Cooling Water Tower Optimization - Microbiological Analyses and Flow bypasses

By Tracy Finnegan

Cooling towers can be a critical process in many industrial production facilities. If not treated properly, an industrial cooling tower can be the perfect media for biological growth. Its, typical pH is 7-9 and its temperature varies widely.

In a cooling tower, the water trickles down a large surface area in order to air-cool the water. The natural evaporation provides the necessary cooling to reuse the water.

As water evaporates, minerals and contaminants in the water concentrate. These minerals and contaminants eventually reach a concentration where they cause problems and interfere with the performance of both the tower and the cooling system. Fouling and corrosion of the cooling tower can impact both treatment and heat transfer losses, causing decrease in efficiency and increased power consumption.

Biofouling can also destroy cooling towers if they are made of lumber & corrosion can occur on metal parts.

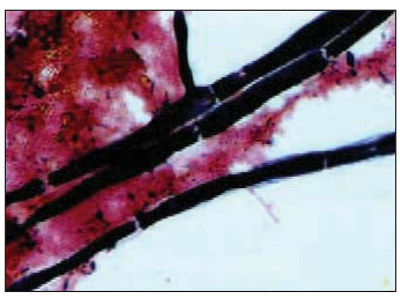
More seriously, such contaminants are harmful to people who come in contact with surface areas, like operational and maintenance personnel. The most notable example has been the outbreaks of Legionnaires' disease. This can affect people in hotels, hospitals, office buildings, and other locations, who have come in contact with cooled air from an air conditioning system or contaminated from cooling tower water of the air conditioning plant.

Typical Biological species found to cause Corrosion and Biofouling

- Fungi
- Mold
- Yeast
- Algae
- Aerobic and anaerobic bacteria
- MIC bacteria (sulfate-reducing, acid producing, nitrate reducing, iron/sulfur oxidizing)
- œ Slime-forming bacteria
- Iron/manganese depositing bacteria
- œ Thiobacillus spp., Gallionella spp., Sphaerotilus spp.

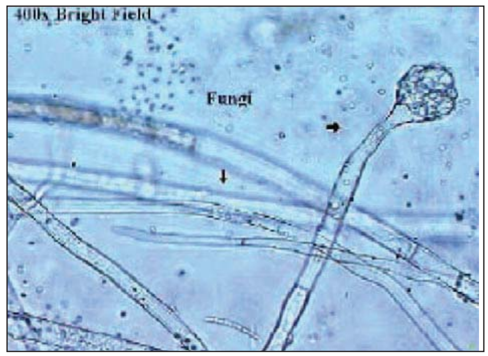
Yeast and Fungi

The presence of large amount of yeast or fungi can indicate a low pH level or existence of fermentative conditions. There are more than 75,000 species of yeast and fungi, which include mold, smut, rust and mildew. They may be colorless or cover the entire color spectrum. Most grow highly in warm, dark, moist places & are aerobic with low oxygen demand. However there are certain yeasts which are anaerobic in nature. Fungi can grow on almost any surface and are considered an attributing factor to wood deterioration. Both yeast and fungi are commonly transported by air currents. They are relatively large and can easily be identified with microscopic analyses.



Fungi

Two forms of fungi commonly encountered are molds (filamentous forms) and yeast (unicellular forms). Molds can be quite troublesome, causing white rot or brown rot of the cooling tower wood, depending on



whether they are cellulolytic (attack cellulose) or lignin degrading. Yeasts are also cellulolytic. They can produce slime in abundant amounts and preferentially colonize wooden surfaces.

Identification:

Fungi are extremely large, non-motile filaments (300-1000 µm). They can be straight, irregularly curved or bent filaments with true branching. Cells are very rectangular (3-8 x 5-15 µm) with very large trichomes and contain

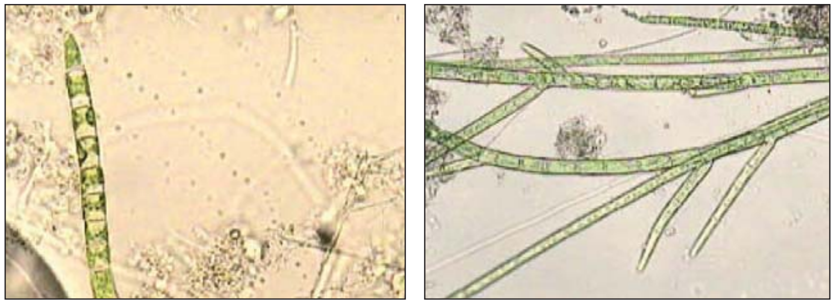
organelles and large intracellular granules and structures. Usually a heavy cell wall is also present.

Environment:

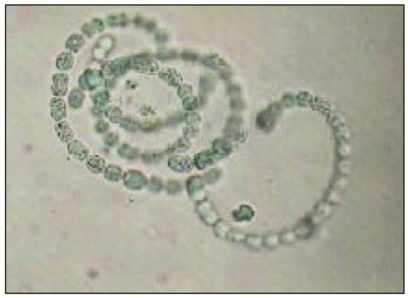
Fungi and yeast are usually found in environment where there is a low pH. They are usually common in a bio tower or a trickling filter. They can cause "plugging or ponding".

Control:

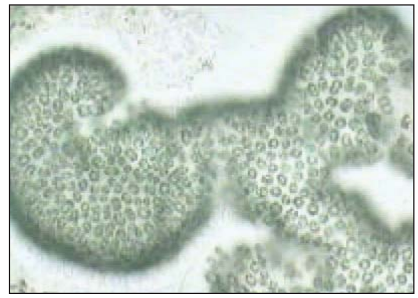
As mentioned, low pH is usually the cause of fungi and yeast therefore increase of pH on the influent or in the MLSS to pH level 6 or higher can help in disappearing of these biological species within a small span of time.



Algae can be curled or in small free floating clusters with a slime coating



Anabaena



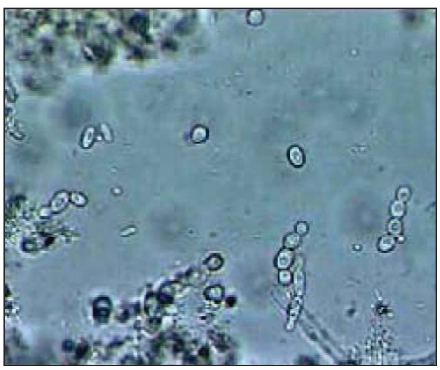
Woronichinia naegeliana

Yeast

Identification: Yeasts are a group of unicellular fungi, a few species of which are commonly used to leaven bread and ferment alcoholic beverages. Most of them belong to the division Ascomycota.

Similar Organisms:

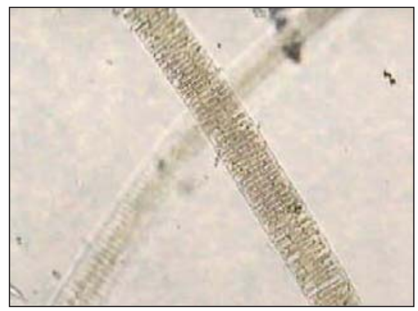
Yeast can be similar to Tetrads The presence of large amounts of yeast in



the wastewater can indicate a low pH level, existence of fermentative conditions or a severe phosphorous deficiency. Raising the pH above 7 usually makes the yeast disappear.

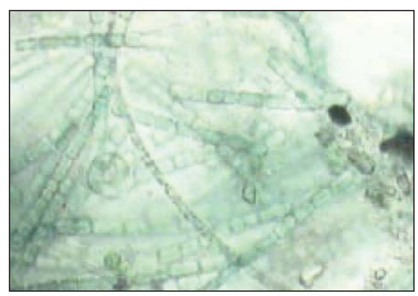
Algae

Algae primarily occur in the tower deck area as most species require sunlight for photosynthesis and growth. Algae slimes can plug distribution nozzles and troughs in the cooling tower deck, causing poor water distribution across the tower and hence reduce cooling efficiency. Water intake screens may also become plugged by algae slimes that can slough off from the tower. The growth of algae may provide a food source which encourages the growth of other organisms, such as bacteria and fungi.

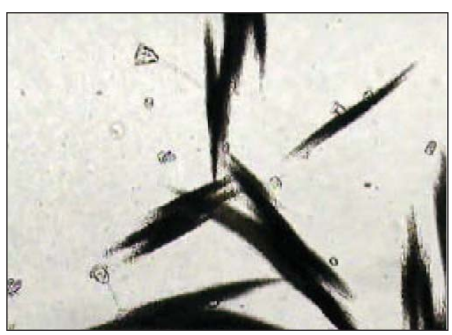


Achnantes taeniata is a brown algae

Algae require control because the biomass can also break loose and cause exchanger fouling. When this happens, slimy, rubbery masses form, which cause plugging and decrease in the tower efficiency. Various types of algae can be responsible for green growths, which block screens and distribution decks. Severe algae fouling can ultimately lead to unbalanced water flow and reduced cooling tower efficiency.



Filamentous Blue Green algae or cyanobacteria and Beggiatoa



Aphanizomenon flos-aquae

Algae can be single celled and free floating, filamentous and cause mattes or can be slime forming. Algae are typically photosynthetic organisms. Green and blue-green algae are very common in cooling systems. Blue-green algae are now classified with the bacteria and are called cyanobacteria.

What type of Algae are you growing in your cooling tower?

Algae can be branched or straight,

Scenedesmus and Flagellate

Branched algae

Algae slime on cement and metal

curled or in small free floating clusters with a slime coating.

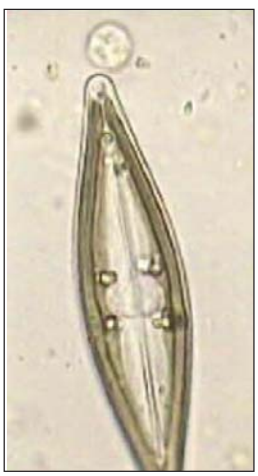
Diatoms

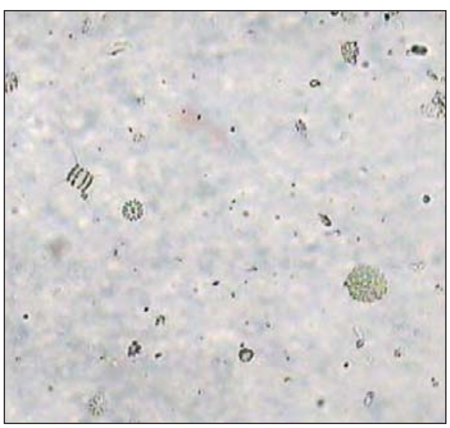
Diatoms are algae enclosed by a silicaceous cell wall and may also be present in cooling towers but generally do not play a significant role in cooling system problems.

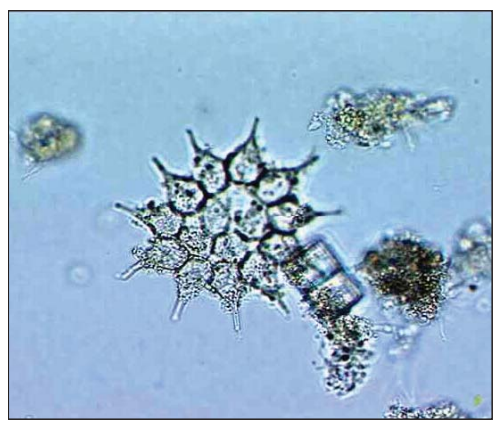
Microbiological Influenced Corrosion or MIC

It is corrosion or deterioration of material, which is initiated and/or accelerated by the activities of micro-organisms. These materials are mainly metal, but also can be concrete or plastics. 1/5 of all corrosion is typically caused by microorganisms and biofouling.

The most common MICs can be categorized into sulphate reducing bacteria (SRB), iron oxidizing bacteria and acid producing bacteria (APB).

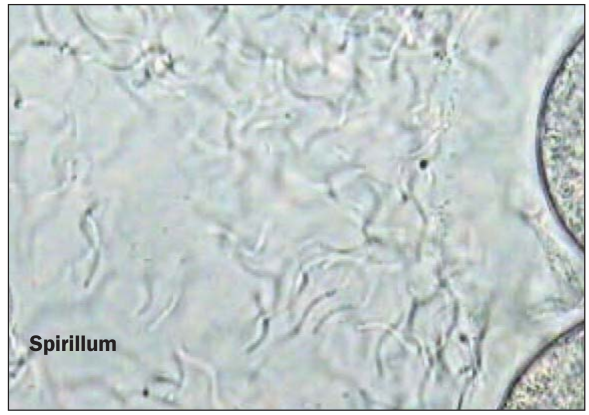






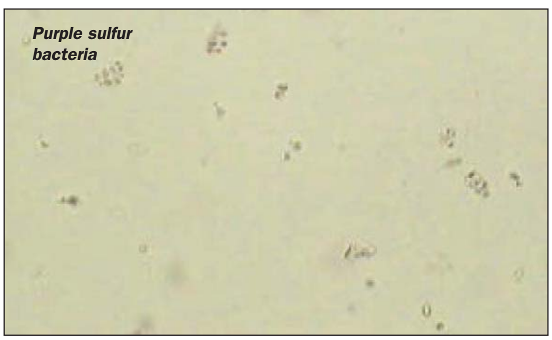
Beggiatoa is a motile sulfur reducing filamentous Bacteria found in many biofilms


DesulfoVibrio

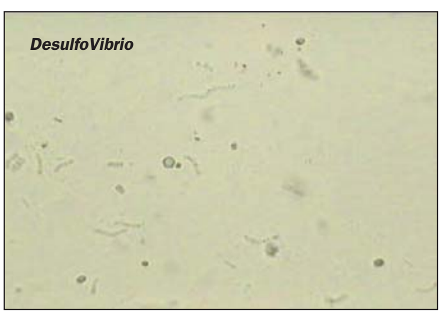

Spirillum

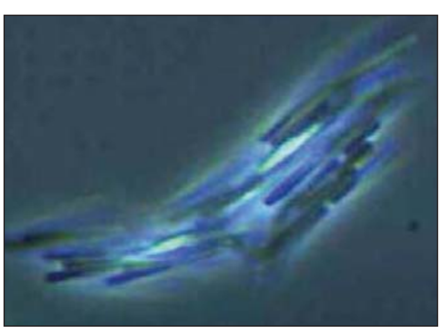
Sulfate Reducing Bacteria can include Desulfovibrio, Purple sulfur bacteria, eggiatoa,Thiobacillus, Spaeratolis Natans

SRBs are characterized by hydrogen sulfide odor and blackened water or black colored deposits. Iron oxidizing bacteria generally form in filamentous clumps and can be detected under microscope by their distinct appearance due to the excreted products that grow. This corrosion by iron bacteria often forms tubercles.


Purple sulfur bacteria

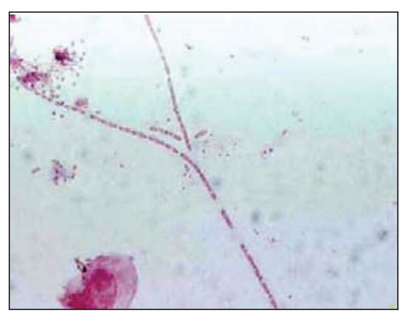

Spirillum with sulfur granules

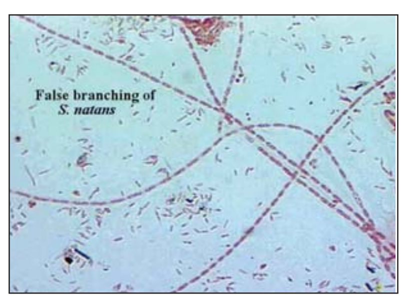

DesulfoVibrio



Iron-depositing bacteria grow best in low oxygen environments but are common in open-circulation systems. Gallionella and Sphaerotilus use soluble, or ferrous, iron as an energy source, and convert it to an insoluble oxide or hydroxide form. These deposits create fouling and set up concentration corrosion cells and conditions under which anaerobic bacteria flourish. Gallionella frequently leave spiderweb-like deposits on metal surfaces. The deposit looks like black iron. Severe corrosion is usually evident under the deposit.

Other bacteria that may be present in cooling water include Pseudomonas, Klebsiella, Eneterobacter, Acinetobacter, Bacillus, Aeromonas, and Legionella.





Sphaerotilus natans or S. natans

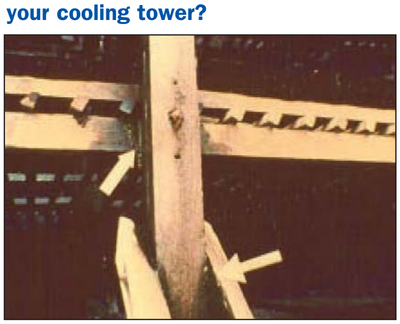
Spore forming bacteria, Denitrifying bacteria, or pseudomonas, can cause the loss of nitrite inhibitor in closed-water systems.

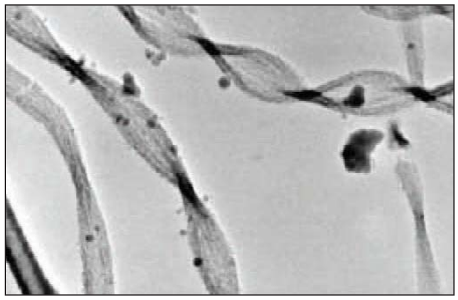
Usually plate counts with differential media are used to determine the exact count of these types of bacteria

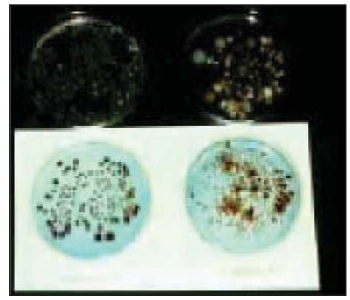
What samples would you submit for a microscopic analysis?

Biofouling Slime found on any surfaces & also the water that comes off the cooling tower would carry any biofilm bacteria that might slough off the tower. Since not all parts of the tower can be accessed, the water would carry at least some of the bacteria and biofilm that might be attached and slough off.

Where do you look for problems on your cooling tower?







Gallionella spp.,

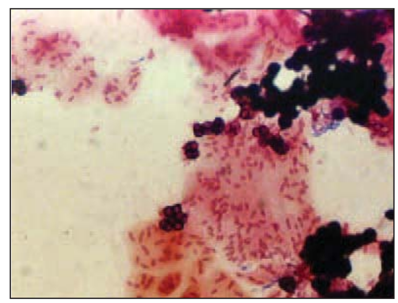
Obviously, every tower is constructed slightly different, but there are some main areas to check on every cooling tower.

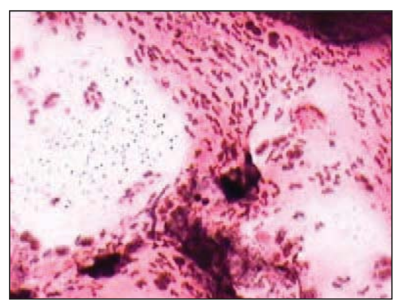
This close-up view shows the growth of biofilm mass at the juncture of the diagonal, horizontal and vertical beams, as well as on the horizontal member. Biofilms can reduce heat exchange efficiency, as well as impeding air flow through the cooling tower.

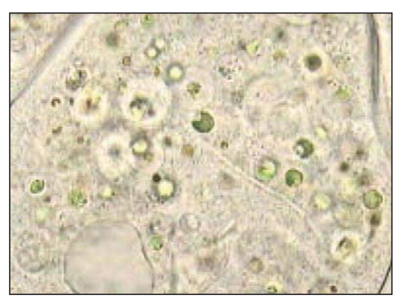
You can see the early indications of wood degradation and rot on the diagonal support toward the right, a result of high chlorine feed rates. Watch the type of cooling tower chemicals you use. Chlorine can cause

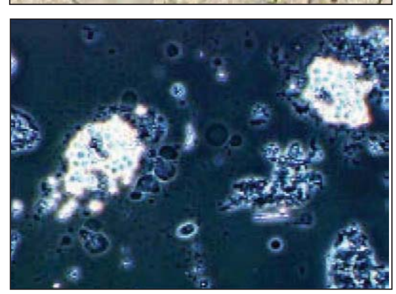
Biofouling Slime or Slime forming Bacteria

As you can see, there are quite a few different things that can be determined under the microscope from cooling tower water samples. Many things can be determined by microscopic analyses that can save time, money and reduce multiple traditional tests.









wood destruction; zinc can cause nitrification inhibition if it is in water that is discharged to a wastewater treatment plant.

Where do you send your Cooling Tower Wastewater?

Industrial Facilities- Cooling Tower Blowdown and Boiler Blowdown

Where does your Cooling tower and Boiler blowdown discharge to?

The primary use of large, industrial cooling tower systems is to remove the heat absorbed in the circulating cooling water systems used in power plants, petroleum refineries, petrochemical and chemical plants, natural gas processing plants and other industrial facilities. The absorbed heat is rejected to the atmosphere by the evaporation of some of the cooling water in mechanical forced-draft or induced draft towers. More than 90 percent of all the water used by industry and about two-thirds of the total wastewater generated by U.S. manufacturing plants is the result of cooling operations.

The circulation rate of cooling water in a typical 700 MW coal-fired power plant with a cooling tower amounts to about 71,600 cubic meters an hour (315,000 U.S. gallons per minute) and the circulating water requires a supply water make-up rate of perhaps 5 percent (i.e., 3,600 cubic meters an hour).

Petroleum refineries also have very large cooling tower systems. In many refineries, makeup water to the cooling tower can account for up to 50% of the total demand for fresh water. A typical large refinery processing 40,000 metric tons of crude oil per day (300,000 barrels per day) circulates about 80,000 cubic meters of water per hour through its cooling tower system.

Some plants have pretty clean boiler and cooling tower blowdown except for dissolved salts, BOD's typically range from 2-5 ppm. This is relatively clean water. If you are discharging to a local POTW, and you have a pretreatment system, your best bet is to add the boiler; cooling tower blowdown flows downstream of your wastewater plant to allow for more time in your wastewater plant for critical loading from the process side. Hydraulic overload during huge spikes of flow from a cooling tower can significantly impact plant efficiency.

Discharge to POTW-Here is a perfect example of a plant - 4 gpm was from the boiler blowdown, and cycles of 18 to 100 gpm came from the cooling tower. The process side only had 5 gpm of concentrated wastewater with a very high BOD.

If the cooling tower flow is taken out, with a BOD of 2-4 ppm, and just run the concentrated wastewater through the system, it takes more time to degrade the organics in that particular system. The addition of the cooling tower and boiler water at the back end adds on to the flow however the extra time in the wastewater plant for the concentrated waste significantly increases the amount of treatment capabilities leading to the lowering of the final effluent. Since the discharging is to a POTW, one need not worry about occasional spills, if cooling tower is constantly monitored & controlled.

Cooling tower blowdown can contain zinc and chromates, which must be removed prior to discharge into the environment. High level of zinc have been known to negatively impact nitrification, therefore check to see what type of chemical is used in the cooling tower.

High sulfates or phosphates may be present depending upon the type of chemical treatment used. High Sulfates can impact oxygen efficiency in the wastewater plant.

Table: 1 Characteristics of effluents from cooling tower

Sl. No	Parameter	Value
1.	pH	7
2.	Conductivity(μs/cm)	3350
3.	Total hardness	351
4.	Calcium hardness	256
5.	Total dissolved Solids	2500
6.	Total suspended solids (TSS)	50
7.	Chloride	713
8.	Sodium	678
9.	Potassium	54
10.	Sulphate	233

Note: Except for pH and conductivity, all other parameters are in mg/l.

Typical Oxygen requirements in a wastewater plant

- 5 lbs. oxygen oxidizes 1 lb. nitrogen
- 3 lbs. oxygen oxidizes 1 lb. carbon
- 1-1.5 lbs. oxygen oxidizes 1 lb. B.O.D.
- .67 lb. oxygen oxidizes 1 lb. manganese
- 1 lb. oxygen oxidizes 1 lb. hydrogen sulfide
- .4 lb. oxygen oxidizes 1 lb. Iron

Most cooling tower applications utilize 6-12 cycles of concentration. That is an optimum range considering the cost of chemicals and blowdown requirements. The cost of cooling tower chemicals increases greatly when you decrease the cycles of concentration. The cost of the raw water and disposal of water have to be addressed.

Treatment alternatives include chemical reduction, ion exchange, and electrochemical reduction. A novel process involves lime softening with recycle of the treated water to the cooling water system.

The best technology to utilize is a function of cooling-water quality. If makeup water is high in hardness, lime softening may be most appropriate.

All systems require a chemical treatment program that addresses four areas:

- Scale
- Corrosion
- Fouling

In many refineries, makeup water to the cooling tower can account for up to 50% of the total demand for fresh water.

• Microbiological growth

Scale and corrosion inhibitors are typically injected into the system by positive displacement pumps that meter precise dosages.

Check to see what types of chemical treatments are used, whether it's using phosphate treatments, toxic chemicals to the bacteria, or have relatively clean blowdown from either the cooling tower or boilers. It can make a big difference in where this water is sent through the wastewater treatment plant.

Other areas to look at that may have excess water or flow if a water balance is done in the plant include - Sand filter backwash, carbon filter drinking water backwash, steam trap condensate, sample lines that are kept open, meters, water softener, make up water, RO filtrate, condensates, holding tanks, wet wells, pits, storm water.

Boiler Blowdown: The use of boiler blowdown as cooling tower makeup is another reuse scheme that has been employed at a number of locations.

Storm water should be relatively clean, and should not be running through wastewater treatment plant as it can significantly cause hydraulic overload.

Do a walkthrough of the plants system, check to see where all the water flow winds up. You willl be surprised at the sources and total water balance if you give it a double check

Examples of typical Plants:

A Refinery circulating 150,000 gpm

- Evaporates about 4.3 million gal/day
- Discharges about 1.0 million gal/day
- Makeup of 5.3 million gal/day

A large Power Plant circulates 400,000 gpm

- Evaporates about 11.5 million gal/day
- Discharges about 2.5 million gal/day
- Makeup of 14 million gal/day

Depending upon where you live, the cost of fresh water ($1.00 to $2.00/1,000 gal or $0.26 to $0.52/m^3). Now add the cost of additional treatment to reach discharge limits ($2.00 to $4.00/1,000 gal or $0.52 to $1.04/m^3)

You can see why performing a total water balance in your plant, and considering all the options you have can make a big difference in operating costs as well as efficiency.

Table 2 – Typical Quality Guidelines for Chemically Treated Circulating Water

Property of Water	Recommended Level
pH	6.5 to 9.0*
Hardness as $CaCO_3$	30 to 750 ppm^2
Alkalinity as $CaCO_3$	500 ppm maximum^2
Total Dissolved Solids	1500 ppm maximum
Conductivity	2400 micromhos^3
Chlorides	250 ppm maximum as Cl 410 ppm maximum as NaCl
Sulfates	250 ppm maximum
Silica	150 ppm maximum

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