Analysis Of The Performance Of Water System In Plastic Manufacturing Plant

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Abstract: Plant is located in Sabhan north of Kuwait city. As described below, the plant began operations in 1994 to manufacture plastic bags, cloth diaper liners and pampers. The plant's major manufacturing equipment includes 5 filling lines, 11 mix tanks (ranging in size of 2,000 – 32,000 liters), 16 sterilization vessels (5-2 place and 11-4 place) and (5) Packaging lines. A technical engineering assessment conducted at the facility, which took place over 3 month's period; the study involved the plant operation engineering, maintenance and production personnel. The goal of the assessment was to account for the modification and improving of water treatment system to identify opportunities to reduce energy consumption and its associated cost. The Manufacturing administration require all in charged Energy Teams, to review the recommendations in the report in addition, provide updates on the progress of the recommendations until all projects are closed off or implemented. Any rejected recommendations need to be reported. A report of every plant's progress towards implementing their recommendations presented to the Manufacturing VPs, for their review and comments.

1. Introduction

The plant manufactures plastic bags, cloth diaper liners and pampers products. The plant's major manufacturing equipment includes 5 filling lines, (11) mix tanks (ranging in size of (2,000 – 32,000 liters), 16 sterilization vessels (5-2 place and 11-4 place) and (5) Packaging lines as shown in the figure (1) :

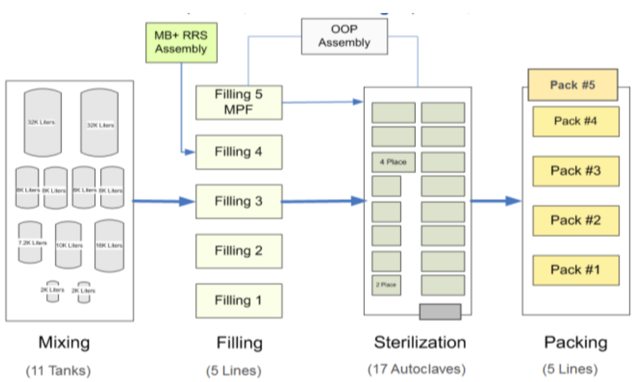


Figure (1) plant manufactures assembly layout

Annual energy costs and consumption by fuel source are from the period March 2018 to February 2019 "Ref. [4] "

Unit	Water Usage	Cost			
	Treated Gal/yr	Total Annual Cost		Cost /1000 Gal	
Raw Water	62,054,828	$	435,489	$	7.02
Filtered Water	42,052,500	$	363,722	$	8.65
Softened Water	44,860,000	$	453,348	$	10.11
Carbon Beds	19,372,500	$	392,152	$	20.24
Reverse Osmosis (RO) Generation	20,160,000	$	387,398	$	19.22
Reverse Osmosis (RO) Distribution		$	428,211	$	21.24
DW/WFI - Production	16,701,000	$	599,558	$	35.90
DW/WFI - Distribution		$	689,018	$	41.26

(Table 1) Annual energy costs

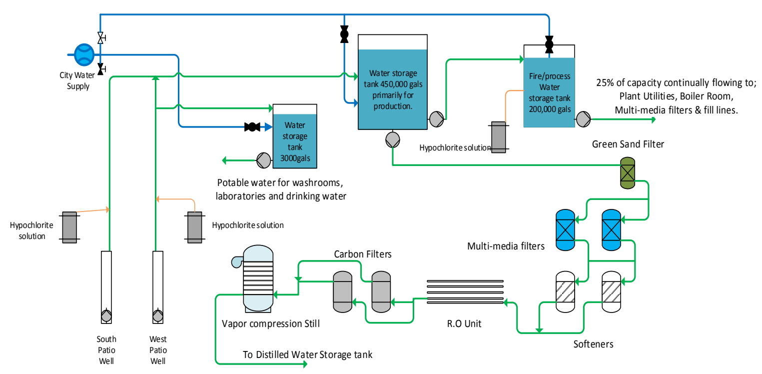
The study requested to evaluate the condition and remaining useful service life of the plant. The scope of work included "Ref. [1], [2] ":

- Field verification of the water piping systems to generate an accurate flow diagram of the existing configuration of each. Components.
- Development of a plan and direction for the detailed chilled water plant design including recommendations for refrigerant utilized by the new plant equipment.
- Determination of system configuration and overall preliminary system capacity.
- Visual inspection and recommendations to structural improvements/modifications necessary during the study.
- Preparation of Design Criteria for owner's use to procure the design services for the detailed design and REVIT modeling of construction documents.

This study based upon our review of the existing available drawings of the mechanical systems, inspection of the facilities including identified mechanical equipment and system operational reading and testing. A very advanced testing equipment's and devices used in the inspection services. This type of inspection clearly reveal most of defect.

2. WATER SYSTEM LAYOUT

System has two sources of water; one is city water the second is well water. Both supplies pumped to three water tanks. The water source that is used 90% of the time is the wells water this due to the lower cost.



(Fig 2) general layout of the water

The intent of this layout was to retain as much chlorine in the system until it was necessary to remove it before the stills. However, this thinking may have had some logic when the quality of the incoming water was less than what it is today. Over the years, it has been an expensive system to run in operating costs. There is a proposal and potential funding to upgrade the system but a rethink of the design should be included in this proposal to eliminate the issues currently plaguing the plant, at least to move the carbon filters before the water softeners.

3. EXISITING PLANT OPERATION PROCCESS:-

3.1- Well water – Chlorination

Well water pumped to the three storage tanks by a (15KW) motor in each well. Prior to the storage tanks, it is chlorinated using hypochlorite solution with a dosing range of (0.5- 5) ppm. Further chlorination takes place in the (200,000) gallon tank .The chlorination process manually dosed to the same level. The procedure is an operator takes a sample of water from the tank every (2-3) hours to check if the chlorine level is within limits. If the level is at the lower end (e.g. 2ppm) then it is manually slug dosed to increase level. Controlling chemical dosing in this manner is a poor way to manage the system. The ranges of chlorine levels are excessive. Controlling levels to a tighter specification to ensure that the chlorine level leaving the tank is a consistent value between (1- 2 ppm). Chlorine dosing to be controlled based on water flow. Higher levels may be needed but as long as the chlorine is removed before the softeners and RO units or is kept below (1-ppm). An additional chlorination station, not shown, is for the sterilizer fill water loop the dosing levels of sodium hypochlorite is (2.5ppm – 9ppm) , this is unheard as normal practice to chlorine dose the water to the sterilizers at these levels. The level target is between (2-3ppm) but because there is no automatic, control of the dosing process is manual and reaches to (9ppm).It is not a normal practice using chlorine in sterilizer fill water in many plants, because it causes all sorts problems with the equipment from corrosion

Annual costs for sodium hypochlorite are ($9,880) this is comprised of approximately (52) drums.

Chlorination	Sodium Hypochlorite	Cost/Drum	190
Volume/month -barrels		Total/year	Annual cost
Well #1	2	24	$4,560.0
Well #2	2	24	$4,560.0
200K tank - as needed		2	$380.0
Sterilizer.as needed		2	$380.0
Totals		52	$9,880.0

(Table 2) Annual costs for sodium hypochlorite

3.2. Green Sand Filter & Multimedia filters.

Water from the (450,000-gallon) tank first pumped through a single green sand filter; the filter originally installed for the first well because of the iron content in the water it produced. Over the years, the plant say the iron content has reduced to not being a problem.

(Fig 3) arrangement of filter tanks and softener

The filter is backwashed at (93 g. p .m) and flushed at (42 g. p.m.). Total time 15 minutes daily, this split (50:50) with backwash and flush. There is a benefit in improved filtration if the filter partially blocked without it causing breakthrough of the media. It is for this reason why backwashing based on differential pressure is a better option. This will provide water savings.

3.3. Multimedia Filters

There are two multimedia filters, operating in duty standby mode. One unit is put online while the other backwashed and flushed at (100gpm) for (20) minutes. This time split 50:50 between backwash and flush. Just as with the green sand filter there is a benefit in improved filtration if the filter and reduced water usage and cost if is allowed to become partially blocked without it causing breakthrough of the media. Other Baxter plants only backwash the multimedia filters once per week or even longer. The higher frequency of backwashing increases the loss of the media because a small volume of the media is lost every time it is backwashed. The picture above shows the water softeners in the foreground with the multimedia filters to the right.

3.4. Maintenance cost

Media replacement costs; Media volume (80ft3 x $933/ ft3 = $74,640) every two years. Typically, 5 years or more expected before replacing the media. The need to replace the media is typically due to media loss from the backwashing process. If the media loss is minimal then the frequency of replacing the media extended.

3.5. Water softeners

The softeners operate in duty standby mode. The unit in standby is regenerated taking (20) minutes to complete the cycle, flow rate is (100gpm). A softener regenerated every day.

Water softeners x 2	Salt use Lbs. Monthly	Annual Salt cost	Annual Resin replacement cost	total annual cost
salt cost $9.8 per bag	2520	$7,409	$7,500	$14,909

(Table 3) Maintenance Cost

Resi replaced every year; the cost is ($7,500). Replacing the cation resin every year is unusual, considering it is normal to expect (5-7) years, or more. This short life is to do with placing softeners before the carbon filters in the original design and not after the carbon filters. The cation resin is porous plastic beads it is highly susceptible to chloramines and chlorine degradation. The dosing levels of chlorine as described above are (0.5ppm – 5ppm) is a range that could easily have the presence of chlorine well outside the acceptable limits for use in a water softener. The presence of 2ppm of residual chlorine can reduce the life expectancy of the softening resin by half.

3.5. Reverse Osmosis

There are two RO units, the #2 is an old single pass unit used for treating recycled water, and conductivity is approximately (195µsiemens). The water used for boiler makeup. The source of this water is the end of cycle water from the sterilizers. The #3 RO is for WFI production and is supplied with chlorinated softened water that receive chlorinated water at levels that higher than what the membranes are designed to accept. Permeate from the #3 RO is sent to a (6000gallon)storage tank used to supply Still #5, the Aquachem. The RO membranes have a chlorine resistance up to (1-ppm).This would normally last (3) years or more before replaced. The membranes in the factory plant are replaced annually this is due to the high levels of chlorine being allowed into the unit. This situation needs correction.

Reverse Osmosis Generation Maintenance

Number of RO Systems for WFI production	1	
Cleaning Frequency	12	times/yr/RO
Cleaning Cost	$500.0	/cleaning
Number of RO Membranes Total	25	
Membrane Cost	$800.0	/membrane
Membrane Replacement Frequency	1	Yearly
Labor cost	$960.0	/year
Total RO Maintenance Cost	$26,960.0	/year

(Table 4) Reverse osmosis generation maintenance

3.6. Carbon Filters

These are the last in the chain before the distillation units. It operate in duty and standby mode and change over every 24 hours. Filter back washed with steam (@ 20psig) for (20) minutes as programmed, then filter is rinsed with water. The carbon in system changes every 5 years. Replacement cost is about ($2,700). A recommendation to relocate the carbon filter before the water softener to remove the chlorine and any additional organic material that has passed through the multimedia filters.

3.7. WFI production.

The basic operating parameters of the two distillation units shown in the table below. Aquachem used all the time; the MECO is standby only, only operates in the event that the Aquachem not running. A new MECO (2400gpm) delivered to site. Expected installation to be complete within the next 6 months.

Distillation Units									
Equip I.D.	Manufacturer Model #	Pump Electrical Load	Average flow	Blow down Rate	% of Blowdown	Production	Sanitizing	Steam Consumption per hour, Ambient	Hot or Ambient System
		HP	Gals/Min	Gals/Min		Hrs/Yr	Hrs/Yr	lb/hr	
#2	MECO	75	20	4	20%		52	1200	Both
#5	AQUACHEM	250	50	8	16%	8000	100	3000	Both

(Table 5) Distillation unit's specifications

3.8. Total Water Costs

The table (6) shows the utility usage and total water costs:

	Water Usage			Utilities		Cost		
Unit	Treated	Waste	Waste to Sewer	Electricity	Steam	Unit Operational Cost	Total Annual Cost	Cost
	Gal/yr	Gal/yr	Gal/yr	kWh/yr	lbs/yr			/1000Gal
Raw Water	62,054,828			113,064		$435,489	$435,489	$7.0
Filtered Water	42,052,500	4,315,500	0			$38,320	$363,722	$8.6
Softened Water	44,860,000	500,000	500,000	210,000	0	$61,019	$453,348	$10.1
R.O. Generation	20,160,000	7,560,000	7,560,000	112,000	0	$107,264	$387,398	$19.2
R.O. Distribution		0	0	252,000	0	$40,813	$428,211	$21.2
Carbon Beds	19,372,500	787,500	493,500		3,500	$4,754	$392,152	$20.2
DW/WFI - Production	16,701,000	2,672,160	0	1,113,400	2,909,128	$227,280	$619,445	$37.1
DW/WFI - Distribution				596,400	0	$89,460	$708,905	$42.4
Total			8,553,500	2,396,864	2,912,628	$1,004,399		

(Table 6) Total water system redesign cost

4. 4- WATER SYSTEM RECOMMENDATION

4.1- Control the chlorination system to specific set point automatically

The problem of inadequate control of the water chlorination system is evident from the higher costs of maintenance of the pretreatment system and the shorter life expectancy of RO membranes and softener resin. It must monitor and control Chlorine levels automatically to minimum levels, sufficient to provide the disinfection required. Industry best practices for system design, indicate that a target residual disinfection concentration of (0.5 to 1mg/l) (0.5 -1mg/l = 0.5 to 1ppm) .Treated product water residual concentration should not vary more than (0.2) mg/l (0.2ppm). It is inappropriate to inject large volumes of sodium hypochlorite during normal operations, as it appears to be the case in the (200,000-gallon) tank. A recommendation of installing an automated dosing control system in the plants water system will accurately control the limits of chlorine to the minimum effective levels throughout the entire system "Ref. [6]". The plant spends approximately ($10,000) per year on sodium hypochlorite. Correct control strategy will reduce plant spends with the. (30 – 50%). In addition, it will reduce the ongoing maintenance costs of the water softeners and reverse osmosis unit for WFI production.

4.2. Water softeners

Since there is no accurate, control or monitoring of the chlorine levels of the water prior to entering the water softener and as stated above chlorine, levels at (2 ppm) will reduce resin life by (50%). The evidence suggests that the cation resin is getting even higher levels because annually replaced. Once the sodium hypochlorite dosing issue has been resolved, the following savings in cation resin replacement is expected.

Water softener x 2		Salt cost $9.8 per bag
Salt use Lbs. monthly		2520
Annual salt cost		$7409
Annual resin replacement cost		$7500
Total annual cost		$14909
Resin cost over 5 years		$37500
Saving over 5 years		$30000
Annual resin saving		$4000
Soft water cost /1000 gallon		$100

(Table 7) Annual resin saving

4.3. RO membranes

The same issue with the water softeners also applies to the RO units with fouling of membranes due to high levels of chlorine. The same solution applies to the RO as it does the softener resin and that is to resolve the excess chlorine in the system and keep it below (1ppm) or eliminate it by putting the carbon filter before the water softener. RO membranes should last 3-4 years, resolving the chlorine issue will provide cost savings by not replacing the membranes. Membrane replacement costs ($20,000) per year, over 3 years this cost becomes $60,000. Savings per year are ($40,000/3 = $13,333).Total potential savings from correcting the issues around sodium hypochlorite dosing are approximately ($23,300).

4.4. Backwash green sand filter and multimedia filters based on differential pressure.

Back wash the green sand filter and the multimedia filters based on pressure differential across the filter bed. This was the method done in the past but when the system broke down, Maintenance personal not attended to repair. Consequently, maintenance cost has gone up. The recommendation is to install a working system to control when backwash and rinse of the multimedia takes place. From a clean backwashed filter determine what the differential pressure is then allow an additional (10psi) before to use as a set point for backwashing. Other plants operating this way have seen the backwashing and rinse cycles reduced to once per week.

	86%	Back wash			Rinse			Total for backwash and rinse (Gals)	Savings	
Item	Frequency	Time - minutes	Flow - gpm	Total	Time - minutes	Flow - gpm	Total		Cost	Water
Green sand filters	daily	10	93	334,800	10	42	151,200	486,000	$4,204	417,960
Multi media filter # 1	daily	**10**	100	360,000	10	100	360,000	720,000	$6,227	619,200
Multi media filter #2	daily	10	100	360,000	10	100	360,000	720,000	$6,227	619,200
Cost/1000gals		**$8.65**					Total Savings		$16,658	1,656,360

(Table 8) back wash saving

The recommendation is to install a pressure differential system to control when backwashing and rinsing taking place. If the pressure differential across a clean filter is measured and then and an additional (10psi) is added; this would be the set point for the system to control when backwashing will take place. Backwashing reduced on weekly bases. Savings are shown in the (table 8); but (1.65) million gallons of water could be saved annually with a cost savings of approximately ($16,600).In addition, the reduced frequency of replacing the media due to loss during backwashing it and would extend the period between either adding new media or replacing it. As stated above, it is common practice to replace the media every five years not every two years. The costs to replace the media in the green sand filter ($28,000), the multimedia filters are ($74,640). Replace the media every two years. Over a period of 5 years, this becomes approximately ($257,000). By implementing automated backwashing based on differential pressure, and the reduced need to replace the media every (2) years, over ($152,000) in costs can be reduced over a 5 year period ($257,000 - $102,000 = 153,000). This would have an annualized cost of ($30,700) per year. Total benefit would be ($47,300) and (1.65million) gallons of water.

4.5. Water Softeners. Control regeneration frequency based on water hardness

Automatically control cation resin regeneration based on hardness. Hach a company who manufactures hardness analyzers has two models that can do the job.

1. The picture below left is the APA600 low range analyzer; this has a range of (50-10,000 ug/l) and costs ($10,700).
2. The picture below right is the SP510 hardness analyzer this has a 1mg/liter trip point, and costs ($2,210).

(Fig 4) low range analyzer and hardness analyzer

In addition to the potential savings in salt reduction, water savings are also to be had this amounts to (357,500 gallons) and ($3,580).

4.6. RO membranes

The same issue with the water softeners also applies to the RO units with fouling of membranes due to high levels of chlorine. The same solution applies to the RO as it does the softener resin and that is to resolve the excess chlorine in the system and keep it below 1ppm or eliminate it by putting the carbon filter before the water softener. RO membranes should last 3-4 years, resolving the chlorine issue will provide cost savings by not replacing the membranes. Membrane replacement costs $20,000 per year, over 3 years this costs becomes $60,000. Savings per year are $40,000/3 = $13,333.

5. CONCLUSION:

We use water in our manufacturing operation as an essential substance. Water operate our factories heating and cooling systems and to clean all our faculties. In many regions and ours is one of these regions of the world faces water scarcity and becomes major challenge .Therefore , it is very important that we give more attention to water efficiency measures and meet universal committees standards and investment criteria. Our study helped us save energy, improve overall efficiency, and reduce waste. Water efficiency improvement showed a great cost saving as indicated in tables shown above.

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