WRPI Report

Ryan Parlier

Cal State University Bakersfield

September 24th, 2018

Summary

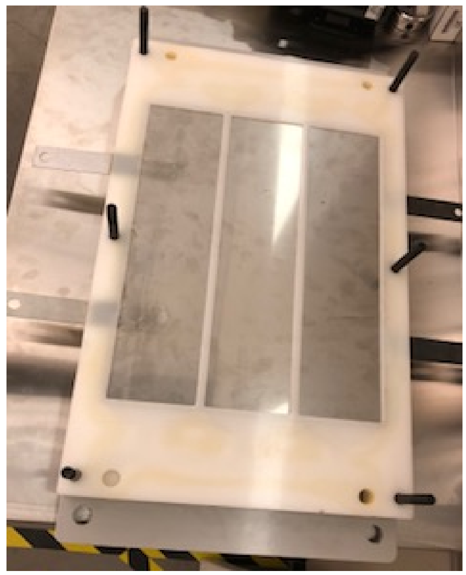
The three main water processes California Energy Research Center (CERC) has been focusing on are produced water, surface water, and ground water. Produced water has characteristics containing hydrocarbons and species, because it is a byproduct from the process of enhanced or tertial oil recovery. There are six main processes that are used to treat produced water: Coagulation, Flocculation, Ultrafiltration, Reverse Osmosis, Electro-Oxidation, and Electrodialysis. Coagulation uses KMnO4 to help stimulate the process, and $Al_2(SO_4)_3$ to allow the colloids and metal ions to bond together by the influence of a change in pH. Flocculation uses a tank where the particles are mixed by turbines in order to bond and create flocks. Ultrafiltration is a process that uses pressure and concentration gradients; the semipermeable membranes filter particulates and macromolecules out. Reverse Osmosis consists of pressure driven membranes, which removes particles larger than 0.1nm. Electro-oxidation is an electrochemical process that generates strong oxidants that oxidize organic and inorganic compounds that remain in the water. Electrodialysis utilizes ion movement to desalinate water, which requires less pretreatment while having the ability to achieve very high water recoveries. These processes use different chemicals and filters too clean toxic water; in order to reuse in a variety of applications, and reduce the volume of produced water by reusing up to 80% out of the water during the 100-gpm process. Surface and ground water also use Coagulation and Flocculation to help certain ions bond and then separate into sedimentation tanks. Pre-filtration removes large impurities before microfiltration, then microfiltration uses .1 micrometer filters and Pall absolute filters to separate small impurities from the solution. These processes provide alternative designs for water treatment in Kern County.

Introduction

Surface water, Ground water, and Produced water are the main sources of water on Earth. All of these sources must go through a filtering process; this will allow the water to be reused for different circumstances (Drinking water, Agriculture, Oil Industry, etc.) Reverse Osmosis, Electro-Oxidation, and Electrodialysis are all filtering processes that rely on a semipermeable membrane. Reverse Osmosis consists of pressure driven membranes, which removes particles larger than 0.1nm. Electro-oxidation is an electrochemical process that generates strong oxidants that oxidize organic and inorganic compounds that remain in the water. Electrodialysis utilizes ion movement to desalinate water, which requires less pretreatment while having the ability to achieve very high water recoveries. All processes use different ways to separate the anodes and cathodes in the mixed sediment. By using these forms of filtering, dirty water or water with high salt concentration can be cleaned and reused for different purposes; the captured water is referred to as permeate water. WRPI has given me the opportunity to study different forms of water filtration and construct a lab of my own at Cal State University Bakersfield. Electrodialysis is the focus for this lab; the main component I will be using is a semipermeable membrane filter, which will be cleaning dirty oilfield water (produced water) samples into reusable nontoxic water.

Methods and Materials

Kern County alone produces approximately 730,000 barrels of oil each day (Schuster), and on average 6.5 barrels of water is generated per 1 barrel of oil (Paraskova). Also, the latest study in 2012 stated , the US produced 21.2 billion barrels of produced water; this is the most recent year for which national volume data has been collected (Produced Water 101). With that being said, produced water is a byproduct from the process of drilling, this water contains many hydrocarbons and also the chemicals in which it was produced from. Produced water's first filtering process begins in the settling tank that allows skimmers to remove the masses of impurities. Then coagulation is a process that uses KMnO4 to help stimulate, and Al2 (SO4) 3 to allow the colloids and metal ions to bond together by the influence of a change in ph. Flocculation then uses a tank where the particles are mixed by turbines in order to bond and create flocks. Ultrafiltration is a process that uses pressure and concentration gradients; the semipermeable membranes filter particulates and macromolecules out. Reverse Osmosis consists of pressure driven membranes, which removes particles larger than 0.1nm. Electro-oxidation is an electrochemical process that generates strong oxidants that oxidize organic and inorganic compounds that remain in the water. Electrodialysis utilizes ion movement to desalinate water, which requires less pretreatment while having the ability to achieve very high water recoveries. These processes use different chemicals and filters too clean toxic water; in order to reuse in a variety of applications, and reduce the volume of produced water by reusing up to 80% out of the water during the 100-gpm processes. Surface and ground water also use Coagulation and Flocculation to help certain ions bond and then separate into sedimentation tanks. Pre-filtration removes large impurities before microfiltration, then microfiltration uses .1 micrometer filters and Pall absolute filters to separate small impurities from the solution. The area of water filtration that I am focusing on, is being built around an ABR electrochemical anion exchange membrane cell filter. The main power supply for this filter is a switch mode rectifier, designed by Volteq to put off 15V, 150A, 120VAC. A rectifier is an electrical device that converts an alternating current into a direct current, by allowing the current to flow through in one direction only. An Electrolyte pump made by Cole Palmer will be pumping contaminated water into the filter. The power speculations of this pump are 2.3A, 115V, 60 Hz, 1/15 HP, 3000 RPM, 10GPM/20.5Ft Head, ODP, Centrifugal.



Results

Water is one of the important matters on Earth, because everything that is living needs water to survive. Although when there is very small amount of clean water due to a drought, it is extremely important to find ways to clean water that has already been used, or is too dirty to consume by anything living, including plant life. Without electrochemical, reverse osmosis, electrodialysis and other filtering processes mentioned above, the majority of the water on Earth would be completely wasted. So, by using these processes on dirty samples, we are able to achieve a clean permeate sample, which is reused for other purposes. Also, different contaminated water samples will be ran through the filter, in order to create accurate data and research reports on the permeate water.

Conclusion

Water is a natural resource that cannot be chemically made or reproduced, so it is very important to utilize the water that Earth provides. Filtering water is a unique aspect of recycling, because not many others have the resources to filtrate water. These filtering processes are essential to our environment and community. Since electrodialysis is area I will be focusing on, it is important for me to know the main concepts of all water filtration systems, that way it will give me a better understanding of the project I am working on. Produced water, surface water, and ground water are all equally important, they just differ in ways of filtering and cleaning. There can be certain chemicals that are not easily removable from the water that is why electrochemical filtering can be so important in the cleaning process. Permeate water will be the end result, this clean water that has been separated from the other wastes, will be reusable for other sources. If water isn't conserved and reused, eventually certain places in California will be without a source of water. Filtering is the only way that the community can achieve high amounts of reusable water for many purposes.

References

1.) Schuster, Ryan. "Kern's Oil Production Declines 3%." *The Bakersfield Californian*, 13 Sept. 2016, www.bakersfield.com/news/business/kern-s-oil-production-declines/article_3de4089b-9ba7-59e6-9cf2-dc0bb839ba11.html.

2.) Paraskova, Tsvetana. "U.S. Shale: Water Is the New Oil." *OilPrice.com*, 21 Sept. 2017, oilprice.com/Energy/Crude-Oil/US-Shale-Water-Is-the-New-Oil.html.

3.) "Produced Water Treatment and Beneficial Use Information Center." *About Produced Water (Produced Water 101)*, aqwatec.mines.edu/produced_water/intro/pw/.

Report for : California Water Service

Prepared by: Alan Fuchs, PhD., Director, California Energy Research Center

Date: September 24, 2018

Summary

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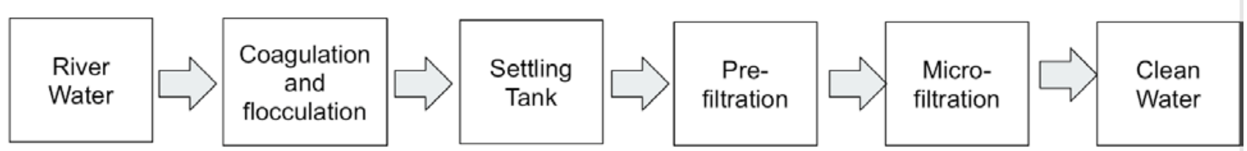
David Gleason
5/16/2018
Energy and Research
Final Report

Process Description: Municipal Water

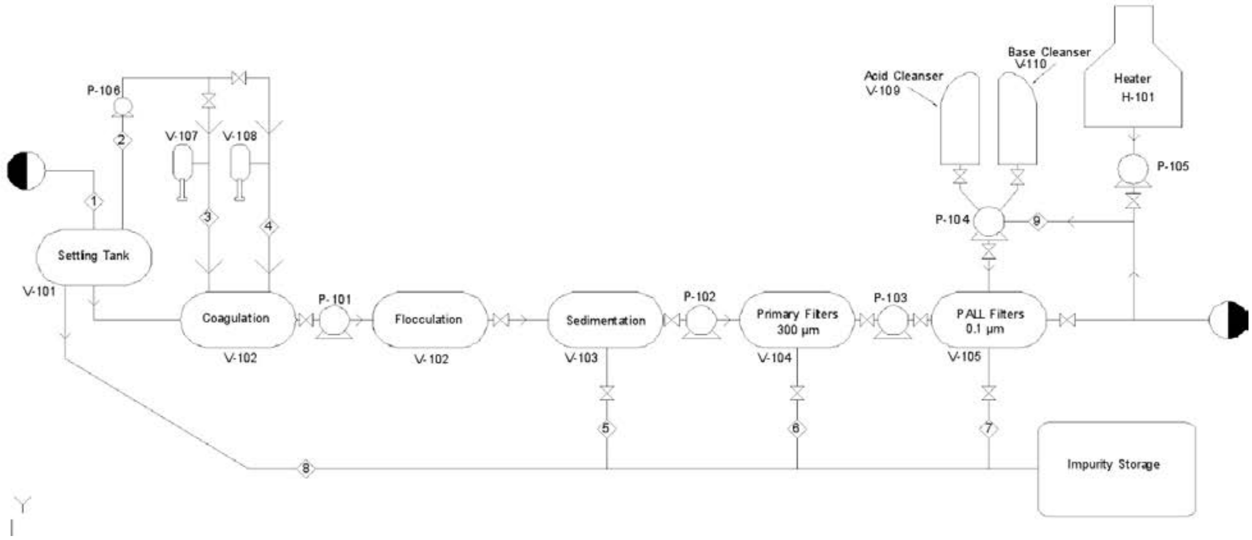
The sources for the water treatment plant include well water and river water. The water enters the plant through a 30-inch feed line where Potassium Permanganate is introduced to the water. The water is then sent into the coagulation and flocculation tanks. Prior to the coagulation and flocculation, a small line is diverted to receive a charge neutralizing solution, Aluminum Chloride, that helps the particles clump together. During coagulation and flocculation, there are blades that churn the water very softly to expedite the process. After coagulation and flocculation, the water goes through some inclined settlers. The inclined settler is a time-consuming process that requires the water to be very peaceful and undisturbed. The particles enter the settlers and travel to the bottom of the tank, which is scraped very slowly to remove sludge to the impurity storage. Water is then sent to the in-door portion of the facility where it goes through a 300 micron pre-filter treatment to remove larger particles from the water. The water then enters the ultra-filtration portion of the treatment where the water passes through filters with a porosity of .1 micron. These filters(Pall Filters) remove anything that is greater in size than .1 micron.

To clean the filters, both the 300 micron and the .1 micron filters are cleaned through a backwashing technique where water is pushed through the lines in reverse direction to clean out the filters, and the sludge diverted to the impurity storage. Backwashing occurs intermittently dependent upon the flow of the facility, once every 30 minutes during high-flow and once every hour during regular operations. The filters also receive cleaning with Citric Acid and Sodium Hydroxide periodically.

Cal Water Block Flow Diagram



Process Flow Diagram



Stream Lines:

Stream #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Back Wash**	**Back Wash**
Temp (C)	30	30	30	30	30	30	30	30	50	40	40
Pressure psi	14.7	5	5	5	5	5	5	5	14.7	25	25
KMnO4 %	0	0	.5	0	0	0	0	0	0	0	0
Al2(SO4)3 %	0	0	0	.5	0	0	0	0	0	0	0

Citric Acid	0	0	0	0	0	0	0	0	0	.5	0
NaOH	0	0	0	0	0	0	0	0	0	0	.5
Water (GPM)	100	10	10	10	5	5	5	5	20	10	10

Equipment Tables:

Equipment	V-101	V-102	V-103	V-104	V-105	V-107	V-108	V-109	V-110
MOC	SS	SS	SS	SS	SS	Poly	Poly	Poly	Poly
Diameter (m)	1.2	1.2	1.2	1.2	1.2	.25	.25	1.2	1.2
Height (m)	3	3	3	3	3	1	1	3	3
Orientation	Vert	Vert	Vert	Vert	Vert	Vert	Vert	Vert	Vert
Internals	SS	SS	SS	SS	SS	SS	SS	Poly	Poly
Pressure	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7

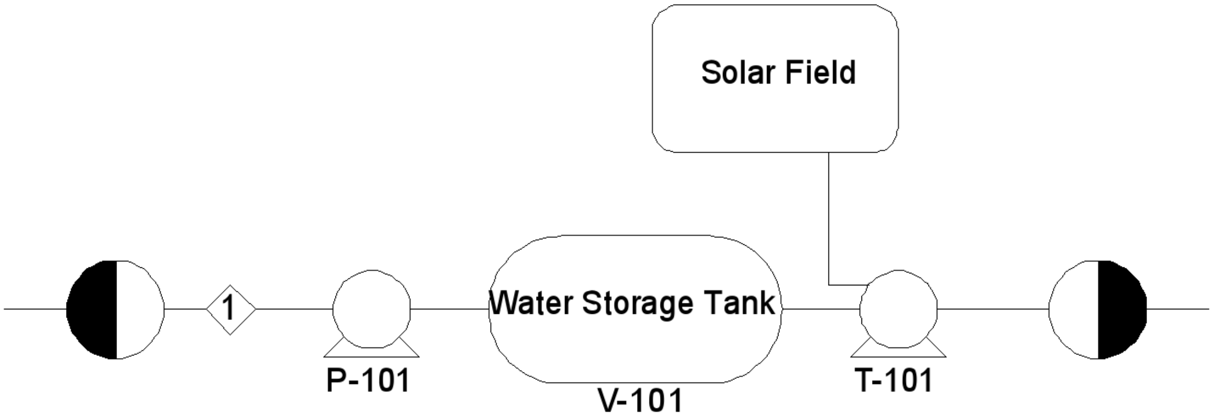
Equipment	P- 101	P- 102	P- 103	P- 104	P- 105	P- 106
MOC	SS	SS	SS	SS	SS	SS
Power (shaft)(kW)	3.1	3.1	3.1	3.1	3.1	1
Efficiency	60%	60%	60%	60%	60%	60%
Type/Drive	C	C	C	C	C	C
Temperature (C)	90	90	90	90	90	90
Pressure (psi)	43	43	43	20	20	20

Equipment	H-101
Type	Fired Heater
Duty (MJ)	79.23

Design Capacity	24 GPM
MOC	Copper
Thermal Efficiency	60%

Cal Water Capital Cost				
	Link	Quantity	Cost ($)	Total cost ($)
V-101	Capital Cost	5	8390	41950
1000-Gallon Stainless Steel Mixing Tank	https://www.indco.com/onethousand-gallon-stainless-steel-mixing-tank	2	17304.25	34608.5
36"x15'x1440 Horizontal Separator	et/for-sale/for-sale-reconditioned-36quotx15x1440-horizontal-separator-	1	34,000	34000
1000 Gallons tank	://www.usabluebook.com/p-324432-100-gallon-316-stainless-steel-tank.	3	2849.95	8549.85
Pall Filters 300 Micron	Estimate	2	5,000	10000
Pall Absolute Filters .1 Nanometer	Estimate	720	25000	18000000
275 Gallon Reconditioned IBC Tote, 2" NPT Valve, Steel Pallet	source=google_shopping&m=simple&gclid=CjwKCAjw75HWBRAwEiw	2	181	362
Plastic Drum - 55 Gallon, Closed Top, Natural	://www.usabluebook.com/p-324432-100-gallon-316-stainless-steel-tank.	2	67	134
Centrifugal Self-Priming 55-150 gpm	nanufacturer/amt/centrifugal-self-priming-55-150-gpm/cast-iron-self-primi	5	506.62	2533.1
10 GPM 1 HP Stainless Steel Portable Transfer Pump	w.waterpumpsdirect.com/Simer-2825SS-Water-Pump/p	1	199.99	199.99
30x30 Water to Air Heat Exchanger 11/4" Copper Ports w/ EZ Install Front Flange	eat-Exchanger-11-4-Copper-Ports-w-EZ-Install-Front-Fl	4	1040	4160
			Total Capital	18136497.44

An alternative case can be examined where solar panels are used to harness the energy of the sun to reduce the amount of power that is purchased from PG&E, thus reducing the costs of operating the plant. The solar panels could be used in junction with a turbine that generates power from processes throughout treatment of the water. Both of these processes could potentially save the plant approximately $35,000 per year.



Solar panels	
Area(Sq ft.)	17.60416667
Production(Watts)	300
Number of Panels	100
#Panels*14 hours*kW	420
365 Days	153300
Revenue	$ 27,594.00

Once we presented to the gentlemen from Cal Water, we were asked to present at a later date. The date is still to be determined, but all of the members, Kyle, Lovre, Isabel, and myself, are willing to present the project again to the engineers employed at Cal Water.

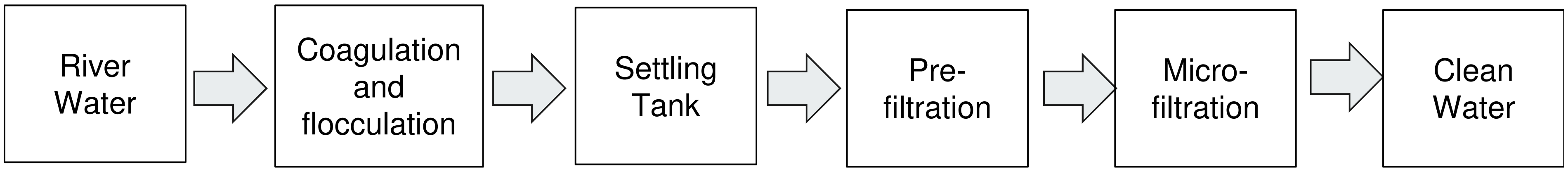
Cal Water

By: David Gleason, Kyle Jameson, Isabel Guerra, and Lovre Soric

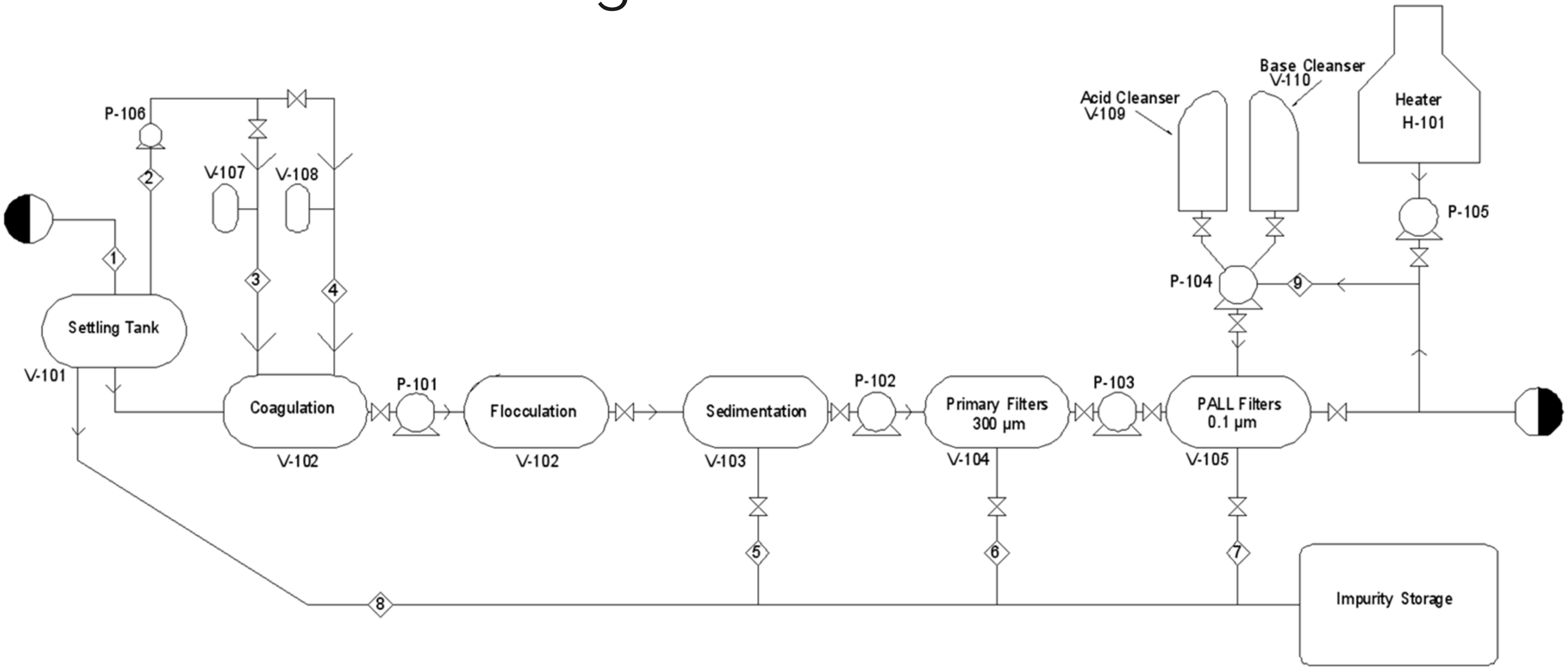
Overview

- Block Flow Diagram
- Process Flow Diagram
- Stream Tables
- Equipment Tables
- Cost Analysis

Block Flow Diagram



Process Flow Diagram



Coagulation

- KMnO4 is added to help stimulate the coagulation process

- Aluminum sulfate - Al2(SO4)3 is added to allow the colloids and metal ions to bond together by the influence of a change in pH

Flocculation

- In the flocculation tank the particles are mixed by turbines in order to bond and create flocks.

- The water is sent to sedimentation tanks where incline plates allow the separation of the flocks from the water.

Pre-filtration and Microfiltration

- Removes larger impurities before the microfiltration
- 300 micron filter

- .1 micrometer filters
- Pall Absolute Filters
- Cryptosporidium
- Giarda

Stream Tables

Stream #	1	2	3	4	5	6	7	8	9	Back Wash	Back Wash
Temp (C)	30	30	30	30	30	30	30	30	50	40	40
Pressure psi	14.7	5	5	5	5	5	5	5	14.7	25	25
KMnO4 %	0	0	.5	0	0	0	0	0	0	0	0
Al2(SO4)3 %	0	0	0	.5	0	0	0	0	0	0	0
Citric Acid	0	0	0	0	0	0	0	0	0	.5	0
NaOH	0	0	0	0	0	0	0	0	0	0	.5
Water (GPM)	100	10	10	10	5	5	5	5	20	10	10

Equipment Tables: Vessels

Equipment	V-101	V-102	V-103	V-104	V-105	V-107	V-108	V-109	V-110
MOC	SS	SS	SS	SS	SS	Poly	Poly	Poly	Poly
Diameter (m)	1.2	1.2	1.2	1.2	1.2	.25	.25	1.2	1.2
Height (m)	3	3	3	3	3	1	1	3	3
Orientation	Vert	Vert	Vert	Vert	Vert	Vert	Vert	Vert	Vert
Internals	SS	SS	SS	SS	SS	SS	SS	Poly	Poly
Pressure	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7

Equipment Tables: Pumps

Equipment	P- 101	P- 102	P- 103	P- 104	P- 105	P- 106
MOC	SS	SS	SS	SS	SS	SS
Power (shaft)(kW)	3.1	3.1	3.1	3.1	3.1	1
Efficiency	60%	60%	60%	60%	60%	60%
Type/Drive	C	C	C	C	C	C
Temperature (C)	90	90	90	90	90	90
Pressure (psi)	43	43	43	20	20	20

Equipment Tables: Heat Exchangers

Equipment	H-101
Type	Fired Heater
Duty (MJ)	79.23
Design Capacity	24 GPM
MOC	Copper
Thermal Efficiency	60%

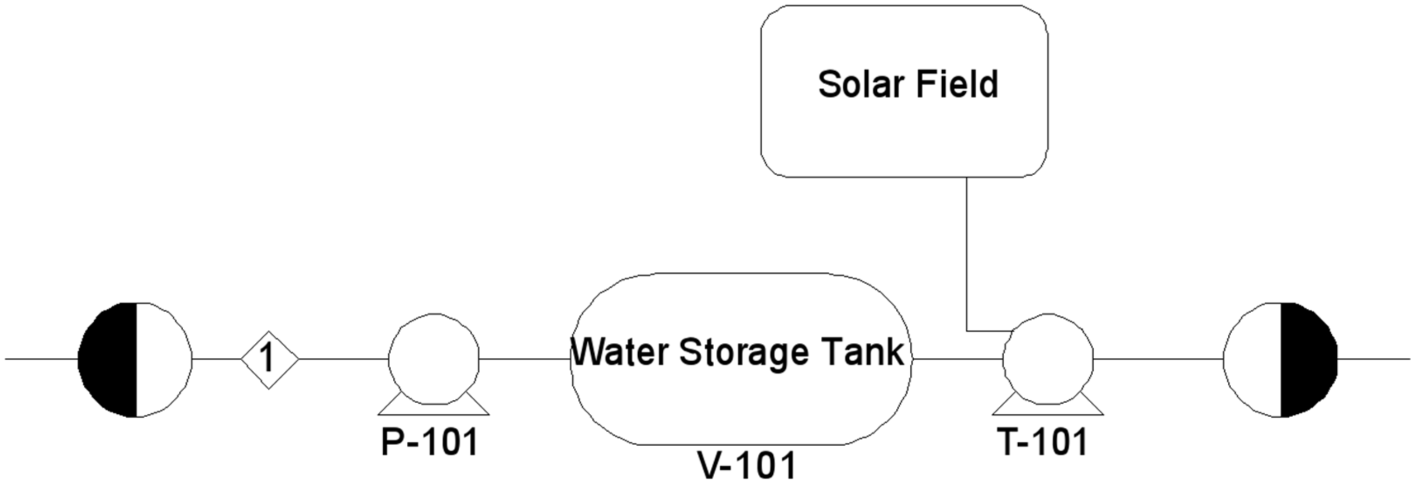
Cost Analysis

Cal Water Capital Cost				
	Link	Quantity	Cost ($)	Total cost ($)
V-101	Capital Cost	5	8390	41950
1000-Gallon Stainless Steel Mixing Tank	https://www.indco.com/onethousand-gallon-stainless-steel-mixing-tank	2	17304.25	34608.5
36"x15'x1440 Horizontal Separator	et/for-sale/for-sale-reconditioned-36quotx15x1440-horizontal-separator-	1	34,000	34000
1000 Gallons tank	://www.usabluebook.com/p-324432-100-gallon-316-stainless-steel-tank.	3	2849.95	8549.85
Pall Filters 300 Micron	Estimate	2	5,000	10000
Pall Absolute Filters .1 Nanometer	Estimate	720	12000	8640000
275 Gallon Reconditioned IBC Tote, 2" NPT Valve, Steel Pallet	source=google_shopping&m=simple&gclid=CjwKCAjw75HWBRAwEiw	2	181	362
Plastic Drum - 55 Gallon, Closed Top, Natural	://www.usabluebook.com/p-324432-100-gallon-316-stainless-steel-tank.	2	67	134
Centrifugal Self-Priming 55-150 gpm	nanufacturer/amt/centrifugal-self-priming-55-150-gpm/cast-iron-self-prim	5	506.62	2533.1
10 GPM 1 HP Stainless Steel Portable Transfer Pump	w.waterpumpsdirect.com/Simer-2825SS-Water-Pump/p	1	199.99	199.99
30x30 Water to Air Heat Exchanger 11/4" Copper Ports w/ EZ Install Front Flange	eat-Exchanger-11-4-Copper-Ports-w-EZ-Install-Front-Fla	4	1040	4160
			Total Capital	**8776497.44**

Operating Costs

Operation	Cost
Labor	$ 320,000.00
Electical Power	$ 19,552.32
Maintenance	$ 877,649.70
Chemical Cleaning Cost	$ 438,824.85
Total	$ 1,656,026.87

Alternative Case



Alternative Case

Solar panels	
Area(Sq ft.)	17.60416667
Production(Watts)	300
Number of Panels	100
#Panels*14 hours*kW	420
365 Days	153300
Revenue	$ 27,594.00

Turbine	
Power Generated(kWhr)	65
Production per year	23725
Revenue	$ 4,270.50

Appendix

- <u>Volume of settling tank-</u>
  100 GPM * 9 min = 900 gal = 3.4 m^3
  Height - 3 m
  r = 0.6 m
  3.4 m^3 = pi*r^2*3

- <u>Power for pumping liquids:</u>
  kW = (1.67)[Flow(m3/min)][ΔP(bar)]/ε
  43 psi = 2.96 bar
  100 GPM = 0.37 m3/min
  ε = 60%
  kW = (1.67)(0.37)(2.96)/0.6
  kW = 3.1

- <u>Filter cleanser:</u>
  For 100 gallons
  c=4.186 J/g°C
  m= 378 541.18 g
  ΔT = 50 °C
  Q= ΔT*m*c= 79.23 MJ

Acknowledgements

- https://www.watertechonline.com/what-is-ultrafiltration-and-what-are-ultrafiltration-processes-in-wastewater/
- http://membranes.edu.au/wiki/index.php/Pore_Size
- https://www.mrwa.com/WaterWorksMnl/Chapter%2012%20Coagulation.pdf

CSU Bakersfield
School of Natural Sciences, Mathematics, and Engineering

CAL WATER

David Gleason, Kyle Jameson, Isabel Guerra, and Lovre Soric

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Processes:

Coagulation:

KMnO4 is added to help stimulate the coagulation process

Aluminum sulfate - Al2(SO4)3 is added to allow the colloids and metal ions to bond together by the influence of a change in pH

Flocculation:

In the flocculation tank the particles are mixed by turbines in order to bond and create flocks.

The water is sent to sedimentation tanks where incline plates allow the separation of the flocks from the water.

Settling Tank:

After flocculation occurs, the water continues to a calm environment where inclined plate settlers work as skimmers to remove the flocs from the surface of the water.

Pre-filtration:

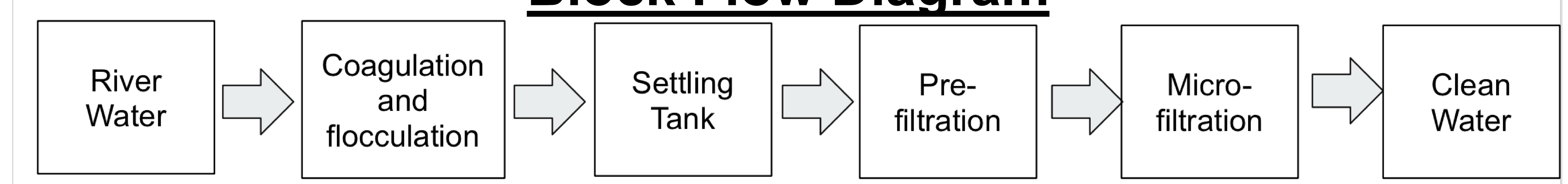
The water goes through a pre-filtration process that filters out larger contaminants, contaminants that are greater than 300 micron in size.

This helps eliminate contaminants that would otherwise gunk up the micro-filtration process and reduce the efficiency of the system.

Micro-filtration:

This is the last step in cleaning the water. This step includes Pall Absolute filters that remove any contaminants greater than .1 micrometer in size. These filters are effective in removing Giarda Cysts and Cryptosporidium.

Block Flow Diagram



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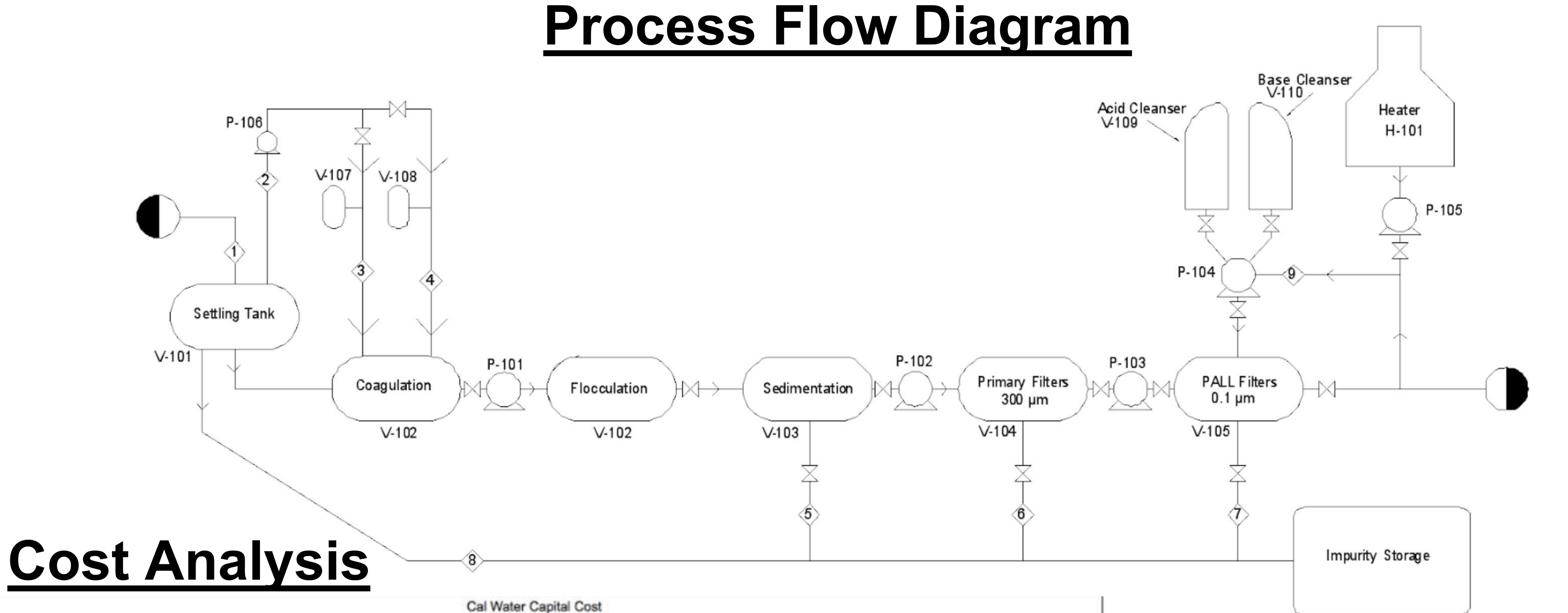

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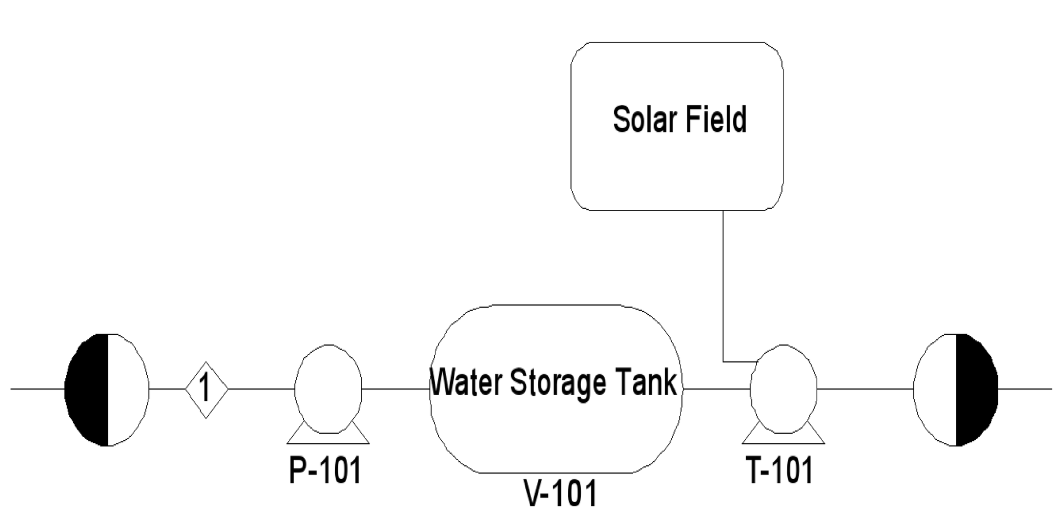

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Revenue	$ 4,270.50

Utilizing the energy from the sun and/or generating hydro-electric energy, the operating costs can be greatly reduced.

Stream Tables

Stream #	1	2	3	4	5	6	7	8	9	Back Wash	Back Wash
Temp (C)	30	30	30	30	30	30	30	30	50	40	40
Pressure psi	14.7	5	5	5	5	5	5	5	14.7	25	25
KMnO4 %	0	0	.5	0	0	0	0	0	0	0	0
Al2(SO4)3 %	0	0	0	.5	0	0	0	0	0	0	0
Citric Acid	0	0	0	0	0	0	0	0	0	.5	0
NaOH	0	0	0	0	0	0	0	0	0	0	.5
Water (GPM)	100	10	10	10	5	5	5	5	20	10	10

Pumps

Equipment	P- 101	P- 102	P- 103	P- 104	P- 105	P- 106
MOC	SS	SS	SS	SS	SS	SS
Power (shaft)(kW)	3.1	3.1	3.1	3.1	3.1	1
Efficiency	60%	60%	60%	60%	60%	60%
Type/Drive	C	C	C	C	C	C
Temperature (C)	90	90	90	90	90	90
Pressure (psi)	43	43	43	20	20	20

Vessels

Equipment	V-101	V-102	V-103	V-104	V-105	V-107	V-108	V-109	V-110
MOC	SS	SS	SS	SS	SS	Poly	Poly	Poly	Poly
Diameter (m)	1.2	1.2	1.2	1.2	1.2	.25	.25	1.2	1.2
Height (m)	3	3	3	3	3	1	1	3	3
Orientation	Vert	Vert	Vert	Vert	Vert	Vert	Vert	Vert	Vert
Internals	SS	SS	SS	SS	SS	SS	SS	Poly	Poly
Pressure	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7

Equipment	H-101
Type	Fired Heater
Duty (MJ)	79.23
Design Capacity	24 GPM
MOC	Copper
Thermal Efficiency	60%