ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

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Original Research Article

The Development of Natural Filtration for Concentrated Conductivity From Industrial Reverse Osmosis Pharmaceutical Company — A Case Study

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Abstract: This project focuses on developing a natural dilution process of highly concentrated conductivity from Reverse Osmosis (RO) at a pharmaceutical company. This company is one of the pharmaceutical companies in Malaysia that uses water as base products. RO has become one of the essential processes needed to produce water with a particular grade used for production lines. The highly concentrated conductivity produced from RO cannot flush into the drainage system because it can harm the environment and is also against the environmental policy. The primary purpose of these studies is to dilute the highly concentrated conductivity from RO using natural dilution without using chemical reactions or hazardous materials before flushing it into the drainage system. The highly focused conductivity from RO flushed to the first out of five created ponds. Coco yams were planted around all five ponds because those plants could absorb dissolved metals from water to generate their foods, such as magnesium, nickel, lead, cadmium, zinc, etc. This process can reduce the water conductivity. Koi fish and catfish are also used in certain ponds to indicate whether the ponds can maintain water conductivity. A water sample from all ponds was sent to a chemical laboratory every day for a year to measure conductivity. A year's water conductivity data were analyzed using Microsoft Excel to see the trend of water conductivity. The analysis shows that this dilution process can decrease water conductivity without using any chemical reaction or hazardous materials. The result showed that conductivity was below 500 µS/cm in pond five before dumping into the drainage system.

Keywords: conductivity; reverse osmosis; dilution; coco yam.

Received: 15th February 2021

Received in revised form: 21st June 2021

Available Online: 1st July 2021

Published:

Citation: Ahmad, A. S. W. (2022). The Development of Natural Filtration for Concentrated Conductivity From Industrial Reverse Osmosis Pharmaceutical Company — A Case Study. *Adv Agri Food Res J* 2022; 3(2): a0000295. https://doi.org/10.36877/aafrj.a0000295

1. Introduction

This company is one of the pharmaceutical companies owned by a local owner. This company was established in 1993. This company uses water as a product base, such as Large Volume Parenterals, Small Volume Parenterals, Irrigation Solutions, Haemodialysis

Concentrates, and Peritoneal Dialysis Solutions. All these products need Water For Injection (WFI) to finish. WFI is high specification water, and according to USP Pharmacopeia, producing WFI must include reverse osmosis. USP Pharmacopeia is a standard or guideline used in pharmaceutical companies. RO is the process used to filter mostly unwanted ions in water, such as magnesium, nickel, lead, cadmium, zinc, etc. Water produced from RO is called dilute water that can be transferred to another process, but about 60% to 70% of the input water will be discharged from the RO process. Discharge water contains high conductivity, around 700 µS/cm to 1200 µS/cm, and the problem is to release into the drainage system. High-level conductivity cannot be discharged to the drainage system unless the conductivity level is less than 500 µS/cm. This is because the company already states in Company Environmental Policy that the standard of dumped RO water must be below 500 µS/cm. Preparing the dilution mechanism for reverse osmosis will use money.

RO is an essential process system used to filter some unused materials contained in water using a semi-permeable membrane. Filtered water from RO flow to the following process, but discharge water with high conductivity must dilute before draining into the drainage system. Discharge water from RO is also called wastewater. Dilution process need because to prevent contamination of water in the drainage system. Environmental Protection Agency (EPA), one of the worldwide agencies that create regulations, covers a range of environmental and public health protection issues, from setting standards for clean water to specifying cleanup levels for toxic waste sites to controlling air pollution from industry and other sources. EPA (2004) cited that over 75 percent of the nation's population is served by centralized wastewater collection and treatment systems. Wastewater treatment is needed to use our rivers and streams for fishing, swimming, and drinking water. One of the famous systems used to dilute wastewater is flocculation or sedimentation. EPA (Safe Drinking Water Act) (1973) write that flocculation refers to water treatment processes that combine or coagulate small particles into larger particles, which settle out of the water as sediment.

Alum and iron salts or synthetic organic polymers (used alone or combined with metal salts) are generally used to promote coagulation. Settling or sedimentation occurs naturally as flocculated particles settle out of the water. All the minerals in moisture can affect the value of conductivity in water. Dalmas (2000) cited that conductivity is also affected by the concentration of ions already present in the water, such as chloride, sodium, and ammonium. This contribution to the conductivity is "extraneous conductivity."

A filtration system has also been used for the dilution of discharge water. Many water treatment facilities use filtration to remove all particles from the water. Those particles include clays and silts, natural organic matter, precipitates from other facility treatment processes, iron, manganese, and microorganisms. Filtration can clarify water and enhance the effectiveness of disinfection. Mechanical wastewater treatment with the filtration of ultrafine particles – also referred to as micro-screening - helps improve sewage plants' flow quality. Schlebusch (2012) cited that downstream ultrafiltration systems, for instance, remain virtually free of solids, and the clarified wastewater can be used without further treatment to irrigate fields or parks. Using a filtration system to dilute high conductivity water will cost much investment. One option is using ion exchange as a dilution method to cut discharge water. It is because ion exchange processes can remove inorganic contaminants if they cannot be removed adequately by filtration or sedimentation. It also can be used to remove arsenic, chromium, excess fluoride, nitrates, radium, and uranium. Skipton *et al.* (2008) cited that the ion exchange water softening process can remove nearly all calcium and magnesium from source water. The softener may also remove as much as 5 – 10 ppm (parts per million; ppm is equal to milligrams per liter, or mg/L) of iron and manganese. To prepare for the ion exchange process, the softener plant must be used to regenerate softener resin and a skilled technician certified to handle chemicals. This situation can cost too much investment.

Taro (Cocoyam) is an important tropical root crop grown purposely for its starchy corms or underground stem. It is regarded as one of the most important staple crops in the Pacific Islands, Asia, and Africa. It is one of the oldest food crops, believed to have been first domesticated in Southeast Asia before its eventual spread to other parts of the world. The two most commonly cultivated species of Taro (Colocasia esculenta and Xanthosoma sagittifolium) belong to the Araceae family and are extensively cultivated in Africa. Taro is an herbaceous monocotyledonous plant of 1–2 m in height. The plant consists of a central corm (below the soil surface), making the leaves grow upwards and roots grow downwards, while cormels, daughter corms, and runners (stolons) grow laterally. The root system is fibrous and lies mainly at a depth of up to one meter of soil. These cocoyams are believed to have the ability to absorb dissolved heavy metals from water or soil and are used to produce food.

This study is to develop nature dilution. This study's scope refers to RO use in this pharmaceutical company. The objectives of this study are: (a) To develop nature dilution for RO discharge water; (b) to dilute discharge water from RO to meet the drainage system requirement; (c) to prepare nature indicator for every step of water flow.

2. Materials and Methods

2.1 Discharge Ponds

Five ponds (3 m diameter) were built at the water treatment plant, as in Figure 1. The depth of the pond was constructed as in Figure 2. This measurement is determined according to the volume of discharge water. It was then filled with discharge water from RO and left for one month to ensure the coco yam began using the minerals in the water to produce their foods. For one month, every pond is just filled with stagnate water.

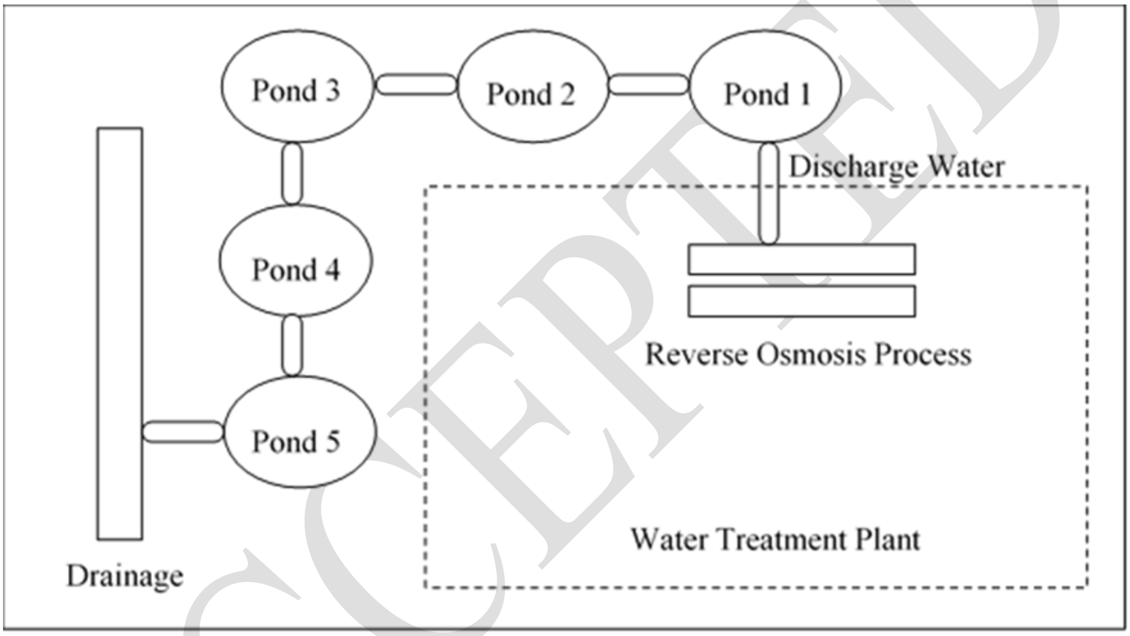

Figure 1. The layout of ponds build around a water treatment plant

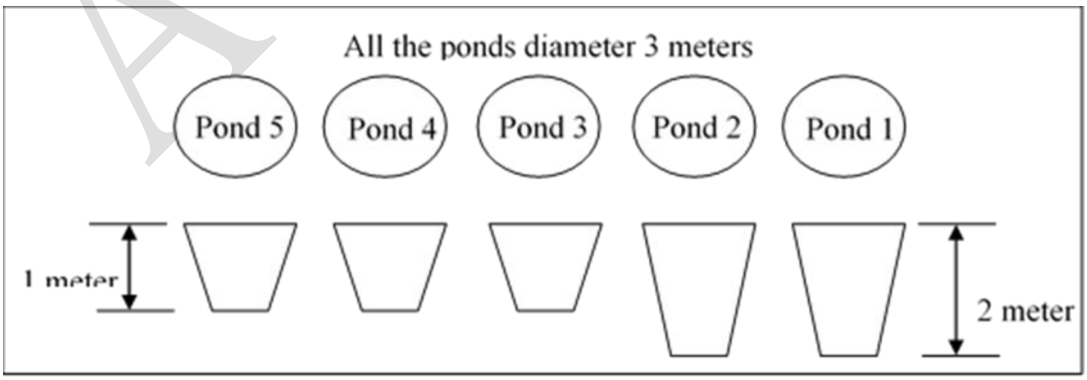

Figure 2. The diameter and depth of every pond for the dilution process

2.2 Natural Filtration

Coco Yam was used as a natural filtration for RO-rejected water because this system did not use any chemicals. Figure 3 shows the coco yam plant that was used to dilute discharge water from RO. Figure 4 shows the location of coco yam planted around the ponds. Oti *et al.* (2013) cited that some metals such as Fe, Zn, and Cu are essential in plant nutrition. However, many other heavy metals do not play any significant role in a plant's physiology. The accumulation of heavy metals including Pb, Ni, Cr, Cd, and As in roots, stem, and leaves of coco yam (Colocesia esculents) and Cassava (Mannihot esculents) grown in polluted soil, an abandoned waste dump soils in Umuahia, Abia State Nigeria has been reported.

Figure 3. Picture of coco yam used to dilute discharge water

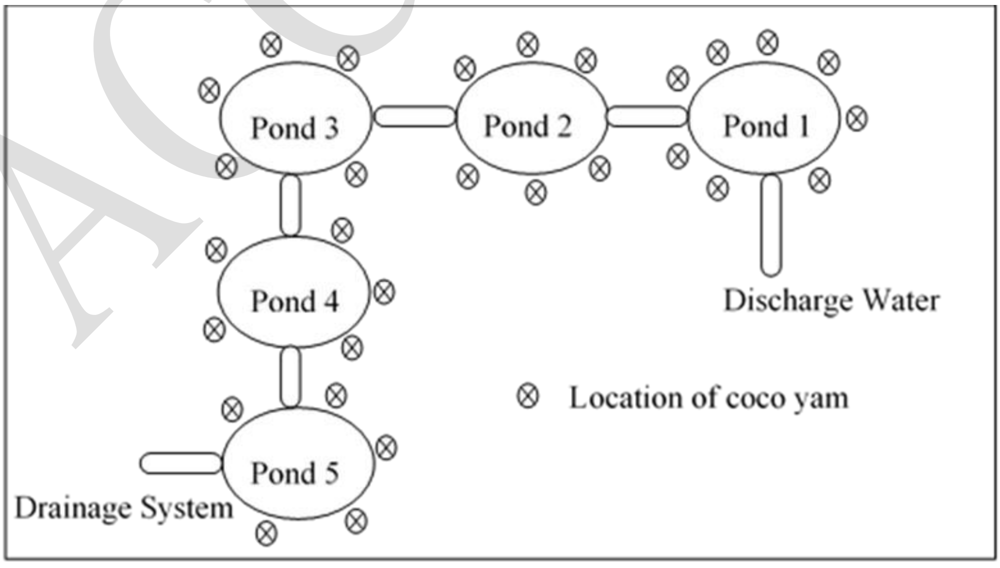

Figure 4. The location of coco yam planted around the ponds

2.3 Water Sampling

Water sampling from every pond was taken every day at 2.00 pm for conductivity analysis at the chemical laboratory. Water sampling was conducted to analyze the trending conductivity from RO discharge water for every pond.

2.4 Validation

When the conductivity showed a decreasing trend, catfish were putting in ponds as an indicator of conductivity. Koi fish was put in pond four and pond 5. Pond 1 did not put any fish because conductivity was too high, which could harm the fish (Burkhart, 1997). Catfish and koi fish are natural indicators of certain ponds. The species of fish gave diverse responses to the significant changes in pH, depth, velocity and conductivity over the river studied by Burkhart (1997). Indicators in every pond as below:

Pond 1: Only RO discharge water
Pond 2: Only catfish
Pond 3: Only catfish
Pond 4: Only Koi fish
Pond 5: Only Koi fish

2.5 Analysis

Water conductivity data were analyzed using Microsoft Excel to describe the trends of water conductivity.

3. Results

Figure 5 shows the table of conductivity trending on average for every pond from January to December. All those everyday data from the chemical lab calculate in everage to make it easier to compare every month and every pond. All the data taken from the water sample after one month of stagnating discharge water in all ponds mean the ponds already build and working correctly with nature indicators. Table 2 shows the condition for two kinds of fish as nature indicators in certain ponds.

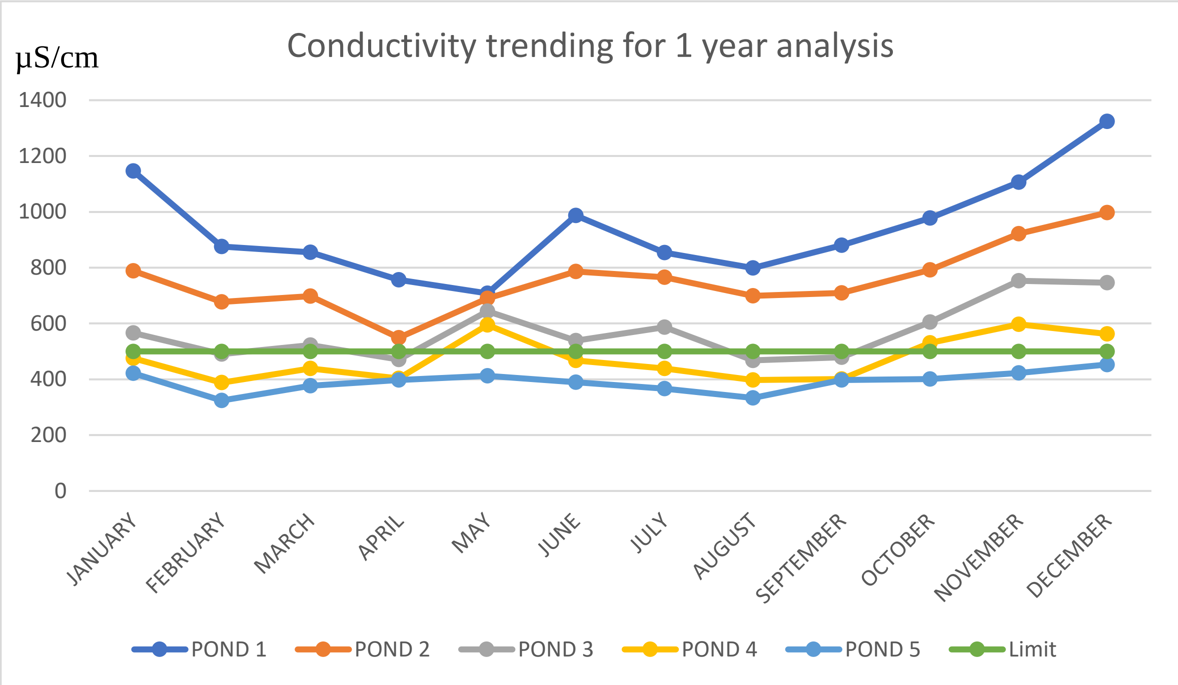

Figure 5. The chart shows the conductivity trending for one year

POND	Koi Fish	Catfish
POND 1		
POND 2		Good
POND 3		Good
POND 4	Good	
POND 5	Good	

Table 2. The table shows the condition of nature indicators in every pond

4. Discussion

All the conductivity data can be taken after all the ponds and nature indicators finish successfully. Table 1 shows the average conductivity data for every pond in 1 year. This table shows that the highest conductivity is 1324 µS/cm in December at pond 1. It is because pond 1 is the first pond discharge water will go through, and December was monsoon season. During the monsoon season, much rain can stir up the pond's water, making it cloudy because of the mud at the bottom of the pond. Silas *et al.* (2018) cited that the increase of pollution load during rainy season indicated the increase in organic matter in River water due to the rise in anthropogenic interferences of the surrounding areas. This table also shows that the conductivity in November, December, and January is slightly increased from others because of the monsoon season. In June, July, and August, the conductivity shows lower for every pond because of the sunny day and less rain. This weather can make sure water in ponds flows calmly. The lowest conductivity shows in February at pond five, about 324 µS/cm, because of the sunny day, and pond 5 was the last pond of dilution. Coco yams from 4 ponds already absorb many metals from discharge water. Figure 5 shows the chart of conductivity trending for every pond in 1-year data. From the chart, we can see that conductivity decreases from pond 1 to pond 5. This trend shows that coco yams could absorb metals in water to produce their foods without harming their system. In pond 5, the trend shows the conductivity for one year lower than 500 µS/cm, which is required for drainage system water. So, discharge water from this pharmaceutical company's RO system at water treatment plant can be drained to the drainage system after pond 5. If we see the trending line pond 1 with pond two and pond 2 with pond 3, the gap between the line is higher than the trending line pond 3 with pond two and pond 2 with pond 1. It is because more coco yams were planted in ponds one and two compared to others. This situation shows that the coco yam successfully is a dilution agent for conductivity. Table 2 shows the nature indicators used to ensure conductivity in range without fluctuating too much. In pond 1, no fish was used because too high conductivity is not suitable for small fish. Pond 2 and pons three catfish were used because catfish can generally live in water with conductivity less than 1000 µS/cm. Koi fish are used in ponds four and pond five because these fish can usually live in water with conductivity less than 600 µS/cm. If coco yams malfunctioned with their system and did not absorb metals from discharge water, all those indicators can show the changes. Koi fish is the best indicator to know whether coco yam is still functioning well or malfunctioning. If something happens to koi fish means the conductivity is not absorbed by coco yam, and coco yam needs to be replaced with the new one

5. Conclusions

This project concludes that nature dilution can be made using coco yams plants that can absorb metals from water to produce their foods. With this nature of dilution, this pharmaceutical company did not invest more money to develop a mechanism for the dilution process for RO discharge water and no chemical consumption use. If using any chemical consumption, the particular step of chemical handling needs to practice.

Conflicts of Interest: The authors declare no conflict of interest.

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