MILL WATER QUALITY IN THE PULP & PAPER INDUSTRY: QUALITY CONSIDERATIONS & TREATMENT OPTIONS

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ABSTRACT:

Different water sources and forms of water contamination can present different challenges to both integrated Pulp / Paper Mills and non-integrated Paper / Tissue Mills whether it is the variability of surface sources or the high mineral content of ground water sources. At the same time, different processes in the mill require different levels of purity, from clarified and sand filtered water to high-purity DI water for high-pressure boilers.

This paper will discuss what different water quality levels can be expected throughout the Paper Making process and what types of technologies are available to efficiently achieve the quality required. Details of contaminants in both surface water and groundwater supply will be reviewed, along with the information needed to guide the reader towards potential solutions. Examples of water quality projects will provide an actual case application and identify the potential benefits for water quality improvements.

INTRODUCTION:

The use of water in Pulp in Paper Operations (PPO) is so integral to the process that Pulp and Paper production would be impossible without it. Yet, since it is not part of the final product, it is considered a utility and typically receives attention only when it interferes with production. While everyone is likely to agree that Mill Water Quality is very important, the questions remain: Just what is "quality" and how is it quantified? Are different levels of quality required in different operations and if so, what different levels of quality? What are the ramifications of poor quality and how can they be prevented by proper treatment?

This paper will provide a basis from which to define water quality and identify the different levels of quality needed in PPO. It will discuss current technologies and identify which technologies provide the best value for specific problems. It will also touch on emerging technologies as well as technologies not commonly used in Pulp and Paper and how they may be capable of improving operations.

SECTION 1 - WATER QUALITY CONSIDERATIONS: CONTAMINANTS IN RAW WATER

Pure water is two Hydrogen atoms bonded to one Oxygen atom. Together, with other water molecules, they form a substance that is highly active in our physical world. In its liquid form, it is an aggressive solvent, being referred to as the "universal solvent". Its liquid form is relatively dense, collecting in low geographical spots and forming powerful streams capable of carrying solids in its mass. Also, being necessary for life, it encourages the growth of organisms with which it comes into contact. These three facts form the basis for what we call contaminants in water:

TABLE 1 – WATER CONTAMINANTS

Contaminant	Example
Total Suspended Solids (TSS)	• Dirt / Silt • Oxidized Material (Iron / Manganese) • Organic (Living or Non-Living)
Total Dissolved Solids (TDS)	• Minerals / Salts • Dissolved Organics
Biological (cfu/ml)	• Virus' • Bacteria • Protozoa

Each of these contaminants causes problems of their own in PPO. TSS can plug nozzles, foul surfaces, provide a food source for microorganisms, and show up as specks in the sheet if not removed. TDS can cause scaling in heat exchangers and on other surfaces. It can contribute to pitch and minerals like Fe and Mn can oxidize and precipitate when contacting air and form suspended solids. Natural biological contaminants are encouraged to reproduce by the warm, nutrient rich conditions found in Pulp and Paper operations. Biological contamination can cause health concerns and drive up chemical usage to combat slime.

SECTION 2 – GENERAL CHARACTERISTICS OF WATER SOURCES & PPO WATER USERS & QUALITY REQUIREMENTS

2.1 – WATER SOURCES AND GENERAL CHARACTERISTICS

Water for PPO comes from one of two sources. Surface water sources such as rivers and lakes or ground water sources such as underground wells. Each of these sources has their own characteristics requiring different strategies to deal with different obstacles. In general:

TABLE 2- WATER SOURCES AND THEIR CHARACTERISTICS

Source	Characteristics
Surface Water	• Low TDS (Relative to Ground Water) • High TSS (Relative to Ground Water) • High Biological Activity • 33-80°F • High Seasonal and Weather Related Variation
Ground Water	• High TDS (Relative to Surface Water) • Low TSS (Relative to Surface Water) • Low Biological Activity • 50-55° F • Low Seasonal and Weather Related Variation

2.2 – PPO WATER USES AND QUALITY REQUIREMENTS

While water is used in every corner of PPO, the quality and uses of the water vary greatly from highly purified fresh water, to internally recycled water, to water used for flushing and clean up. Examples:

TABLE 3 – PPO WATER USERS, QUALITY REQUIREMENTS AND SOURCES

Use	Quality Required	Sources (Typical)
Wash-Up and Flushing (Junk Traps, etc.)	Low, Just Good Enough to Not Cause Problems	• White-Water • Filtered White-Water • Re-Used Fresh Water – Cooling Water, etc. (NOT Ideal) • Fresh Water (REALLY NOT Ideal!!)
Dilution Water	Process Dependent	• Process Dependent, Though Often Use a Fresh Water Makeup
Shower Water (Direct Contact)	Low to High, Varies by Operation	• White-Water for Process or Waste-Treatment Equipment Showers • Clarified and Filtered - Clarified White Water for Paper Machine Showers • Fresh and Filtered- Fresh Water for Paper Machine Showers • Softened, Demineralized (RO/DI) for Paper Machine Showers
Chemical Dilution	High	• Fresh Water • Softened Water • Demineralized (RO/DI)
Steam and Power Generation	Very High	• Demineralized (DI)

SECTION 3 – PROBLEMS AND SOLUTIONS

Each source, each problem, and each level of quality desired can have many solutions. The question is what technology provides the BEST solution from the standpoint of quality and value for each application. The answer to that question depends on:

- With what are you starting? While water can generally be categorized into Surface and Ground, each source can still vary significantly between different surface and ground sources.
- Where do you need to go? How much of what kind of water do you need and for what purposes? While you want to treat the water up to the quality required, you do not want to spend unnecessary capital and operating money by over-treating.

3.1 – TSS

Suspended Solids will be the primary concern if you are supplied from a surface source. When providing Mill Water from these sources for plant operations, the conventional solution has been using a settling clarifier with sand filtration of the clarified effluent. The quality achieved by this traditional approach is not always sufficient for down-stream operations. Further filtration at the point of use is required for other applications. TSS can also come from ground water sources, usually as a result of oxidation of dissolved minerals when they come into contact with the air or chlorine. Plugging problems caused by these oxidized minerals can be treated at the point of use. These point of use applications can be strainers or traditional cartridge filters designed to achieve a specific TSS level, micron level, or both.

Newer technologies exist for treating surface water that are every bit as proven as the conventional treatment method, though not widely used in PPO. Also, current technologies can be applied in non-traditional operations to improve performance. Some examples, common use points, and their relative strengths are listed below:

TABLE 4 – TSS TREATMENT OPTIONS

Method	Location	Strength / Weaknesses
Clarification	Mill Water	• (+) Efficient at Treating Large Volumes • (-) Large Space Requirements • (-) Prone to Upsets • (-) Quality Not Sufficient for All Down-Stream Uses
Sand / Media Filtration	Mill Water (Polishing Clarifier Effluent) and Point of Use	• (+) Efficient at Treating Large Volumes • (-) Large Space Requirements • (-) Uses Large Volumes of Water for Backwashing • (-) Quality Not Sufficient for All Down-Stream Uses
Membrane Treatment (Micro / Ultra Filtration)	Mill Water	• (+) Efficient at Treating Large Volumes • (+) Superior Filtration (Sub-Micron) Requiring No Down-Stream Filtration for Other Uses • (+) Less Space Required Than Conventional Treatment • (-) Capital Expense
Automatic Strainers 	Point of Use	• (+) Efficient at Treating Large Volumes • (+) Less Space Requirements than Sand Filtration • (+) Uses Less Water for Backwashing than Sand Filtration • (+) Backwashes while Operating • (+) Can Hit Specific Micron Targets (Sometimes Requires Multiple Stages) • (-) Use Motors to Operate Cleaning Apparatus • (-) More Moving Parts than Sand Filters
Cartridge Filtration	Point of Use	• (+) Very Simple • (+) Can Achieve Low-Micron Filtration • (-) Only Good for Small Volumes • (-) Produce a Solid Waste (Used Filters)

3.2 – TDS

Dissolved Solids are a concern, regardless of the source, though they will be higher in ground water and require more aggressive treatment. As mentioned, Iron (Fe) and Manganese (Mn) can oxidize and form TSS. Calcium (Ca) and Magnesium (Mg), which become LESS soluble as water temperature increases, form scale with CO3 and reduces the effectiveness of heat-exchangers and can plug showers. In the Powerhouse, very high quality water is needed for High-Pressure Boilers for Turbines and Steam Production for PPO. Conventional forms of treatment involve ion-exchange technology, whether softeners for cooling water applications or Cation / Anion / Mixed-DI for Powerhouse operations. For the most part, treatment for TDS is too expensive from a capital and operating cost to use mill-wide. It would be ideal to identify what sources require which treatment methods and provide the appropriate treatment for all users at a central point.

For TDS treatment, it may be beneficial to use multiple treatment steps to achieve the required purity at the lowest possible cost. For instance, while Reverse Osmosis (RO) Permeate is not of sufficient quality to feed a High-Pressure Boiler, it can reduce the operating cost of the conventional Cation / Anion / MB DI System by removing the bulk of the TDS and reducing acid and caustic usage by minimizing regenerations.

There are other technologies, not yet widely adapted, that also bear consideration for specific applications. Plant uses, appropriate technologies and their relative benefits can be seen below:

TABLE 5 – TDS TREATMENT OPTIONS

Technology	Application	Strengths / Weaknesses
Water Softeners	• Remove Ca and Mg to Prevent Scale on Heating Surfaces and in Showers • Removes Dissolved Minerals Prone to Oxidation / Precipitation	• (+) Easy to Operate • (+) Inexpensive to Treat High Volumes of Low Hardness Water • (-) Uses NaCl to Regenerate and Requires Regular Loading of Salt For Regens • (-) Can Be Very Expensive to Treat High Volumes of High-Hardness Water • (-) Using Softeners on Sources With High Fe, Mn Reduces Effectiveness and Requires Resin Cleaners in Addition to NaCl For Regens • (+/-) Only Exchanges Ca, Mg, Fe, Mn for Na and Does Not Reduce TDS
Targeted Ion-Exchange Media	• Greensand to Remove Fe and Mn From Source Water	• (+) Effectively Removes High Levels of Fe and Mn • (+) New Products Only Require the Addition of Chlorine to Keep Media Regenerated • (-) Used in Media Filters, Thus Requiring High Volumes of Water for Backwashing
Reverse Osmosis / Nanofiltration	• Demineralize Water	• (+) Effective for Low or High Volumes of Water • (+) Excellent as Pretreatment To Di Systems

		• (+) Can Be Effective Pretreatment to Softeners in Certain Cases • (+) Byproduct / Wastewater is Chemically Inert and Lower TDS Than Softened Water and Can Be Used as Wash-Up Water or Makeup In Cooling Towers • (-) Does Not Produce the Quality of Di Systems • (-) Reduces, But Does Not Eliminate, Hardness
Cation / Anion / Mixed Bed DI	• Deionize Water	• (+) Produces the Highest Purity Water • (+) Effectively Treats Large Volumes of Water • (+) Simple to Operate • (-) High-Operating Cost • (-) Uses Strong, Dangerous Chemicals to Regenerate
Electro-Deionization (EDI) 	• Deionize Water	• (+) Produces DI Water Sufficient for High-Pressure Boilers • (+) Effectively Treats High and Low Volumes of Water • (+) Uses Electricity to Regenerate, Thus Eliminating the Use of Dangerous Chemicals • (-) Requires RO Water to Operate, Thus More Dependent on RO Operation Than Conventional DI Systems

3.3 – MICROBIOLOGICAL

When it comes to feed water sources, even the more heavily contaminated surface waters are likely negligible to the biological activity created by the PPO themselves. Other than chlorination of the feed sources, there is no real treatment of source water that will have a significant impact on overall operations. Even the chlorination of the feed source is more for the protection of plant personnel who may come into contact with the water than any anticipated benefit to operations.

Although you may not have resources with the expertise or the time to determine what contamination is impacting your process the most or what technologies to consider, Jedson Engineering can help with this. Understanding the situation is very important to implementing the best solution. Often there are multiple options, or a combination of vendor technologies to evaluate. This is where experience and the Jedson Edge can provide you with the technical expertise to determine exactly what your process requires and which solution offers the best value.

SECTION 4 – BEST VALUE ANALYSIS

As has been discussed, the problems that can be encountered depend on the individual source and the quality to be achieved. There are many solutions, but which solution provides the quality desired at a profitable capital and operating cost?

4.1 SAMPLE CASE STUDY #1

Application	Boiler feed water system at integrated PPO mill, supplied by groundwater, located in Midwest
Technology	Single stage RO unit downstream of water softeners
Design / Performance	79% recovery rate at 1500 gpm rated capacity
Opportunity	Optimize the operation to improve performance without significant costs
Results	Recovery rate improved to 84%, 70 additional gpm of permeate / water savings, system capacity dropped by 1%
Capital Costs	$0
Supplemental Benefits	1MMBtu/hr. incremental energy savings

The number of RO units installed in PPO operations has increased more than ten-fold from the count 15 years ago. Today, the rate of change for this technology and its pricing warrants a review every 3-5 years. A great example of this is RO units installed with a design recovery rate of 75%; they can now be optimized to achieve above 80%. That is a significant change considering the uptime, the operating costs per 1000 gallons of water, and the sustainability benefits (water savings due to reduced discharge flows).

4.2 SAMPLE CASE STUDY #2

Application	Cooling Tower Side-Stream Filtration, 300 GPM – Industrial user, S.E. USA	
Technology	Comparison – Conventional Sand Filter vs. Automatic Strainer	
Equipment	*Sand Filter	Automatic Strainer
Footprint (H" x L" x W")	75 x 116 x 41	44 x 20 x 11
Weight (Empty/Operating)	1720 lbs./7,000 lbs.	80 lbs./160 lbs.
Backwash Volume (24 hr.)	1300-1700 GPD	144-240 GPD
Approximate Capital Cost	$6,000	$21,000

*Single Media, No coagulant

As can be seen, an automatic strainer weighs less, takes up less room, and uses much less water than a typical sand filter. Depending on feed conditions and outlet requirements, multiple stages of strainers may be required to achieve the same TSS removal as a sand filter using multi-media and coagulant. Each case needs to be examined to see what filtration level is truly required, and how many stages may be necessary to achieve the quality desired.

4.3 SAMPLE CASE STUDY #3

Application	High-Pressure Boiler Feed Water	
Technology	Reverse Osmosis System Pretreating Conventional DI System	
System Flow (gpm)	450	
Feed Water TDS (ppm)	250	
System Costs	Low	High
Energy ($/kw-hr)	0.04	0.10
Acid – HCl ($/lb.)	0.18	0.26
Caustic – NaOH ($/lb.)	0.23	0.31
Mill Water Cost ($/1000)	1.00	4.00
Waste Water Cost ($/1000)	1.00	4.00
Payback*	1.3 years	1.13 years

*Using Manufacturers "Standard" System with Pre-filtration. Install ≈50% of Capital Cost, installed in existing space.

When it comes to using an RO System to pretreat a DI System, the trade-off is between energy costs to operate the RO and chemical and water costs to regenerate the DI. The lower the power costs and the higher the chemical and water costs, the quicker the payback of the RO. Heavy customization of the RO System, or having to build or extend building space will extend the payback.

SECTION 5 – WHAT'S NEXT? EMERGING TECHNOLOGIES / APPLICATIONS

When it comes to water treatment technologies, most are fairly mature. Advances are mainly bringing down the costs (operating and capital) rather than major changes in technologies. For example, membrane costs for Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis have decreased greatly over the past 20 years and performance improvements have brought down operating costs. As shown above, the operating and capital costs have decreased to the point where RO Systems can improve reliability of plant operations while saving operating costs at an acceptable pay back. Given this, are there any emerging technologies that may be a benefit to the Pulp and Paper Industry? Or are existing technologies finding new uses that may be applicable to the Pulp and Paper Industry?

SECTION 5.1 – ANAEROBIC WASTE WATER TREATMENT

Most of the advances in water treatment are likely to come in the waste treatment sector of water treatment. Anaerobic Waste Treatment Systems are capable of taking wastewater with high BOD / COD and generating methane that is capable of operating a waste-gas turbine. If the BOD / COD is high enough, the gas generated is enough to generate the power required to operate the treatment plant itself. The water from these systems can now be passed through a membrane system and the low BOD, TSS effluent treatment in an RO System and then be reused in the plant. Therefore, it may be possible, and economic, to segregate high BOD streams in a plant for separate treatment in an anaerobic system with the system itself generating the power through the methane production. Thus making the remaining wastewater of the plant easier to treat due to the removal of the high organic streams from the main treatment plant.

5.2 – ELECTRO-DIALYSIS REVERSAL

Electro-Dialysis Reversal (EDR) is actually and old form of water treatment from the 1960's that uses electro-dialysis to demineralize water and periodically reverses the poles as a means of keeping the electrodes clean. It has been largely replaced by RO in water purification applications, though there remain niches where the technology remains viable. It does not produce the water quality of RO systems, but EDR can tolerate higher levels of TSS and Total Organic Carbon (TOC) in the feed water. In applications for reuse, where the water quality requirements aren't as high (i.e. Gray-Water Systems), it can present a viable alternative to membrane systems or just discharging the water to waste treatment. EDR systems do not remove silica from the water allowing it to treat waters with high-silica levels without scaling, so long as silica removal isn't required for the treated water.

CONCLUSION

In general, the technology needed is low risk and well proven with multiple applications. As technology costs have changed, so have the capital investments to take advantage of these options. Many opportunities still exist to apply value added solutions at different levels within the water systems of a PPO.

In the manufacturing process, competitive advantages allow companies to secure a spot in the marketplace and provide a strong livelihood for people. Most companies are always looking for the opportunity to improve their position in the marketplace, and it can start with something as simple as water quality.

Improvements in water quality can translate into improvements in machine uptime, process variability and product quality, and both direct and indirect costs. Other strategic initiatives / key metrics that will benefit include raw water consumption, mill effluent, energy consumption, machine efficiency, and cost savings initiatives.

There are multiple opportunities to consider how improvements in water quality will benefit your location. Is there a comprehensive plan at your facility to meet the strategic initiatives for the next 2 to 5 years? Has a comprehensive study been completed to identify all the potential water quality projects and the quality of water required at each application point in your process? If you are unsure of how best to take advantage of these opportunities, please contact me at the Jedson office, here in Cincinnati for details and direct support.

ABOUT THE AUTHOR

David Cifuentes is a Process Engineer for Jedson Engineering headquartered in Cincinnati, Ohio. He has over 20 years of experience in Water Treatment, including the Pulp and Paper Industry and Pure Water Membrane and DI Systems. He has a Paper Science and Engineering Degree from Miami University.