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Reverse Osmosis (RO) Application for Cooling Water in the Electricity Power Stations

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Abstract
Water is one of the wonderful things that god created. Cooling towers for water are used for the condensers, air coolers and oil coolers. The water is circulated through the heat exchangers by the main cooling water (C.W) Pumps and back to the cooling tower. Most of the water goes back to the river Nile, and Reverse Osmosis is used to recycle cooling tower water and thus reducing the total cost of the raw water.

Keywords: Reverse Osmosis, Raw Water, Cooling Tower, Pumps

1. Introduction
When we talk about water in general, we usually mean water for some specific purpose, e.g. drinking water or process water for industry. Many industries use large volumes of water in their manufacturing operations. Some of this water becomes contaminated, hence it requires treatment before discharge. Thermal power plants use large volumes of water for cooling purpose and for the steam cycle to continue as close cycle.
There are several types of water found in the power station, all of different quality and composition. This identifies the water, its source and composition. The water is contained within the boiler drum and steam generation tubes and headers. The water which is converted into steam is to produce mechanical and then electrical energy within the turbine.
This water is used for the condensers, air coolers and oil coolers. It is circulated through the heat exchangers by the main cooling water (C.W) Pumps and back to the cooling tower where the water is cooled by the cooling tower.
This paper concentrates on the optimization of water in the power plant by reuse of waste water after treatment. Waste water treatment plants are designed to convert liquid wastes into an acceptable final effluent.

2. Literature Review
Improvements in determining the effects of industrial waste discharges have led to the adoption of environmental laws. Discharge permits to regulate the amount of pollutants that an industry can return to the water source. The permitted quantities are designed to ensure that other users of the water will have a source that meets their needs, whether these needs are for municipal water supply, industrial or agricultural uses, or fishing and recreation. Consideration is given to the feasibility of removing a pollutant, as well as the natural assimilative capacity of the receiving stream. This assimilative capacity varies with the type and amount of pollutant.
Waste water treatment plants are designed to convert liquid wastes into an acceptable form. In most cases, treatment is required for both suspended and dissolved contaminants. Special processes are required for the removal of certain pollutants, such as phosphorus or heavy metals [2].

3. Thermal Power Plants in Sudan
Thermal power plants in Sudan contribute 40% of the total electric power generation in Sudan. The biggest thermal power plant is of total capacity of 560 MW. It is composed of 4 blocks of combined cycle units, each consists of two gas turbines with one steam turbine, and

two steam turbines work with sponge coke fired boilers. The second bigger thermal power plant contains 6 steam turbines of total capacity of 380 MW power generation. The case study of this paper will focus on the second thermal power plant. The other power plants are small diesel generating units scattered in many towns.

Reverse Osmosis System

Since the 1940's, ion exchange resins have been used to remove dissolved salts from water. These resins exchange ions in the water and hold them until released by a regeneration solution. Many ion exchange processes exist for a variety of industrial water and waste water applications. The ion exchange process consumes large quantities of regeneration chemicals, such as brine, acid, and caustic materials that can present significant handling and disposal problems.

In recent years, membrane processes have been used increasingly for the production of "pure" waters from fresh water and sea water. Membrane processes are also being applied in process and waste water systems.

Although typically thought to be expensive and relatively experimental, membrane technology is advancing quickly becoming less expensive, improving performance, and extending life expectancy [6].

Reverse Osmosis

Reverse Osmosis is the flow of solvent through a semi-permeable membrane, from a concentrated solution to dilute solution. This flow results from the driving force created by the difference in pressure between the two solutions. Osmotic pressure is the pressure that must be added to the concentrated solution side in order to stop the solvent flow through the membrane. Reverse osmosis is the process of reversing the flow, forcing water through a membrane from a concentrated solution to a dilute solution to produce filtered water.

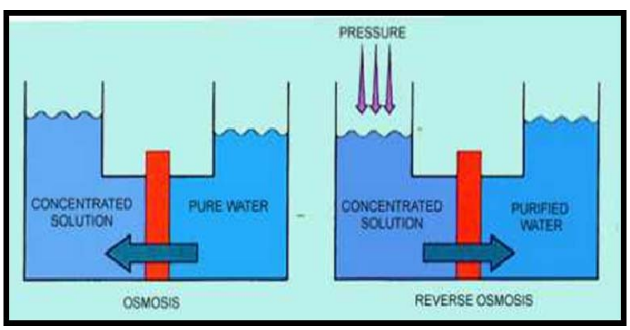

Fig 1: the osmosis process [1]

Reverse osmosis is created when sufficient pressure is applied to the concentrated solution to overcome the osmotic pressure and to create a driving force. This pressure is provided by feed water pumps. Concentrated contaminants (brine) are reduced from the high-pressure side of the RO membrane, and filtered water (permeate) is reduced from the low-pressure side. Membrane modules may be staged in various design configurations, producing the highest-quality permeate with the least amount of waste.

Typically, 95% of dissolved salts are reduced from the brine. All particulates are removed. However, due to their molecular porosity, RO membranes do not remove dissolved gases, such as Cl_2, CO_2, and O_2.

RO Membranes. The two most common RO membranes used in industrial water treatment are cellulose acetate (CA) and polyamide (PA) composite. Currently, most membranes are spiral wound, however hollow fiber configurations are available. In the spiral wound configuration, a flat sheet membrane and spacers are wound around the permeate collection tube to produce flow channels for permeate and feed water. This design maximizes flow while minimizing the membrane module size.

Hollow fiber systems are bundles of tiny, hair-like membrane tubes. Ions are rejected when the feed water permeates the walls of these tubes, and permeate is collected through the hollow center of the fibers. Concentrated brine is produced on the outside of the fibers contained by the module housing [5].

4. Methodology

Table (1) below shows the ASTM methods for the properties of Water.

Table 1: ASTM methods for the properties of Water

No	Test	Methodology
1	PH	ASTM D 1293-99
2	Conductivity	ASTM D 1125-95
3	Turbidity	ASTM D 1889-00
4	Total hardness	ASTM D 1126-02

Test Method

The Standard Test Methods for pH of Water is a direct standardization technique. It is employed in this test method for routine batch samples. Two buffer solutions are used to standardize the instrument under controlled parameters. The Conductivity of Water is applicable to field and routine laboratory measurement of the electrical conductivity of water using static samples. The Turbidity of Water is done by the photoelectric nephelomete operation. It is based on instrumental comparison of the intensity of light scattered by the contained static water sample under defined conditions to the intensity of light scattered by a reference standard in the sample container. The higher the intensity of scattered light, the higher the turbidity of sample. The hardness is the Calcium and magnesium ions in water. It is sequestered by the addition of disodium ethylene di amine tetra acetate. The end point of the reaction is detected by means of Chrome BlackT[4], which has a red color in the presence of calcium and magnesium and a blue color when they are sequestered [3].

5. Results and Discussion

Results Analysis of cooling towers water before and after filtration

Analysis of cooling towers water before and after filtration through RO unit in several volumes is to explain about the Reverse Osmosis system if used whether it is affective or not. Tables (2 to 7) below gives the analysis of the cooling tower water for different sample volumes.

Table 2: Analysis of cooling tower water before filtration through RO unit (samples volume 500 ml).

Test	C.T(1)	C.T(3)	C.T(4)
pH	8.04	7.5	7.5
Conductivity	1036	862	825
Turbidity	1.63	0.86	0.69
T D S	828.8	689.6	660

Table 3: Analysis of cooling towers water after filtration through RO unit (sample volume 500 ml).

Test	C.T(1)	C.T(3)	C.T(4)
pH	7.9	7.4	7.35
Conductivity	976	846	754
Turbidity	0.5	0.5	0.2
T D S	780	676.8	603.2

Table 4: Analysis of cooling towers water before filtration through RO unit (sample volume 1000ml).

Test	C.T(1)	C.T(3)	C.T(4)
pH	7.6	7.55	7.68
Conductivity	576	866	867
Turbidity	10.8	0.79	0.94
T D S	460.8	692.8	693.6

Table 5: Analysis 0f cooling towers water after filtration through RO unit (Samples volume 1000 ml).

Test	C.T(1)	C.T(3)	C.T(4)
pH	7.5	7.53	7.63
Conductivity	520	821	828
Turbidity	0.7	0.63	0.8
T D S	416	656.8	662.4

Table 6: Analysis of cooling towers water before filtration through RO unit (volume 1500 ml).

Test	C.T(1)	C.T(3)	C.T(4)
pH	7.95	7.20	7.66
Conductivity	614	974	944
Turbidity	12.9	2.01	2.91
T D S	491.2	779.2	755.2

Table 7: Analysis of cooling towers water after filtration through RO unit (volume 1500 ml).

Test	C.T(1)	C.T(3)	C.T(4)
pH	7.92	7.16	7.59
Conductivity	544	945	906
Turbidity	0.47	0.72	0.61
T D S	435.2	756	724.8

Discussion

- Analysis Cooling Towers Water before and After Filtration shows that the use RO system is effective.
- **Total cost of one m^3 raw water** = 4.36 SDG/m^3 (SDG = SUDAN currency)

The cooling tower water

Total saving of cooling tower water due to the optimization process = Total of three Periods

In the first Period =115.2 m^3/h
In the second Period =230.4 m^3/h
In the third Period =230.4 m^3/h
Total of the three Periods = 576.0 m^3/h

Total cost of 576 m^3/h cooling tower water

= 2511. 36 SDG/h
= 21999513.6 SDG/year

- **Cost of installing RO process**

Reverse Osmosis system commercial of capacity = 50000 GPD
Cost of RO process = 402322.8 SDG
Cost of building for RO process= 4765 $ = 41455.5 SDG

Total = process + building for RO process
= 443778.3 SDG

Man Power

Man Power = Salary + cost of transportation
The total cost of Man Power = 26620+ 69000 = 95620 SDG/year
Total cost of RO process = Man Power +Total
=539398.3 SDG

The total cost of RO process is less than the total cost of 576 m^3/h cooling tower water per year.

6. Conclusion

Analysis of Cooling Towers Water before and After Filtration indicates that the use RO system is effective. The calculated Total cost of one m^3 of raw water in Thermal Power Stations was very high.

The total cost of RO process is less than the total cost of the three Periods m^3/h cooling tower water per year. It is recommended to use reverse osmosis [RO] system, and make a complete feasibility study for the verification of constructing an RO station.

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