for pharmaceutical industry including the manufacturing process and product development.

2.2 Water Consumption in Pharmaceutical Industry

Water consumption in pharmaceutical industry can be divided into three factors which are long-term lifecycle costs, regulatory requirements and corporate responsibility. Operating cost of water systems in pharmaceutical industry is high caused by the requirement to maintain certain level of quality to ensure product efficacy is well maintained. This led to complex designs and costly operation of water systems in pharmaceutical industry. Operating costs reduction had been one of the main issues in the industry to ensure companies operate efficiently as possible. Systems are designed such that the cost for maintenance is low and new methods are looked upon to reduce the cost of treating waste and to limit the water being discharged which is the main problem for older system designs. These new methods will ensure better reliability and performance of the water systems installed and hence reducing the costs of operations.

Regulatory requirement is one of the key element in pharmaceutical industry to meet the minimum water quality requirement and the limit of water discharge set for the industry in order to maintain regulatory compliance at all times. Since pharmaceutical industry carries the company image seriously as any negative influences would damage the companies' reputation in terms of public perception and level of trust given by regulatory to the companies as well the shareholders of the companies. Conservation of natural resources such as water will give more recognition for the companies for efficiency in managing natural resources. Water has become crucial resource for pharmaceutical industry for manufacturing processes as well as product development.

Water is used as direct ingredient and indirect uses such as cleaning, rinsing, sanitizing in pharmaceutical manufacturing processes whereby the water quality must be maintained to prevent microbial contamination which will have serious impact on the product and eventually affecting the product efficacy (Ridgway, H. F., & Safarik, J. 1991). Conventional methods such as recirculation of purified water supply and sanitization of the piping to prevent microbial contamination in the water supply used in the manufacturing processes. This makes the water system used in pharmaceutical industry costly and difficult to maintain as bacteria and viruses which can even challenge the best system designs. Thus, optimizing operating costs have become critical aspect in pharmaceutical and eventually any other industries as well.

Water systems are usually designed to be in redundancy to ensure water supply is available always as well as water supply can be maintained even during any maintenance or periodic preventive maintenance carried out in the system. Standby or backup water systems considered as redundant water systems and consume significant amount of energy in terms of electricity and water consumption as well as more wastewater generated as result of rejected water from the system which will eventually increase cost for treating wastewater for the companies.

Technologies are being developed for these water systems to eliminate unnecessary operating costs and reduce the amount of wastewater generated from the systems. For an example, The S3® system, a new technology provided by Siemens Water Technologies introduces a sanitize/start/stop design eliminated the unnecessary water wastages by simply shutting down the system when the manufacturing processes does not require water. While in standby mode, the system will perform periodic heat sanitization during the idle period of the system to prevent microbial contamination in the water supply. The system also performs brief pulse sanitization just before water is sent to the manufacturing process when needed. This system can also be incorporated with chemical cleaning, chemical sanitization and so on. Savings can be seen in both relatively small systems and higher savings can be seen in larger systems. These kinds of new methods are constantly developed as part of optimising the operating costs of water systems in pharmaceutical industry.

2.3 Water Purification System

There is an increased demand for efficient water treatment plants and this has motivated to the industry to explore systems in water purification which include using Reverse Osmosis (RO) processes. Reverse Osmosis (RO) utilizes the natural water osmosis phenomenon in reverse in order to produce purified water. The Reverse Osmosis (RO) can be carried out to different types of feed water with different specifications and parameters. For example, Reverse Osmosis can be applied to seawater, brackish water or reclaimed water. Different classifications of water sply come with different characteristics such as salinity, Total Dissolved Solids (TDS), Total Organic Carbon (TOC), pH, conductivity, etc. Reverse Osmosis specifications is dermined depending on the required water quality by the industry.

With high water consumption, wastewater management is another challenging issue. Wastewater Treatment Plant operates to treat waste water which is linked to the water purification systems as part of treating the rejects from the systems before being discharged. However, reducing the rejects is critical to utilize the water purification system efffciently as well as contributing in potential energy savings. Challenges involved in water purification systems would be reducing and controlling the water usage, minimizing the waste, saving the energy consumed and optimizing the processes that are carried out in the systems.

Water consumption in pharmaceutical sites is relatively high and demand on high quality water the water as perified water will be used in pharmaceutical products produced leading to sites having own purifications plants and WWTP.

2.4 Data Analysis

Water system data collection and analytical studies on the system in terms of analysing the water usage, the excessive use sources and the water is crucial in identifying and detecting the issues arising from the system and the areas of possible improvements on the systems.

Data analysis (Jain (2013) include scope and benefits as follow:

a. Organising the observations and findings from different sources of data
b. Breakdown of main issued into many minor issues
c. Filter and identification of important points in many complex data
d. Reliable research conclusion based on proper statistical and factual data

2.5 Reverse Osmosis System

Reverse Osmosis (Kar, 1994) process is a form of a membrane separation process. All the components will be retained in the solution other than the solvent itself from its idle form. Reverse Osmosis is a pressure driven process whereby is the first membrane-based separation to be commercialized to this level, and it consists of passing a pressurized feed solution through the membrane which leads to the purified membrane permeate which usually happens at atmospheric pressure and surrounding temperature and it is widely used for separation, concentration or fractionation of substances in fluid solutions (Sourirajan, S. 1970).

According to Greenlee, Lawler, Freeman, Marrot and Moulin (2009), reverse osmosis membrane technology has developed over the past 40 years to a 44% share in the total desalting worldwide, and an 80% share in the total number of desalination plants around the world.

There are generally two types of water sources used for Reverse Osmosis process which are seawater reverse osmosis (SWRO) and brackish water reverse osmosis (BWRO). This two water sources have differences in terms of process development, implementation, and the technical issues faced (Greenlee et. al ,2009).

According to the U.S. Energy Information Administration report for 2016, Reverse Osmosis plant is facing demand towards developing new plants that will deliver quality purified water with less costs as current energy costs make up to 40% of the total operational costs. Operating costs is a major concern and need to be optimised (MacHarg, 2011).

2.6 Energy Recovery Device

Energy recovery devices are devices to recover the pressure energy from the reject stream and reuse it back in the process as the reject stream has a signifiant amount of energy resulted from high pressure and low recovery characteristic of Reverse osmosis system. The utilization of energy revovery device could save on the operating cost. However, usage of energy recovery device is less prefered in brackish water reverse osmosis due to comparatively low pressure of the feed and reject stream (Martin and Eisberg, 2010). Nevertheless, potential for energy recovery devices in brackish water reverse osmosis process is encouraging as the need for reducing operating cost and the success of the devices in Seawater reverse osmosis process. However, due to different recovery level between brackish water reverse osmosis and seawater water reverse osmosis water recovery the implementation of the energy recovery device will also differ (MacHarg, 2011).

In a study by Macharg and McClellan done in 2004, pressure exchanger was succssfully applied brackish water reverse osmosis systems and could result in saving. The study concluded that the energy recovery device shows that energy recovery, with specifically throw pressure exchangers, can be applied to brackish water reverse osmosis plants with savings ranging between 10 to 30%. Martin and Eisberg (2010) also conducted a similar study concluding the energy recovery device effective in most brackish water reverse osmosis with a payback of less than 5 years for those plants that have a feed pressure of 150 psi or more.

Recirculation of the reject stream in order to get more overall system recovery can be achieved through installation of pressure exchanger by unbalancing the two streams through the device (MacHarg, 2011).

The unit applies the principle of positive displacement to pressurize the Reverse Osmosis feed stream that is filtered by contact with the high-pressure reject stream from a brackish water reverse osmosis. Pressure transfer happens in longitudinal ducts inside of a ceramic rotor, which is rotating within a ceramic sleeve. Each of the ducts operates individually as an isobaric chamber. This assembly is held between two ceramic end covers. At any instant, half the ducts are filled with the high pressure stream and the other half are filled with the low pressure stream (MacHarg, 2011). Figure 2.1 is an illustration of how a pressure exchanger operates, when the high and low-pressure flows are balanced i.e. B=D and I = H.

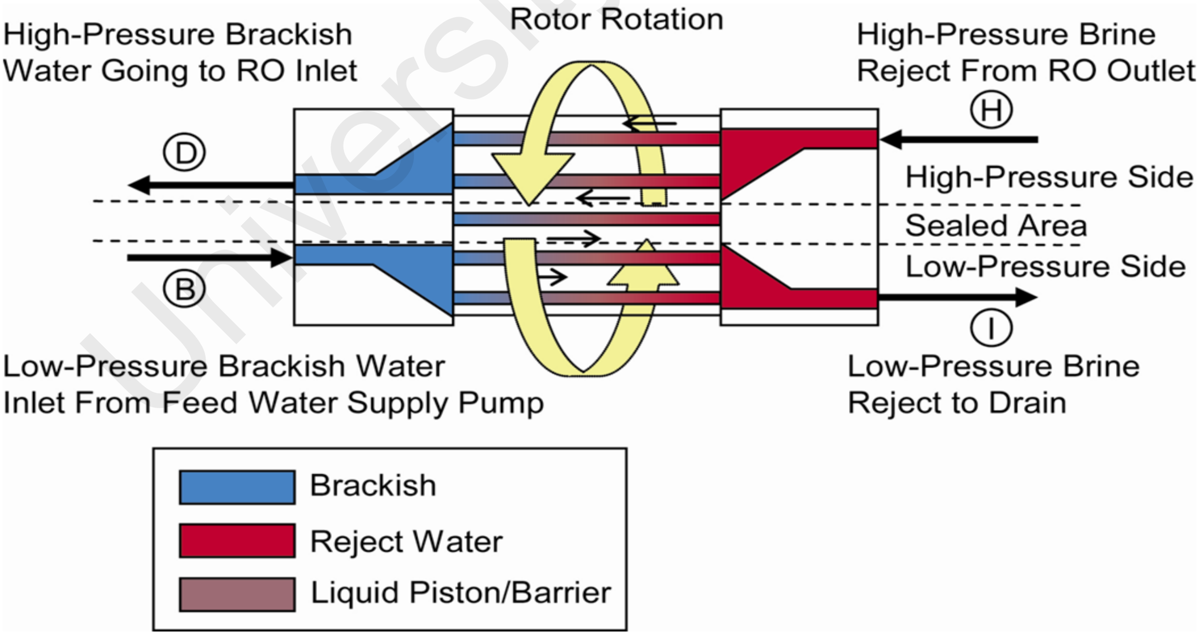

Figure 2.1: The internal flow paths of a pressure exchanger

2.7 Water Recycling

According to EPA (1991, 1992, 2012), water recycling is reusing water for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin (referred to as ground water recharge) which offers resource and financial savings. Wastewater treatment can be designed to meet the water quality requirements according to the intended usage. For example, recycled water for landscape irrigation requires less treatment compared to the requirement for drinking water. There is no human health problems documented due to contact with recycled water that has been treated to the required standards. Water can be recycled and reused onsite such as for cooling processes in industries. The most common type of recycled water is reclaimed water from municipal wastewater, or sewage. This is usually defined as water reclamation and water reuse.

Water recycling is often defined as "unplanned" or "planned." For example, unplanned water recycling occurs when cities draw their water supplies from rivers, such as the Colorado River and the Mississippi River, that receive wastewater discharges upstream from those cities. Water from these rivers has been reused, treated, and piped into the water supply a number of times before the last downstream user withdraws the water. Whereas planned projects are those that are developed with the goal of beneficially reusing a recycled water supply.

Recycled water if sufficiently treated to ensure water quality appropriate for the intended use will satify most of the water usage demands. Additional treatment might be needed where human exposure to the water is identified. Furthermore, health problems could arise from drinking or being exposed to recycled water if it is not treated properly.

Recycled water can be classified as nonpotable purposes, such as agriculture, landscape public parks, golf course irrigation, cooling water for power plants and oil refineries, processing water for mill, plants, toilet flushing, gardening and so on (Amin et al. 2011). However, there are number of projects use recycled water indirectly for potable purposes. These projects include recharging ground water aquifers and augmenting surface water reservoirs with recycled water whereby recycled water can be spread or injected into ground water aquifers to augment ground water supplies, and to prevent salt water intrusion in coastal areas. For example, since 1976, the Water Factory 21 Direct Injection Project, located in Orange County, California, treated recycled water was injected into the aquifer to prevent salt water intrusion, while augmenting the potable ground water supply.

Ground water recharge projects are common, planned augmentation of surface water reservoirs has been less common. For example, since 1978, the upper Occoquan Sewage Authority has been discharging recycled water into a stream above Occoquan Reservoir, a potable water supply source for Fairfax County, Virginia. In San Diego, California, the Indirect Potable Reuse Reservoir Augmentation Project is currently being studied. If the study is found feasible and approved, this project would be seen augmenting the San Vicente Reservoir with 12,000 acre-feet per year of recycled water treated at a new Advanced Water Treatment Plant.

Water recycling also provides benefits to the environment vy providing an alternative source of water and thus contributing in reduction in diversion of water from sensitive ecosystems while reducing wastewater discharges and preventing pollution.

Water recycling can decrease diversion of freshwater from sensitive ecosystems whereby plants, wildlife, and fish rely on water flowing to their habitat to live and reproduce which may be affected by diversion for agricultural, urban, and industrial purposes which can cause issues to quality and ecosystem health. Rrecycled water can supplement the current water demand which can spare significant amount of water for the environment and increase flows to important ecosystems.

Water recycling may not be caused by water supply need, but from a need to eliminate or decrease wastewater discharge to the ocean, an estuary, or a stream. For example, high volumes of treated wastewater discharged may affect the area's natural salt water marsh which may threaten the survival rate of endangered species. When treated water is reused, the pollutant loadings to these oceans, revers and other areas are decreased. For example, recycled water may contain higher levels of nutrients which when reused such as for agricultural and landscape irrigation can provide additional source of nutrients and lessen the need to apply synthetic fertilizers.

As the demand for water grows, more water is used which have environemental impacts such as the level of ground water becomes lower if the source is from ground water. Recycling water on site or nearby reduces the energy to transport and treat the water as well as providing water with sufficient treatement to meet required water quality to intended use. Recycled water that is of lower quality for uses such as toilet flushing could save energy and cost for tratment. However, treatment of wastewater for reuse and the installation of distribution systems can be expensive initially which can make it difficult to implement water recycling projects early in the planning process, agencies must reach out to the public to address any concerns and to keep the public informed and involved in the planning process.

As water energy demands and environmental needs grow, water recycling will play a greater role in our overall water supply as well in industry (Gadipely, 2014). By working together to overcome obstacles, water recycling, along with water conservation and efficiency, can help us to sustainably manage our vital water resources.

2.8 Summary of Literature Review

a. Water systems in industry us known for water wastages as there is no systems with 100% effeciency whereby the water being consumed is utilised fully and no water is rejected from the systems.

b. This literature review had also led to one of the most common water systems used in pharmaceutical industry which is Reverse Osmosis system which consumes significant amount of both energy and water as well as generating high amount of wastewater. This increases the operating cost as well wastages of water.

c. Since, Reverse Osmosis plant had been identified as high consumption of energy and water which needs to be analysed to implement the energy recovery system as potential to reduce the consumption energy in the plant as well as increase the efficientcy of the system.

d. Water recycling will also play a greater role in our overall water supply as water energy demands and environmental needs grow,. By working together to overcome obstacles, water recycling, along with water conservation and efficiency, can help us to sustainably manage our vital water resources.

e. The common water recycling is recycling of treated wastewater as the discharge is controlled at pharmaceutical industry. Exceeding the discharge limit will severe financial penalties or put a plant's operation at risk. In particular, pharmaceutical manufacturers must operate within strict national and local regulatory limits.

CHAPTER 3: METHODOLOGY

In this chapter, the methodology of this study is explained. This chapter highlights the overall flow of the study from literature research to recommendation from the study.

3.1 Averall Methodology Flow Chart

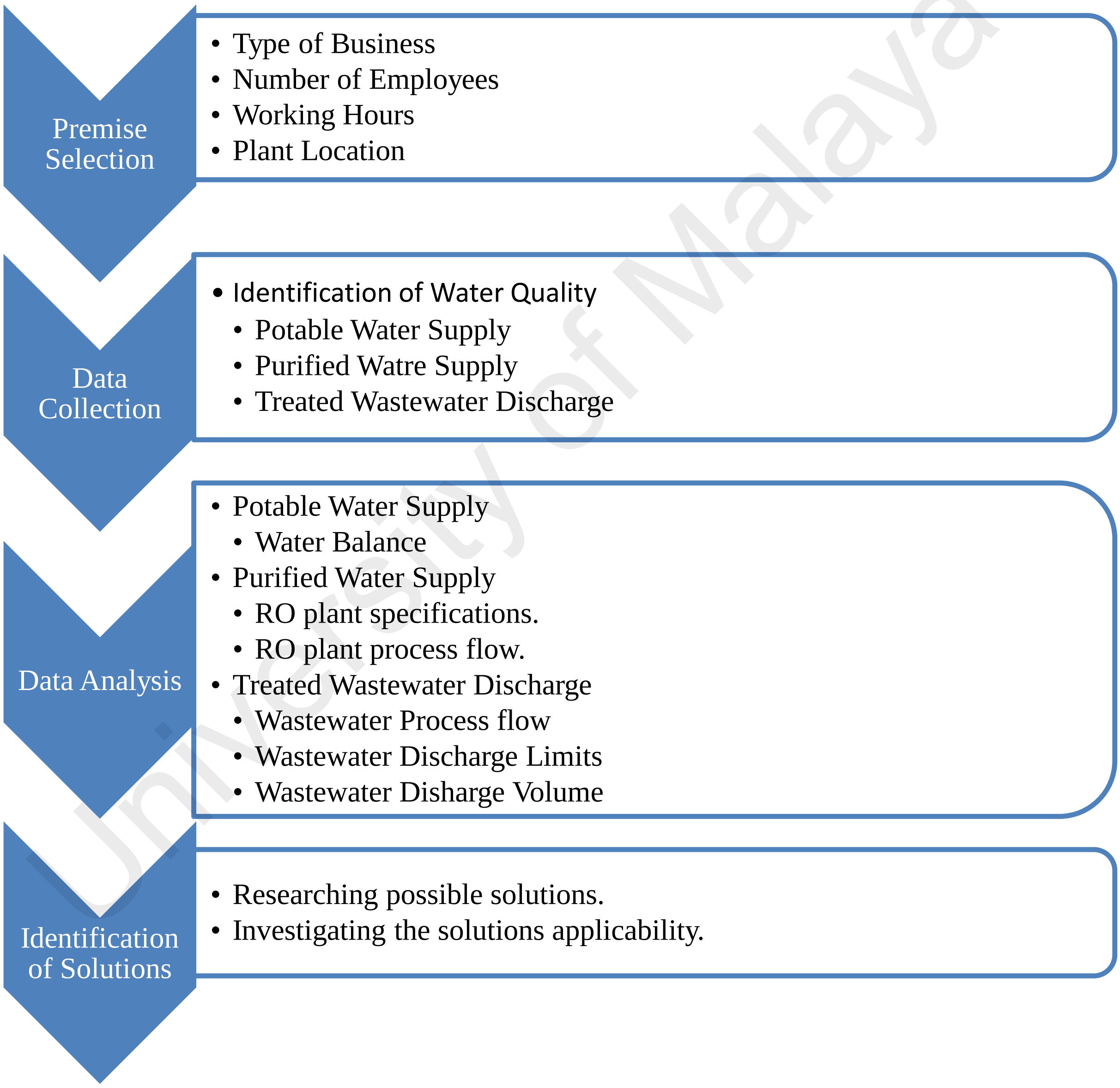

Figure 3.1 Methodology Flow Chart

3.2 Premise Selection

Most of the pharmaceutical manufacturing sites are located around Peninsular Malaysia. In this study, a pharmaceutical manufacturing plant was selected as case study. Basic information of the plant was retrieved from the plant is presented in table below.

Table 3.1: Information on Selected Premise

No.	Item	Description
2	Type of Business	Generic Consumer Healthcare Products Manufacturing
3	No. of Employees	200-250 Employees
4	Working Hours	Production: 3 shift operation (24 hours operation) Office: Normal Working Hours (8.00 am – 5.00 pm)
5	Plant Location	Central Region

3.3 Data Collection

The basic processes involved in water consumption, water treatment and waste water treatments had been discussed in Chapter 2. Information on process flow of water consumption and treatment available site will be collected. This section will also involve of collection of data for this study in the form of quantitive study to obtain the water consumption patern and the water and waste water treatment involved at site.

3.3.1 Identification of Water Quality

3.3.1.1 Potable Water Supply

This step, which is the water usage investigation, revolved around type of water consumption and quality of water required by the site. For example, water supplied for the toilets, offices are potable water suplied by local water services and the water used for production processes are purified water from Reverse Osmosis Plant which have different water quality requirements.

An Excel sheet (Daily Water Tracking Sheet) to better show the water consumption trends and irregularities and use it as a way of identifying those areas. The data to fill the Excel sheet was obtained from the company's daily readings taken for the water consumption through the site.

Date	Meter reading	Actual (m^3)	Target (m^3)	Is the target met?	Remark
	5032.218				
1-Jan	5032.265	0.047	1	YES	
2-Jan	5032.505	0.24	1	YES	
3-Jan	5032.622	0.117	1	YES	
4-Jan	5032.815	0.193	1	YES	
5-Jan	5033.040	0.225	1	YES	
6-Jan	5033.370	0.33	1	YES	
7-Jan	5033.551	0.181	1	YES	
8-Jan	5033.885	0.334	1	YES	

Figure 3.2: Daily Water Tracking Sheet (Data Recording)

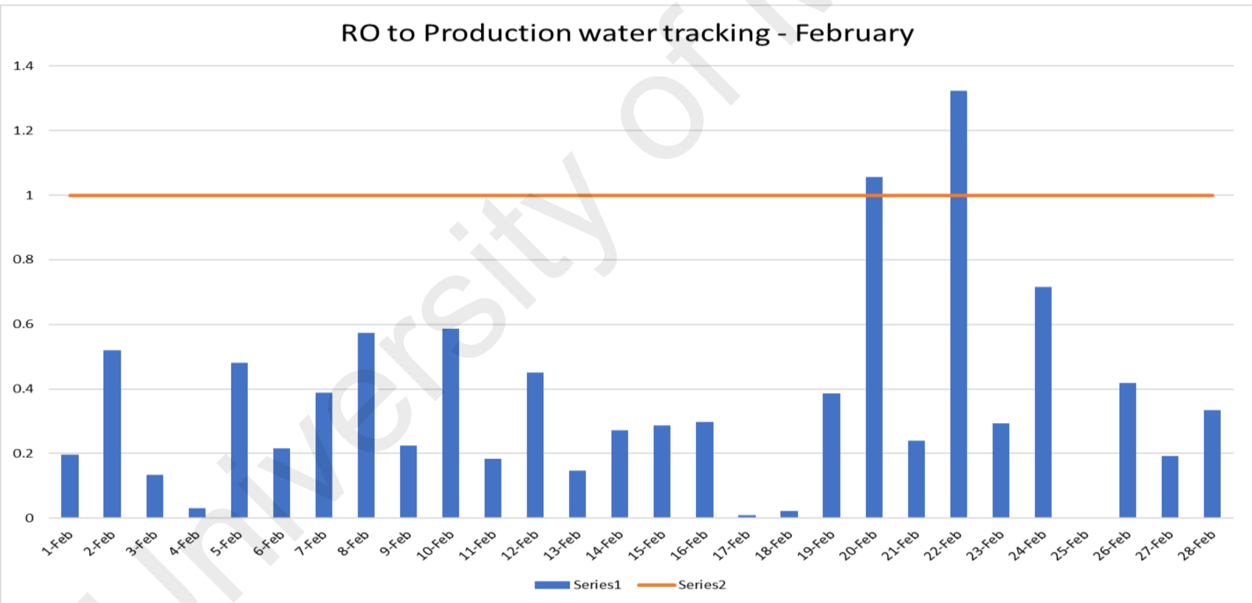

Figure 3.3: Daily Water Tracking Sheet (Graph)

Figure 3.1 and Figure 3.2 are examples of data being taken which is from different water meter readings taken at different areas at site and graph of the consumption plotted to show the water consumption trends and identify any abnormalities or high consumption of water that need to be rectified. Each meter reading is recorded along with the date of reading taken and compared against the target consumption which was derived from the average consumption of water for the past years as well as the excel sheet is also able to idendity whether the water consumption is met to be below the targeted value. This will ensure the water consumption is maintained below the target values and any abnormalities can be identified easily and rectified as soon as possible.

3.2.1.2 Purified Water Supply

The Data Collection that was done on the proposed option consisted of two points as follows:

a. Reverse Osmosis plant specifications.
b. Reverse Osmosis plant process flow.

For the first part the Reverse Osmosis plant specifications and parameters were collected from the validation documents of the company. The site has a validation system for every system installed. The documents used were the Design Review (DR), User Requirements Specifications (URS) and the Performance Qualifications (PQ).

Also, the manual provided by the vendor was checked for specifications. And to find the ranges for these specifications the logbooks and Preventive Maintenance (PM) reports of the company used to follow up and monitor the Reverse Osmosis plant were used.

To check the process flow and the philosophy used in the process, reference to the company documents was the only source as the Reverse Osmosis plant on the site is custom built to fit the specific needs for the site. This part has a significant importance as the applicability of any improvement to be implemented is highly dependent on the specific system flow adopted on the plant.

Water treatment involved in the site is Double Stage Reverse Osmosis system with the following specifications:

Table 3.2: Parameter Specifications for the Reverse Osmosis Treatment Loop

Parameters	Guide Value
Stage 1 Concentrate Flow to drain	• NLT 1500L/h
Stage 1 Permeate Flow rate	• NLT 2500L/h
Stage 1 Concentrate Flow rate	• NLT 15bar
Stage 1 Permeate Pressure	• NLT 4bar
1st Stage Recovery rate	• 65±10%
Stage 2 Concentrate Pressure	• NLT 18bar
Stage 2 Concentrate Flow to tank	• NLT 800L/h
Stage 2 Permeate Flow rate	• NLT 1700L/h
2nd Stage Recovery Rate	• 60±10%
Global Recovery rate	• 40±10%

Parameters of Purified Water produces are as follows:

Table 3.3: Parameter Specifications for the Purified Water Supply

Parameters	Specifications
TOC	NMT 500ppb
Conductivity	NMT 1.1µS/cm at 20^{o}C
Microbial count	NMT 100cfu/ml
Metal	NMT 0.1 ppm
Nitrate	NMT 0.2 ppm

3.3.1.2 Treated Wastewater Discharge

The quality of water discharged to the drains is investigated and monitored to gather the discharge parameters and limits for the site to ensure the treated water discharged meets the regulatory requirements.

Specification Limit of WWTP Treated Water Discharge parameters which fall under DOE regulations Standard B (DOE, 2009), and the allowed discharge limits are as below:

Table 3 4: Parameters Specifications for Treated Water Discharge

Parameters	Specifications
Suspended Solids	NMT 100 mg/L
COD	NMT 200 mg/L
BOD	NMT 50 mg/L
Oil and Grease	NMT 10 mg/L
pH	Between 5.5 – 9.0

3.4 Data Analysis

3.4.1 Water balance

Water balance will be conducted based on the data collected to achieve the objective of this study. Usage paterns identified will help the optimization strategy to define the suitable targets (McCabe, 2007). For this step the same Excel sheet used in the previous step was utilized. The Excel sheet was designed so as to show which readings exceeded the limits and to automatically plot graphs and show trends of the data entered (Hunnings, 1996).

To perform this step, the company's site piping drawings were checked to identify the water piping and the meters' locations. Then use the meter readings, with consideration to the piping strategy, to identify a water balance equation. The investigation was done using an Excel sheet

(Water Balance Conformation Sheet) developed to perform the water balancing after identifying the proper equation. The data used was data from the year of 2017 for the daily readings of the water consumption was used.

Each of the areas above is fitted with independent water meters to obtain daily reading and tracked in excel sheet for record. This data is used to analyse for any abnormalities which may indicate leakages or wastages of water.

SYABAS	Laundry	Toilets/Cafeteria	RO tank	Boiler	Production	WWTP	Pallet washing	RO to Production	Balance
11	1	0.001	10	0.05	2	0.294	0.357	0.047	2.345
29	14	1.461	9	0.079	3	2.244	1.538	0.24	0.784
43	19	1.105	11	0.655	3	2.916	2.575	0.117	-5.324
46	19	0.557	15	3.152	1	3.72	1.236	0.193	-3.571
52	24	1.131	16	0.016	5	3.327	3.268	0.225	-2.526
43	12	1.365	22	0.01	3	6	2.902	0.33	1.375
23	3	0.004	12	0.955	6	0.436	0.498	0.181	0.605
42	20	1.894	8	1.359	4	2.117	1.226	0.334	-4.63
74	25	1.387	37	3.126	7	1.533	1.604	1.715	-3.954
70	32	1.44	18	1.284	9	4.861	3.067	0.064	-3.415
58	23	1.51	24	0.676	0	2.579	1.793	0.806	-6.235
60	22	1.413	23	0.509	16	4.028	2.592	0.287	-6.95
48	16	1.223	17	0.615	11	1.251	1.304	1.491	-0.911
39	6	0	24	0.505	2	3.111	3.2	1.187	-3.384
59	21	1.492	19	0.982	9	2.885	1.521	-0.564	-4.641
57	28	1.72	16	1.118	6	2.217	2.207	0.294	-1.945
75	29	1.757	23	0.446	10	3.555	2.484	0.243	-7.242

Figure 3.4: Water Balance Conformation Sheet

Figure 3.4 shows example of overall water consumption is compared against individual water meter readings to idenitfy any abnormalities and also to confirm the total incoming water is equal to the total consumption of water recorded from the individual water meter readings. The data collected will then be analysed for any water conservation and energy saving initiative that can be implemented within the site in order to achieve efficient water management (Federer, 1996). Water balance will be conducted based on the data collected. This will involve water and energy optimisation in water treatment and waste water treatment processes to achieve the objective of this study.

3.4.2 Energy Recovery Device

From the previous step, it was concluded that the area of improvement to be investigated is the Reverse Osmosis plant. The first part of this step was done through researching papers and projects that were done to optimize the water usage and the Reverse Osmosis process in general. The research was done through access to scientific websites and platforms to figure out the different ways possible to accomplish the objectives.

Using the knowledge gained from the previous steps, each possible improvement strategy/project was checked against the specifications and data collected to investigate its applicability to the specific water systems on site. Each way that was seen to be applicable was further researched to identify the best option within the scope and time frame of the project.

The option identified as the best taking the different considerations, was adding an Energy Recovery Device to the Reverse Osmosis plant to optimize the process by reducing the energy consumption. This option was then further researched to come up with enough data and findings for this project to be enough for the company to decide on whether to implement it or not.

3.5 Identification of Solutions

Solutions for optimisation of water consumption from data analysis will be identified and explained further on the savings and efficiency of the processes involved. This will also identify any additional initiatives that can be taken besides water optimisation such as energy recovery for the processes involved in water consumption and treatment.

With the previous steps being done and after having the knowledge of the water usages on site, the wastages of the water, the possible leakages happening on site and the water piping and balance equation- the next step was to offer solutions. This step has two parts to accomplish:

a. Researching possible solutions.

b. Investigating the solutions applicability

Reusing and recycling of treated water discharge had been identified as the possible solution to optimise water consumption at site. This part will involve data collection of potable water consumption at site and the treated water discharge from the wastewater treatment plant to obtain the daily average treated water discharged which can be reused and recycled.

Besides that, method of reusing and recycling of the treated water discharge will be determined to optimise water consumption at site as well as achieving efficient water management at site as per the objective of this research.

3.6 Site Tours

The site tours were used to help in:

3 Data collection, such as going around the site to collect data from the water meters.

4 System monitoring, by going around the site and spending time in the RO plant in order to monitor the systems so as to gain better understanding on them and thus making the project implementation and proposal easier to do and more reliable in terms of the outcome.

5 Applicability investigations, by going around the site to look the systems in discussion to make sure that the suggestions are implementable and valid for what's given.

3.7 Safety

Pharmaceutical industry is regarded as highly focusing on safety at workplace. Working at height, confined space and hot working environment is common in a typical manufacturing plant. The selected premise gives significant importance to safety for its employees. Safety induction done by the safety department is compulsory for all the employees which they will only be allowed to enter the site once they have completed their safety induction. Contactors are given safety pass which must be renewed by attending refresher safety briefings every year to keep reminding the contractors of how safety is regarded as important aspect of the company.

Third party workers follow as per the employee’s induction plan which includes safety induction and periodic refresher trainings on safety by the safety department as well as their job hazard is identified initially by risk assessments to ensure the safety of workplace is maintained and the workers understand the task performed as well as the associated hazards at their workplace. The personal protective equipment (PPE) needs to be strictly adheresd to the plant guidelines which is not compromised by the plant. personal protective equipment (PPE) include safety shoes, long sleeve safety jacket with luminescence reflector, safety helmet with luminescence stripes and safety goggle.

CHAPTER 4 : RESULTS AND DISCUSSION

4.1 Data Collection

4.1.1 Water Consumption

Water for the site is obtained from Public Water Supply service provider. The areas that consume water on site include toilets, cafeteria, general area (e.g: carpark, building perimeter, etc.), laundry, Boiler room, Wastewater Treatment Plant and Production area. Most of the areas are individually metered to monitor the water usage which is used to record in Daily Water Tracking Sheet and compared against the target values. The set limits for these areas are as follows obtained from the Water Balance Conformation Sheet:

Table 4.1: Limits of Water Consumption for Water Usage according to Areas

AREA	TARGET (in m^3)
Toilets and cafeteria	25
Reverse Osmosis plant	30
Production	5
Total	60

Total daily target for water consumption will be 60 m3/day.

4.1.2 Water Treatment System

The basic system involved in the Reverse Osmosis system are:

Figure 4.1: Basic Treatment process flow of Reverse Osmosis System at site

Overall system consist of the following subsystems:

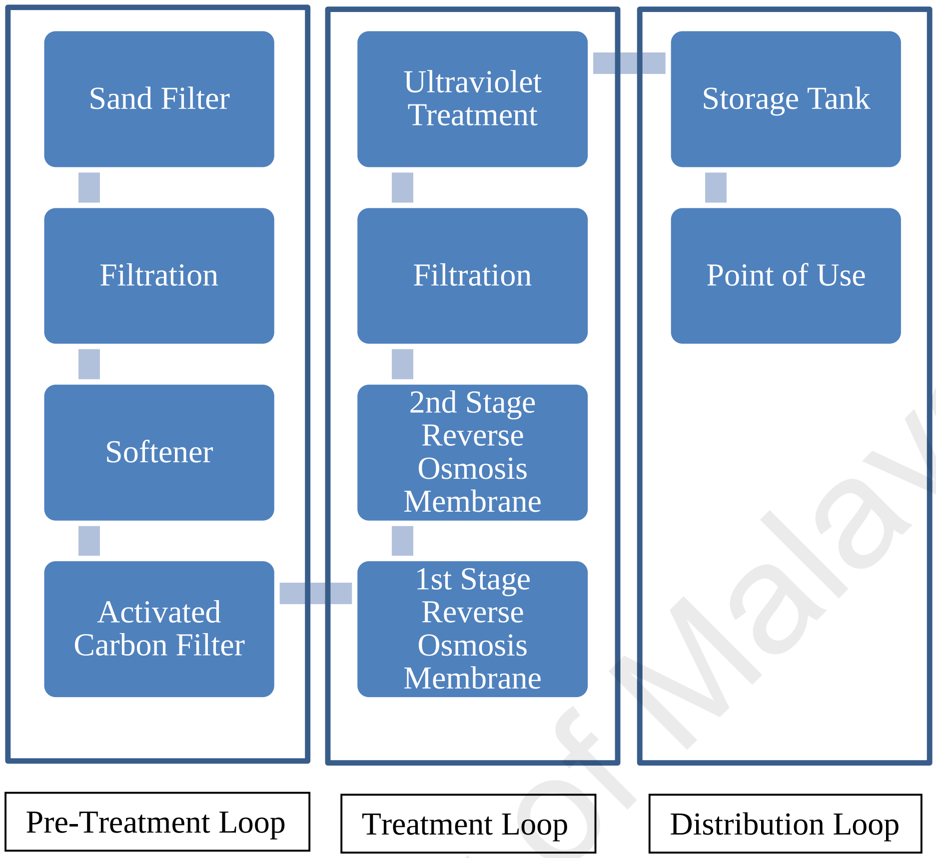

Figure 4.2: Overall System in Reverse Osmosis Plant

4.1.2.1 System Description

The feed water is subjected to various filtration in order to acquire the intended water quality which will be supplied to the Reverse Osmosis membrane i.e. to supply the Generation Loop. The entire system is controlled via a centralized PLC system which shall operate to cater daily operation control, monitoring, maintenance (automated backwashing) and alert system. Every single component of the system is backwashed automatically at defined intervals depending on the water quality being fed into the system and final output water quality. The first level is the Sand Filter which is the Multimedia Filter that acts to remove large particulates thereby reducing turbidity. This system will be backwashed automatically on regular basis. The next level is the cartridge pre-filter to eliminate micron level particulates but mainly it functions as a protector to the next section of pre-treatment. The softener equipped with double unit is the next level of treatment where it removes divalent and trivalent ions and replaces them with sodium. The reduction hardness level not only reduces the selected 'hard' ions but also protects the Reverse Osmosis membranes. This is followed by the Activated Carbon Filter which mainly acts as chlorine removal mechanism. The final stage of the pre-treatment section is the membrane protective cartridge filter. The water flows through this system to generation loop to produce Purified Water.

The pre-treated water is then subjected to the Reverse Osmosis system in order to acquire the intended water quality which will be used for production i.e. the desired final output water quality. The pre-treated water is stored in an intermediate storage tank and the water will then be subjected to Dual Pass Reverse Osmosis purification via high-pressured pump. Prior to this the pH level is adjusted by a Sodium Hydroxide Dosing unit, which will correct the pH. Only water with the desired pH level will be allowed to pass this section. The water, which is subjected to reverse osmosis treatment, will circulate until the desired water quality with intended water quality for second pass, is achieved. The same type of treatment will affect the water at the second pass reverse osmosis unit via a high-pressure pump. The latter pump is configured to apply higher pressure than the former (pump for 1st pass). Upon this, the water will go through a series of extra protection via a cartridge filter and finally through a UV light for disinfection of susceptible organisms. The water beyond this level is deemed to be equivalent or better than the intended water quality and thereby the water will be supplied to the distribution loop.

The purified water quality which is supplied by the generation / purification loop, is collected in a storage tank. From here, the purified water is circulated within the distribution loop by a high-pressure pump.

The purified water is circulated continuously within the distribution loop at low temperature and this temperature is maintained heat exchanger mounted adjacent to the return of the storage tank.

4.1.3 Wastewater Treatment Plant

Wastewater Treatment Plant at selected premise runs on Conventional Activated Sludge system which is Biological Process (GladyJr, 2011). Sources of waste water entering the treatment plant including production waste, kitchen waste, toilet waste, Reverse Osmosis Reject Water and Boiler Blowdown Water. An interceptor sump is present to collect production and kitchen waste prior to discharging into Pump Sump. Waste water will be transfered from Pump Sump into Equalization Tank. The water rejected from the Reverse Osmosis system is then collected at Reverse Osmosis Reject Sump which will be directed to Equilization Tank. Boiler Blowdown Water will be discharged into Equilization Tank directly.

Upon entering the Equilization Tank, the wastewater will allowed to homogenise by blower blowing air into the equilization tank. The wastewater will be transfered to Neutralization Sump at 9m3/hr through a totalizer flow meter. pH will be regulated in the Neutralization Sump through a Sodium Hydroxide (Caustic) dosing system to maintain pH between 5.5 to 9.0.

Wastewater will overflow into Aeration Tank which is controlled by Blower to maintain Dissolved Oxygen level in between 2.0 to 4.0 mg/l. Wastewater will overflow to Clarifier Tank 1 and 2 to promote settlement of sludge contained in wastewater.

Wastewater will be transfered to the subsequent Final Discharge Monitoring Tank through gravity flow. Treated wastewater will discharge into drain through the outlet pipe located at the top part of the tank after going through another flow sensor to collect flow rate and quantity of discharged water. The discharge is continuous.

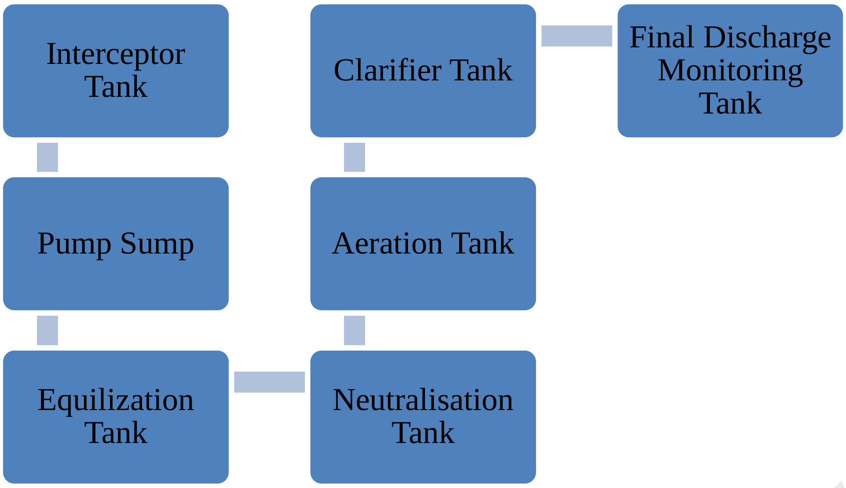

Figure 4. 3: Wastewater Treatment Plant Process Flow Diagram

Average of daily discharge of treated water is approximately 50 m3/day. This is obtained from the daily monitoring sheet that is being recorded at Wastewater Water Tretment Plant.

4.2 Data Analysis

4.2.1 Energy Conservation

The Reverse Osmosis plant on the site is a dual pass plant. Meaning that the water goes through two membranes and thus it is subjected to the Reverse Osmosis process twice. The feed water is kept in a break tank first. From the tank the water goes to the first stage Reverse Osmosis process. The reject of the first Reverse Osmosis stage is disposed and the permeate goes to the second Reverse Osmosis process. As the second Reverse Osmosis reject is better in quality than the feed water to the first Reverse Osmosis, it is not disposed but rather circulated back to the break tank and added to the feed water. The process is outlined in Figure below:

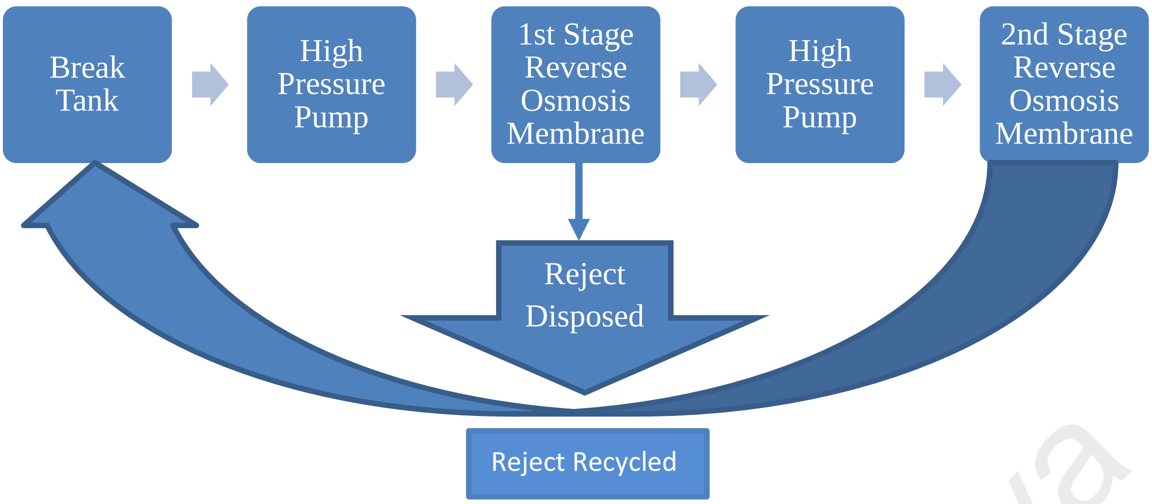

Figure 4.4: RO Reject Cycles

Energy Recovery Devices are used to recover the energy losses that a system incurs and reuse that energy to minimize the losses. Disposed have many types and designs depending on the type of energy lost as well as the desired type of energy to recover, and thus they might carry out energy conversions.

In the case of the reverse Osmosis plant, one of the energy losses is the kinetic energy resembled in the pressurized reject of the process. This energy can be converted to electrical energy that feeds the plant or it can be utilised through a pressure exchanger to be reused to pressure the feed water and thus reducing the high-pressure pump work. The second choice is the one chosen for this project.

Energy Recovery Devices are employed in almost all the Seawater Reverse Osmosis Plants. This is due to two factors. First, Seawater Reverse Osmosis plants have a high pressure compared to the brackish water reverse osmosis plants. This is because of the high salinity in seawater compared to brackish water which puts a higher specification on the required osmotic pressure to overcome the natural flow direction. Another reason is that Seawater Reverse Osmosis plants' membranes have a lower permeate recovery rates than brackish water reverse osmosis plants, this means that the amount of reject is relatively huge and, and with reject having high pressure, the pressure losses are considered more significant.

The Reverse Osmosis plant on the site is considered a brackish water reverse osmosis plant as the feed water is not seawater and does not have high salinity rates. The recovery rates of the plant and its hydraulic specifications required for the investigation of adding an Energy Recovery Device are as shown in table below.

Table 4.2: Hydraulic Characteristics of the RO Plant.

Parameter	Unit	Specification
Feed water flow rate	m^3/h	12
Feed water pressure	bar	4
Pre-filter flow rate	m^3/h	10
Softener flow rate	m^3/h	7
1st stage feed flow rate	m^3/h	3.5
1st stage pressure	bar	15
1st stage recovery	$-$	75%
1st stage product flow rate	m^3/h	2.5
2nd stage feed flow rate	m^3/h	2.5
2nd stage pressure	bar	12
2nd stage recovery	$-$	80%
2nd stage product flow rate	m^3/h	2

The Energy Recovery Device that is to be used is a rotary pressure exchanger, refer Figure 2.1. Pressure exchangers are used to transfer pressure energy from a high-pressure fluid stream to a low-pressure fluid stream.

Pressure exchangers of the rotary type are cylindrical rotor, with inside ducts for the fluids to go through. These ducts are parallel to the device's rotational axis. As the high-pressure stream goes inside the device, the rotor spins inside of a sleeve that connects two closed ends. The high pressure is then transferred to the low-pressure feed water leaving the consumed reject with no energy, in exchange, the low-pressure feed water transfers its low pressure to that consumed reject stream, disposing it with a low-pressure. This exchange is done through the rotary movement of the middle sleeve that keeps exchanging the two levels of the streams. The new feed water then goes to enter the Reverse Osmosis process.

During the pressure exchange process the two streams are separated by a barrier. This barrier is either a mix of the two streams (no actual barrier) or another fluid that does not mix with any of the two streams. The reason for making it a fluid is to keep the exchanger efficiency at maximum. If the barrier is to be made as a solid it will have higher resistance in terms of mass and friction which will consume a lot of the pressure transferred if not all.

After adding the above Pressure Exchanger, the reject water stream from the first stage Reverse Osmosis will now go first through the pressure exchanger instead of being immediately disposed of. The pressure exchanger will transfer the pressure energy to the feed water being supplied to it. After this that feed water will go to join up with the water being supplied to the first stage Reverse osmosis. There are two things to note here; the first thing is that the feed water existing the pressure exchanger will go through a circulation pump first before joining the rest of the feed water to the first Reverse osmosis. This circulation pump is used to make up for the losses due to the slight pressure drops in the Reverse osmosis membrane and the pressure exchanger as well as for the piping friction losses.

This was the water will be at the same desired pressure to enter the Reverse osmosis membrane. The second thing is that this water does not go through the high-pressure pump but rather joins the water exiting the high-pressure pump. Clearly, this is no point of the whole new system addition if all the water circulates back through the high-pressure pump, and of course the water exiting the pressure exchanger will not need the pressure from the high-pressure pump anyway.

The kWh savings were calculated as follows:

The first stage reject flow rate was calculated as follows:

$$Flow\ rate_{1st\ reject} = Flow\ rate_{1st\ feed} - Flow\ rate_{1st\ permeate}$$

$$Flow\ rate_{1st\ reject} = 3.5 - 2.5 = 1\ m^3/h$$

Assuming as 98% efficiency pressure exchanger, the flow rate acquired by the feed water will be:

$$Flow\ rate_{px\ feed\ out} = Flow\ rate_{px\ raject\ in} \times \frac{98}{100}$$

$$Flow\ rate_{px\ feed\ out} = 1 \times \frac{98}{100} = 0.98\ \ m^3/h$$

The flow rate provided by the high-pressure pump to the 1st stage RO is 3.5 m^3/h

This mean that the pressure exchanger will provide the following percentage of the pump flow rate, and thus its work:

$$Percentage\ provided\ by\ the\ pressure\ exchanger = \frac{0.98}{3.5} \times 100 = 28\ \%$$

The pump operates at 4 kW power, and thus its annual consumption is:

$$daily\ kWh = 4\ \times 24 = 96\ kWh$$

$$annual\ kWh = 96 \times 365 = 35{,}040\ kWh$$

28% of this power will be saved:

$$savings = 35040 \times \frac{28}{100} = 9{,}811\ kWh$$

4.2.2 Water Saving

The treated water discharge could be recycled to be used for other various usage such as gardening, external area cleaning, toilet flushing and so on. This could save additonal water consumption and increase recycling the water. In this way, the treated water is not left discharged to the drain as wastage but used as source of water usage.

Besides that, treated water can be used as closed loop usage whereby the treated water can be used within the Wastewater Treatment Plant. The treated water can be used for cleaning the wastewater tanks, general cleaning of the area and etc. This will save water usage as currently public water supply is used as source of water for washing and cleaning activity at WWTP.

Treated water can also be used as Chiller make up water as will be used for cooling system at site. The site uses chilled water system to cool the building using several Air Handling Units for cool air. Hence, the treated water can be used as make up water for the chiller water tank and this will reduce usage of public water supply to the site.

Treated water can also be used for cooling of ambient temperature of chiller units. The combination of cooler incoming air, the shading from the mesh and a cleaner coil can result in output increase for most systems. As long as the refrigeration machinery, increasing system overall capacity without adding any additional refrigeration machinery is possible.

This can be achieved through spraying water onto a mesh placed in front of the heat reduction surface. The water spray can be triggered by an ambient sensor or refrigeration head pressure override i.e. condensing pressure limit. The water on the mesh provides an adiabatic cooling effect on the incoming air, reducing the temperature before it has even reached your heat rejection coil and reducing power. Additional air cooling reduces the refrigeration cycle head pressure and discharge temperatures. Reduced discharge pressures and lower temperatures significantly increases the compressor life.

The reduction in the excessive high discharge pressure and temperatures for the refrigeration cycle, reduce the mechanical stress on the system which provides reliable operation and much less maintenance.

4.3 Summary of Results and Discussion

Table 4.3: Summary of Results and Discussion

Issue	Solution	Impact
High energy consumption in Reverse Osmosis System	Application of Energy Recovery Device through Pressure Exchanger to reduce energy consumption in Reverse osmosis System.	Maximum saving of 9811 kWh annually which would reduce overall site energy consumption.
High water consumption at site and average about 50 m3/day of treated water being discharged daily.	Reuse and recycle of treated water discharge for non-drinking purpose. Treated water can be used for following purposes - gardening, external area cleaning, toilet flushing, Chiller make up water, and cooling of ambient temperature of chiller units	Water consumption at site can be reduced and treated water discharge could be recycled which will reduce the discharge to the surrounding. Hence, less impact to the environment and better management of natural resources at site.

4.4 Recommendation

There are two recommendations found to further improve the RO plant that were not studied in detail in this project but are shown as recommended further improvements for future implementation.

a. Filtering the Reject Water:

The Feed water to the RO must be of a certain quality so as not to harm the RO membranes. Feed water with inadequate quality can cause fouling and scaling to the membranes and thus would force the site to change the membranes or go through extra maintenance, and hence the pre-treatment loop. This result in high RO concentrate is rejected and not reused because in the case of doing that it will cause harm to the membranes. In the proposed solution, the reject of the first stage RO will go through a Filter which will purify it changing its specifications to ones that fall within the required levels of the RO feed water.

b. Changing the Water Meters:

The water meters have been showing irregular results compared to the actual readings. This falls as a data analysis and collection hazard. It is very important to have working meters and get the accurate daily readings for each of the areas of consumption as it is critical in identifying which parts of the site are consuming water more than the limit, whether there are wastages or not and detect problems to offer solutions. Faulty water meters can cause a problem in terms of misunderstanding certain situations or giving wrong observations which can cause the site losses. And thus, it is critical for the continuous efficient monitoring of the water system on site to replace the meters.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project was made to investigate the water system on a pharmaceutical company in terms of supply and consumption and analyse the data collected to come up with findings to help detect the areas for improvements. The data analysis was done and the areas requiring further improvements were identified.

a. One of the areas was the on-site reverse osmosis plant. The plant was identified as excessive usage of energy which needs to be investigated for ways of improvement. The solution investigated was to improve the energy consumption and increase the efficiency of the overall system in future.

b. The solution investigated was adding an Energy Recovery Device to the plant to recover the kinetic energy from the reject stream and reuse back in the system to pressurize the feed water going inside the system. The Energy Recovery Device chosen was the Pressure Exchanger with assumed efficiency of 98%. The device was found to recover 28% of the high-pressure pump work, achieving annual savings of 9811 kWh for the site.

c. Overall high water consumption identified at site and average about 50 m3/day of treated water being discharged daily to the perimeter drain. This treated water can be reused for other that drinking water usage which could save water consumption and the cost involved. Treated water can be used for following purposes - gardening, external area cleaning, toilet flushing, Chiller make up water, and cooling of ambient temperature of chiller units. Reusing treated water can reduce water consumption at site and treated water discharge could be recycled which will reduce the discharge to the surrounding. Hence, less impact to the environment and better management of natural resources at site.

d. The overall research highlighted there are various solutions in pharmaceutical manufacturing plant in terms of efficient water management at site. This research project have identified few key areas for better energy and water management which can be useful any other industry with similar systems as well.

In conclusion, the obejectives are achieved with the key areas with accessive wastage being identified and proper solutions being analysed for the issues identified in this project.

5.2 Recommendations

a. This research can be one in more depth in terms of the process optimisation as in the manufacturing processes as this current research is about reducing and controlling the existing system energy consumption which does not impact the manufacturing processes. This can be developed for manufacturing processes which consumes water which will contribute in significant water reduction and better water management at site.
b. This research can also be further developed in terms of energy saving solutions such as heating ventillation and air conditioning (HVAC) system as as the most of the energy consumption at site is in this system.

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