# Levi Strauss & Company Recycle & Reuse Standard and Guidelines

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## Summary

Fresh water is a precious resource and it is especially limited in many parts of the world. Levi Strauss & Company (LS&Co.) has developed Recycle & Reuse Standard and Guidelines as part of the Recycle & Reuse (R&R) Program. **These guidelines aim to minimize the environmental impact of fresh water usage in water-scarce areas by encouraging the reduction of water consumption through water reuse.** LS&Co. has been working with innovative supplier partners to implement this R&R program after the initial launch of the Water<Less program, which conserves water through advanced finishing techniques (such as requiring less rinses). Vendors who participate in this program can use it to build their own sustainability campaigns.

Any costs incurred in an effort to implement necessary procedures and technologies to meet the R&R Standard, apply for R&R verification, and obtain reverification are the responsibility of the vendor.

**"The interest is driven by two primary factors: first, a belief that these investments will [save] money on rising costs for fresh water; and second, increasing evidence of water scarcity across many of these regions."**
(Clancy, 2014)

**Figure 1: Yida Wastewater Treatment Plant (Crystal Group, 2011)**

### Benefits

- Less fresh water intake resulting in lower water expenses
- Reliability on a guaranteed volume of quality water
- Reduced concern about the lack of fresh water available
- Ability to publicly promote sustainability, which may boost company's public image
- All LS&Co. garments that are produced using 20% or more recycled water in their finishing process will qualify as Water<Less products and will contribute to LS&Co.'s Water<Less unit volume goal.
- Increased legislative pressure: R&R provides opportunity to be proactive and prevent fines or risk of shut-down by local government due to water restrictions
- Contribute to LS&Co. efforts to reduce negative environmental impact on the planet by shrinking water footprint

### Challenges

- May require initial investments for a wastewater treatment plant
- Certain finishes cannot use 100% recycled water
- May require more energy to operate
- Requires careful monitoring of water quality as concentrations of some chemicals may increase as a result of reusing water

# List of Acronyms/Abbreviations

| | |
|---|---|
| ACF | Activated Carbon Fiber Filter |
| AOX | Adsorbable Organic Halides |
| As | Arsenic |
| BOD | Biochemical Oxygen Demand |
| Cd | Cadmium |
| Cl | Chloride ion |
| CN | Cyanide |
| Co | Cobalt |
| COD | Chemical Oxygen Demand |
| Cr | Chromium |
| Cu | Copper |
| DO | Dissolved Oxygen |
| EC | Effluent Concentration (active concentration) |
| EDR | Electrodialysis reversal |
| Fe | Iron |
| GER | Global Effluent Requirement |
| Hg | Mercury |
| HU | Hazen Unit |
| IMS | Information Management System |
| LS&Co. | Levi Strauss & Company |
| Mg/L | milligram per liter |
| Mn | Manganese |
| N/A | Not available / Not applicable |
| Na | Sodium |
| Ni | Nickel |
| NL | No (known) Limits |
| NR | Not Required |
| NTU | Nephelometric Turbidity Unit |
| Pb | Lead |
| PPE | Personal Protective Equipment |
| POTW | Publicly or Privately Owned Treatment Works |
| PSF | Pressurized Sand Filter |
| RO | Reverse Osmosis |
| RRSG | Recycle & Reuse Standard and Guidelines |
| R&R | Recycle & Reuse |
| TCU | Total Color Units |
| TDS | Total Dissolved Solids |
| TH | Total Hardness |
| TSS | Total Suspended Solids |
| UV | Ultraviolet |
| WWTP | Wastewater Treatment Plant |
| WHO | World Health Organization |
| Zn | Zinc |

# Introduction

Fresh water is a precious resource. The limited fresh water resources are under increasing pressure as populations grow around the world and from the possible impacts of global climate change, which may reduce water supplies in some areas compared to their historical levels. Figure 2 shows the world's current water supply risk.

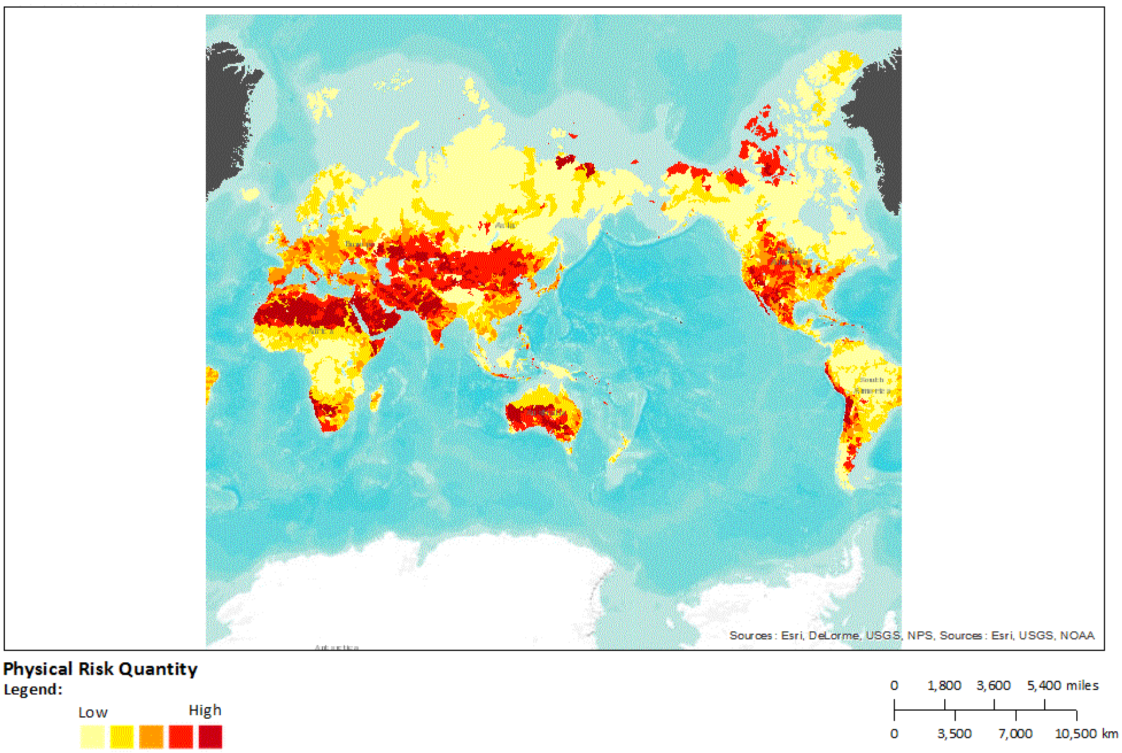



**Figure 2: Current Water Supply Risk (WRI Aqueduct 2014)**

To help preserve fresh water supplies for drinking and other necessary uses, Levi Strauss & Co. (LS&Co.) has taken several steps to conserve water. LS&Co. has implemented the Water<Less program, which utilizes alternative finishing techniques to reduce water consumption. The Recycle & Reuse (R&R) program is designed to provide standards to encourage preservation of fresh water by reducing water consumption in the supply chain through water recycling.

**The Global Effluent Requirements (GER) applies to all industrial wastewater discharges from factories that finish or launder garments for LS&Co. The *Recycle & Reuse Standard and Guidelines* are recommended for all facilities that finish or launder garments for LS&Co., are in compliance with the GER, and would like to utilize reclaimed or recycled water within the facility or on facility property.** For the purposes of these standards and guidelines, "reclaimed" or "recycled water" applies to water treated for reuse from one of the following sources:

1. Treated wastewater from facility's separate system (only industrial wastewater)
2. Treated wastewater from facility's combined system (industrial wastewater plus domestic wastewater)
3. Treated wastewater from offsite privately or publicly-owned treatment works (POTW).

Fresh water is defined as water taken directly from lakes, rivers, wells or other sources that has not been treated. Potable water is defined as water suitable for drinking and meets all local and federal drinking water standards. All three of these water types - recycled, fresh, and potable - must be handled properly to ensure potable water quality is maintained throughout the facility.

LS&Co. is recommending that facilities consider recycling treated wastewater as a full or partial replacement of fresh water used at the facility. In order to qualify for this program, the facility must be in compliance with the GER and must install flow meters that can quantify the water savings for LS&Co. R&R products.

# Purpose

Water reuse/recycling is a proven method to conserve fresh water resources and has been demonstrated to be safe when water is first treated appropriately for the intended use. These *Recycle & Reuse Standard and Guidelines* were designed to support facilities that finish or launder garments for LS&Co. by providing guidance on implementing water reuse/recycling programs to reduce impacts to fresh water resources. The *Recycle & Reuse Standard and Guidelines* provide **minimum requirements for the protection of human health and the environment based on global reuse standards from various countries (see Appendix A) and the World Health Organization (WHO), and guidelines for various allowable facilities reuse applications.** Facility owners are responsible for ensuring the recycled water quality meets all applicable regulatory requirements of the applicable country (federal, provincial, state, local) for the intended use.

## Allowable Uses

Recycled water may be used for facility process water (laundry), facility landscape irrigation, facility cooling tower makeup water, or onsite sanitary toilet flushing, provided the water quality meets the *Recycle & Reuse Standard and Guidelines*, all legal requirements, permits, and permit conditions .

## Prohibited Uses

Recycled water shall not be used for activities involving direct human or food contact including bathing, bidets, washing hands, preparing food, irrigation of food crops, or drinking. Recycled water shall not be provided for use outside of the facility (except where water quality meets the stricter of local legal or LS&Co. requirements, the facility is in possession of valid authorizations/permits, AND appropriate control programs are applied).

## Restricted Access

Recycled water shall be used in a way that minimizes potential for contact with humans. Recycled water used for landscape irrigation shall be limited to areas where public access can be controlled. Any irrigation with recycled water of landscaped areas that are accessible to employees shall be done during the hours that employees are not working, or utilizing drip irrigation method. Recycled water used for sanitary toilet flushing shall be limited to 'restricted access facility toilets' only in order to control public access. Restricted access shall be maintained as set forth in these *Recycle & Reuse Standard and Guidelines* and will include signage indicating that reclaimed water is being used.

## R&R Program Requirements

In order to be recognized as part of the LS&Co. R&R Program, each facility must comply with all requirements of the program. This manual identifies the six main aspects of the R&R program, which include following: requirements for recycling treated water, implementing required preventative measures, installing flow meters at appropriate locations, meeting recycled water quality parameters, following sampling and reporting guidelines, and successfully meeting the third-party verification. These requirements are listed in Figure 3 and further described in the subsequent sections.

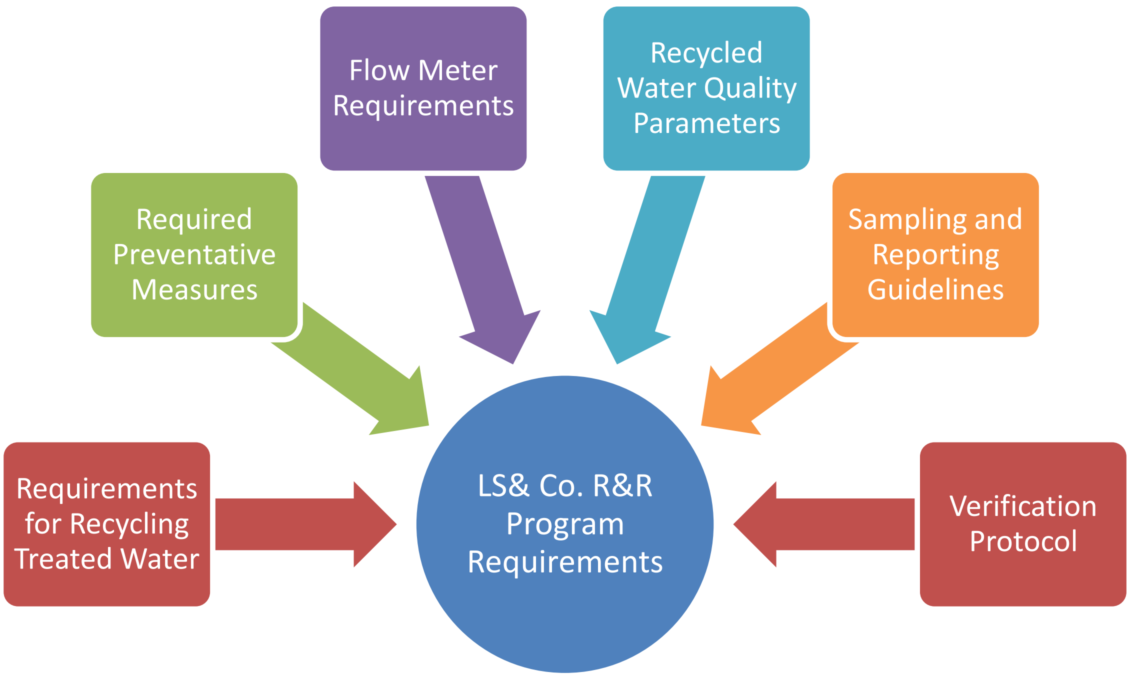



**Figure 3: LS&Co. R&R Program Requirements**

# Requirements for Recycling of Treated Water

The following requirements must be implemented by factories that reuse treated water obtained from either their on-site treatment system or a POTW:

1. Maintain a supplemental water source to receive water in the event that the treated wastewater source is not available or is unable to provide sufficient supply or quality of recycled water. The source should have capacity to meet 100% of the facility's water requirements. Develop procedures to switch facility's source water. Storage of recycled water beyond daily usage requirements may also help provide water at times when treatment is offline.
2. Update the industrial Wastewater Emergency Plan per LS&Co.'s *GER*, to be used in case the recycled water does not meet applicable regulations or the requirements described herein.
3. Obtain a current and valid permit from all applicable governing agencies to operate or utilize any additional facility for treatment of recycled water, if required.
4. Obtain a current and valid permit from all applicable governing agencies, if required, to utilize recycled water.
5. Meet the stricter of:
    a. All applicable governing agency requirements
    b. LS&Co. *Recycle & Reuse Standard and Guidelines*
6. Conduct laboratory analysis of recycled water to demonstrate that it complies with the stricter of the applicable governing agency requirements and/or LS&Co.'s *Recycle & Reuse Standard and Guidelines* for the parameter limits listed in Table 1.
    a. Sample recycled water at least twice a year by April 30 and October 1st of each year. Maintain analytical data onsite for LS&Co.'s *Recycle & Reuse Standard and Guidelines* parameters.
    b. Arrange collection, analyses, and laboratory reporting of recycled water samples per requirements set forth in LS&Co. *Global Effluent Requirement* for "Direct Dischargers."
    c. For recycled water sampling points and collection, follow the procedures in the "Sampling and Reporting Guidelines" within this document.
    d. More frequent sampling and analysis is recommended if a facility has onsite laboratory capabilities to ensure the treatment system is operating properly. See "Sampling Guidelines" for recommended testing frequency by parameter (Appendix D).
7. Enter all recycled water laboratory and flow data into the appropriate system(s), as required per the GER.
    a. Install flow meters at appropriate locations in order to document quantity of recycled water used during production of LS&Co. product.
8. Implement the measures described below under "Required Preventive Measures."
9. Maintain the following minimum laboratory equipment to ensure recycled water is of sufficient quality: dissolved oxygen (DO) meter, pH meter, and thermometer. See LS&Co. *GER* for additional information.
10. If a recycled water treatment system is utilized at the factory, maintain an up-to-date flow diagram of the recycled water treatment system.
11. Maintain a log of dissolved oxygen for all stored recycled water in tanks, ponds or other impoundments. At a minimum, the log should include dissolved oxygen levels, dates and times onsite.
12. For any water that is discharged to the environment, ensure that final effluent discharges meet all applicable local requirements along with LS&Co. *GER*.
13. Maintain records of water sampling logs and make them available for external monitors.

## Required Preventative Measures

The following preventative measures are to be followed for protection of **human health and the environment** when recycled/reused water is being utilized in the facility:

1. LS&Co. shall be notified of intent to produce or receive recycled water prior to first producing or utilizing recycled water.
2. Landscape irrigation with recycled water is allowable. Restricted access facility property areas are defined as areas where public access is controlled with a fence, wall, or other barrier. The following guidelines must be implemented for landscape irrigation with recycled water.
    a. Do not use recycled water to irrigate any areas where uncontrolled public access is permitted.
    b. Do not irrigate with recycled water within 2 meters of any domestic drinking water supply well if using spray irrigation method. Drip irrigation is preferred method; no buffer zone is needed if drinking water supply is encapsulated.
    c. A setback distance (or buffer) of 2 meters from the property lines of public places shall be maintained when spray irrigating. This restriction will not apply if drip irrigation system is utilized. Public places include private residence, park, playground, outside cafeteria, or other areas with public access.
    d. Manage the timing of recycled water irrigation to minimize the potential for direct human contact. Do not spray irrigate at times when people (facility employees or public) may be nearby preparing or eating food. Any spray irrigation with recycled water of landscaped areas that are accessible to employees shall be done during the hours that employees are not present at the irrigation area or utilize drip irrigation method.
3. Sanitary toilet flushing with recycled water is allowable for 'restricted access facility toilets' only. Restricted access facility toilets are defined as toilets that are used by facility owners, managers, and employees/workers only, and where public access is controlled. Do not use recycled water for any systems involving human contact with the water (bidets, sink, other washing).
4. Recycle and Reuse system shall be designed to prevent ponding of recycled water outside bermed areas, basins, or tanks intended to store recycled water.
5. If recycled water is either placed in a surface impoundment or used for irrigation, the system should be designed to prevent <u>all</u> overflows or offsite runoff of recycled water from being collected so that it cannot be used again for irrigation, washing, or other uses.
6. The Recycle and Reuse system shall be designed to prevent recycled water from entering potable or fresh water systems under any circumstance (Figure 4).
    a. If blending of potable or fresh water and recycled water is required, provide a minimum elevation difference (air gap) of 0.5-meters between supplemental water supply outlet and top of receiving vessel or piping for distribution system (Figure 5) for cross-connection control.
    b. All impoundments or tanks used for storage of delivered recycled water must have a minimum of 0.5 meters of "freeboard", or vertical clearance from overflow pipes or top of impoundment or tank, at all times (Figure 4 & Figure 5).
    c. Provide agitator, aeration, and/or mixing equipment (Figure 6) to prevent algal blooms and for aerating the stored water to maintain a minimum dissolved oxygen content of 2 mg/L at all times.

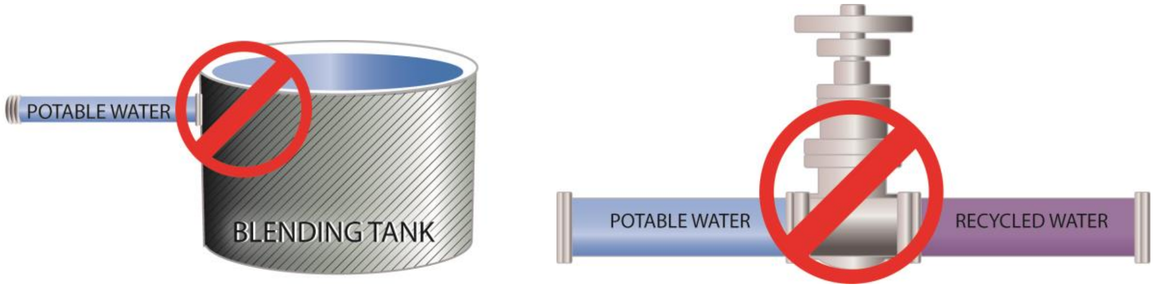



**Figure 4: Potable and fresh water should never be directly connected to blending tank or recycled water system**

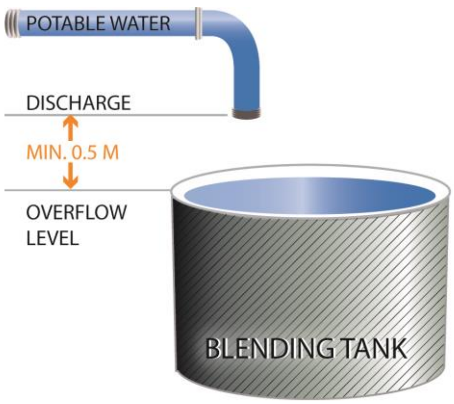



**Figure 5: Maintain minimum air gap**

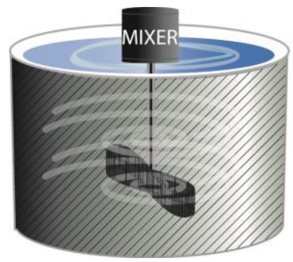



**Figure 6: Provide mixing equipment for aeration for all stored recycled water (tanks, ponds, or basins)**

7. Provide signs at each recycled water point of use (landscape irrigation discharges, laundry, toilet, cooling tower). Signs shall read "Recycled Water – Do Not Drink," in the language(s) understandable by all employees, and be readily visible. (Figure 7)

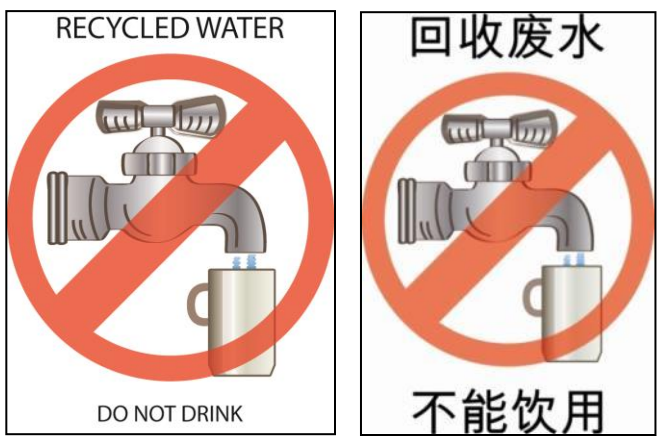



**Figure 7: Post signs at each recycled water point of use in languages understood by all employees**

8. Provide personal protective equipment (at a minimum, gloves and goggles) to all employees working with recycled water.
9. Color code all recycled water, fresh water, and potable water pipes according to local laws and regulations. If no regulations exist, ensure that recycled water piping, fresh water piping, and potable water piping are dissimilar in color from each other and from other piping in the facility. Labels ("recycled water," "fresh water," or "potable water") will further help identification and should be provided in the language(s) understandable by all employees, as specified in the Sustainability Guidebook section on labelling.

## Flow Meter Requirements

LS&Co. recognizes that each facility is unique and therefore has developed multiple schematics depicting ways to configure piping and flow meters. Flow meters are required as part of the R&R program in order to maintain an accurate record of the recycled water being used in the making of LS&Co. product. This allows LS&Co. to track the water saved through various process improvements and this R&R program. The following figure provides illustrations of possible piping arrangements for recycled water use and flow meter placement. A fresh water source is shown in each option to comply with the requirement of the R&R program for a backup water supply, but potable water can also be used as a backup water supply.

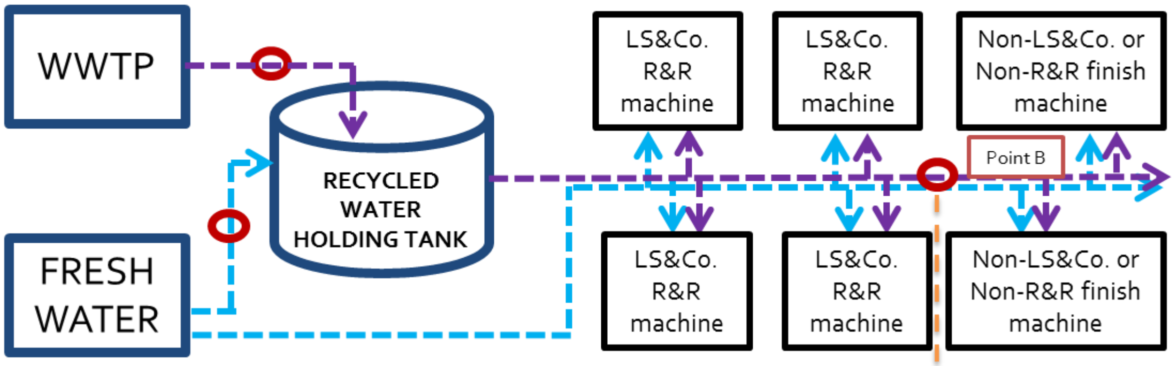
Option 1 is configured with a holding, or mixing tank, which allows the facility to blend treated wastewater and fresh water to meet parameter limits, as shown in Figure 8. The blended water must include at least 20% recycled water. This option measures the influent flow of the treated wastewater and fresh water entering a holding tank, and has the option to mix both water types in the holding tank. Flow meters are placed on the inlet lines to the holding tank. An additional flow meter would be required if there are non-LS&Co. machines so that the amount of recycled and fresh water used only on LS&Co. product can be calculated. A non-LS&Co. machine is one used for another retail partner and a non-R&R finish machine is one not configured to use recycled water. There is an emergency by-pass line of fresh water that bypasses the holding tank and connects to each machine.

Option 2 differs from Option 1 because it does not include a holding or mixing tank, and therefore, does not allow for use of blended water. In this configuration, the facility must use either 100% recycled water or 100% fresh water. Option 2 has two main lines, one for recycled water and one for fresh water, to be used as a back-up supply. Flow meters only need to be placed on the recycled water lines at the effluent to the WWTP. An additional flow meter would be required if there are non-LS&Co. machines so that the amount of recycled and fresh water used only on LS&Co. product can be calculated.

As noted, these configurations may need to be adjusted with each facility. For example, if a facility has LS&Co. machines scattered throughout the facility and not physically located near each other, flow meters may be required on each individual line to the machines in order to quantify recycled water being used for LS&Co. R&R machines.

# Option 1: 20-100% Recycled Water

•Two meters at the beginning to quantify amount of recycled and fresh water being added to the holding/mixing tank.
•Configured to allow for blending of recycled and fresh water if desired. Blended water must include at least 20% Recycled water.
•There are two main lines: one is for recycled water, the other is for the fresh water back-up source.
•Each laundry machine has two pipe connections.




•Flow meters are required at Point B <u>**if**</u> there are Non-LS&Co. machines or Non-R&R finishes **after** the LS&Co. R&R machines so that the quantity of water used for these machines is not counted with LS&Co. R&R water.
Note: A non-LS&Co. machine is used for another retail partner and a non-R&R finish machine is used for LS&Co. but does not use recycled water.
•We later subtract the water flowing at Point B to calculate how much R&R and fresh water is used <u>only</u> for LS&Co. product.

= flow control/ meter

# Option 2: 100% Recycled Water or 100% Fresh Water

•Two main lines: One for recycled water and one for fresh water.
•Does not include a holding/mixing tank and therefore, does not allow for blended water.
•Configured to operate with either 100% Recycled water OR 100% Fresh water
•Each laundry machine has two pipe connections, with flow meters on the recycled water line.

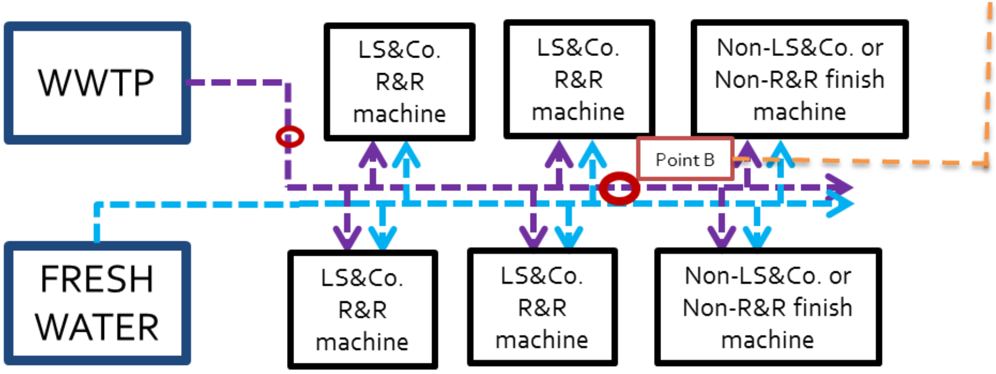



**Figure 8: Machine Set-Up Options**

## Flow Meter Installation

In order to obtain accurate flow measurements, flow meters should be installed per manufacturer specifications and recommendations. Straight pipe before and after the flow meter will help provide more accurate measurements. The length of the straight run is dependent on the diameter size of the pipe and the type of flow meter, and may vary before and after the flow meter. The figure below shows a pipe, where XD is the straight length of pipe before the flow meter and YD is the straight length of pipe after the flow meter, as depicted in Figure 9. D is the diameter of the pipe, and X and Y are determined based on the flow meter type. The straight length pipe required for a typical flow meter is 5-10 times the diameter upstream and 2-5 times the diameter downstream.

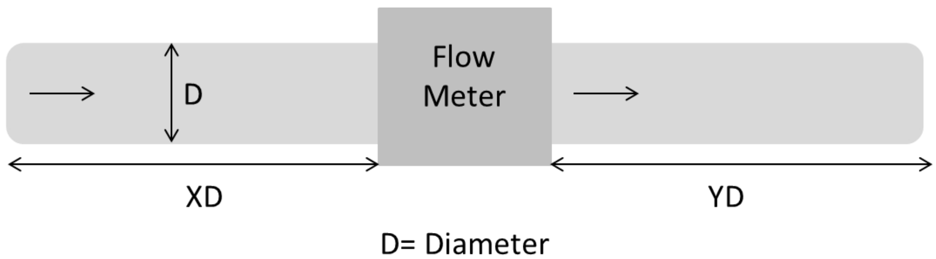



**Figure 9: Flow Meter Installation**

## Recycled Water Parameter Limits

Table 1 summarizes the recycled water parameter limits for compliance with LS&Co. *Recycle & Reuse Standard and Guidelines* based on protection of human health and the environment and suitability for the intended reuse application (process water/laundry, landscape irrigation, cooling tower makeup water, and sanitary toilet flushing). These guidelines are based on global reuse standards and limited process information and provide a basis for development of refined water quality guidelines appropriate for LS&Co. finishing facilities. Local regulations or permits may specify additional requirements for recycled water, including higher quality or operational requirements. The table also includes the GER acceptable limit as reference.

The R&R water standard must be tested for and met twice per year, in addition to the GER water test for each of the specified parameters. **Water sample for the test must be taken at the exit point of the blend tank, if applicable, or at the effluent of the wastewater treatment tank.** Blended water must be comprised of at least 20% recycled water in order to be considered part of the R&R program.

**Table 1: Recycle/Reuse Parameter Limits**

| | | GER | REUSE APPLICATION | | | | |
|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | |
| **Parameter** | **Unit** | **Acceptable Parameter Limit** | **Facility Process (Laundry) Water** | **Landscape Irrigation (Restricted Access)[1, 2]** | **Cooling Tower Water[3]** | **Sanitary Toilet Flushing (Restricted Access)[2]** | **Notes** |
| pH | pH | 6.0-9.0 | 6.0 - 9.0[a] | 6.0 - 9.0[h] | 6.0 - 9.0[a] | 6.0 - 9.0[a] | Acceptable if within the given range; not acceptable if out of range |
| Temp. | °C | 37.0 | N/A | N/A | N/A | N/A | |
| Total Suspended Solids (TSS) | mg/L | 30 | 10[c] | 30[h] | 100[b] | 30[i] | |
| Total Dissolved Solids (TDS) | mg/L | NL | 2000[c] | 1000[f] * | 500[b] | NL | * Sensitive plants may require lower TDS, down to 500. |
| Biochemical Oxygen Demand (BOD5) | mg/L | 30 | 30[a] | 30[h] | 10[a] | 30[i] | Based on a 5-day BOD test |
| Chemical Oxygen Demand (COD) | mg/L | Test, Monitor and Report | N/A | N/A | N/A | N/A | |
| Color | color units | Qualitative observation | 5 CU or 150 ADMI[j] | NL | NL | 40 CU * | * Guideline is based on aesthetics |
| Total Hardness | mg/L as $CaCO_3$ | NL | 90[c] | NL | 130[b] | NL | |

| | | GER | REUSE APPLICATION | | | | |
|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | |
| **Parameter** | **Unit** | **Acceptable Parameter Limit** | **Facility Process (Laundry) Water** | **Landscape Irrigation (Restricted Access)** [1, 2] | **Cooling Tower Water** [3] | **Sanitary Toilet Flushing (Restricted Access)** [2] | **Notes** |
| Turbidity | NTU | NL | 2[a] | NL | NL | NL | Higher turbidity levels may be allowed if they can be shown to correlate to the required TSS levels |
| Chlorine Residual | mg/L | NL | 1[a] - 2[e] | 1[h] - 2[f] * | 1[a] - 4[e] | 1[a] - 4[e] | Acceptable if within the given range; not acceptable if out of range. * Sensitive plants may be damaged at levels as low as 0.5 mg/L. |
| Iron | mg/L | NL | 0.1[c] | 5[f] | 0.5[b] | 0.3 * | * Guideline is based on potential to stain fixtures |
| Mercury (Hg) | mg/L | 0.01 | 0.01 | n/a | n/a | 0.015 | |
| Cadmium (Cd) | mg/L | 0.01 | 0.01 | n/a | n/a | 0.015 | |
| Lead (Pb) | mg/L | 0.10 | 0.10 | n/a | n/a | 0.15 | |
| Arsenic (As) | mg/L | 0.01 | 0.01 | n/a | n/a | 0.015 | |
| Copper (Cu) | mg/L | 0.25 | 0.25 | n/a | n/a | 0.375 | |
| Nickel (Ni) | mg/L | 0.20 | 0.20 | n/a | n/a | 0.30 | |
| Chromium (Cr) | mg/L | 0.10 | 0.10 | n/a | n/a | 0.15 | |
| Zinc (Zn) | mg/L | 1.0 | 1.0 | n/a | n/a | 1.50 | |
| Cyanide (CN) | mg/L | 0.20 | 0.20 | n/a | n/a | 0.30 | |
| Cobalt (Co) | mg/L | 0.02 | 0.02 | n/a | n/a | 0.03 | Applicable to non-denim facilities only |
| Manganese | mg/L | 0.10 | 0.1[c] | 0.2[f] | 0.5[b] | 0.05 * | * Guideline is based on potential to stain fixtures |
| Antimony (Sb) | mg/L | 0.01 | N/A | N/A | N/A | N/A | |
| Sodium (Na) | mg/L | NL | NL | 70[g] | NL | NL | |

| Parameter | Unit | GER | REUSE APPLICATION | | | | Notes |
|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | |
| | | Acceptable Parameter Limit | Facility Process (Laundry) Water | Landscape Irrigation (Restricted Access)[1, 2] | Cooling Tower Water[3] | Sanitary Toilet Flushing (Restricted Access)[2] | |
| Chloride | mg/L | NL | NL | 100[g] * | 500[b] | NL | * Chloride sensitivity varies widely. Consult local agronomists as part of the preliminary design efforts. |
| Fecal Coliform (for combined systems[k]) | CFU/ 100 mL | 25 CFU/100 mL | 75% ND, 25 max[d] * | 200 average; 800 max[h] ** | 75% ND, 25 max[d] * | 200 average; 800 max[i] ** | * Non-detect for 75% of samples, 25 CFU/100 mL max. ** 200 CFU/100 mL average for year, 800 CFU/100 mL max. |
| Foam | | Not persistent | N/A | N/A | N/A | N/A | |

Notes:
[1] If drip irrigation is used, lower water quality limits are recommended for iron and manganese.
[2] Water quality requirements based on RESTRICTED ACCESS. Minimize the potential for human contact with recycled water.
[3] Additional pretreatment may be required due to variability among manufacturer recommendations.
ND = Non-detect, or below detection limit
NL = No limit
[a] Adapted from Suggested Guidelines for Urban Reuse (US EPA)
[b] Adapted from Typical Reclaimed Water Quality Requirements for Cooling Water, makeup for recirculation (Asano, Burton, Leverenz) A lower TSS may be required to comply with the fecal Coliform limits. Higher TDS concentrations may be used but this will reduce potential cycles of concentration and increase precipitation and corrosion problems.
[c] Based on correspondence with LS&Co. process experts (September 2010)
[d] Adapted from State of Florida mandatory reuse standards
[e] Based on USEPA National Primary Drinking Water Standards
[f] Adapted from recommended limits for irrigation (USEPA)
[g] Adapted from Quality of Water for Irrigation (Ayers)
[h] Adapted from Suggested Guidelines for Restricted Access Irrigation (US EPA)
[i] Adapted from Suggested Guidelines for Industrial Reuse (US EPA)
[j] Adapted from Typical Reclaimed Water Quality Requirements for Textiles (Asano, Burton, Leverenz)
[k] Combined systems contain domestic wastewater, in addition to industrial (process) wastewater.

For full references, see Appendix A

## Meeting Parameter Limits: Treatment and Blending

If a facility does not meet the requirements for recycling water, further wastewater treatment may be required. Recommended treatment schemes and processes can be found in Appendix B. Alternatively, if a facility does not wish to invest in further treatment of the treated effluent, the water to be recycled can be blended with potable or fresh water to obtain a new stream. **The blended stream must contain at least 20% recycled water to be considered part of the R&R program.** Additional information on using blended water is found in Appendix B.

# Sampling and Reporting Guidelines

In order to comply with the Recycle & Reuse Standard and Guidelines, all facilities using recycled water must conduct sampling and submit reports summarizing data twice per year. Sampling methodology is found in the GER. This section describes how to collect a composite sample, what equipment should be used, who should conduct sampling, how to complete chain of custody record, and more.

## Sampling Methodology and Analytical Methods

Samples should be tested by an outside laboratory at least twice annually. It is recommended, however, that facilities sample on a daily basis for some parameters in order to monitor the recycled water quality and ensure the WWTP is functioning properly. Recommended sampling frequency varies by parameter, from once per shift to once per week. These recommendations, along with parameter specific test procedures and precautions are presented in Appendix D. Sampling and testing procedures should be completed based on the guidelines in Table 2 and according to the analytical methods defined in Table 3.

**Table 2: Suggested Sampling Guidelines**

| Parameter | Volume Required (mL) | Type of Container | Preserving Method | Maximum Holding Time |
|---|---|---|---|---|
| pH | 25 | Plastic or glass | Determine on site | 2 hours |
| $BOD_5$ | 1000 | Glass | Chill to near freezing | 48 hours |
| TSS | 50 | Plastic or glass | Cool to 4°C | 7 days |
| TDS | 100 | Plastic or glass | Cool to 4°C | 7 days |
| Fecal Coliform | 250 | Plastic | Cool to 4°C, 0.008% sodium thiosulfate | 6 hours |
| Turbidity | 100 | Plastic or glass | Cool to 4°C | 48 hours |
| Chlorine Residual | 200 | Plastic or glass | No headspace | Immediately |
| Metals | 100 per metal | Plastic | Nitric acid to pH<2 | 6 months |
| Mercury | 500 | Plastic or glass | Nitric acid to pH<2 | 28 days (glass) 13 days (plastic) |
| Color | 500 | Plastic or glass | Cool to 4°C | 24hours |
| Total Hardness | 100 | Plastic or glass | Nitric acid to pH<2 | 6 months |
| Chloride | 100 | Plastic or glass | Cool to 4°C | 6 months |
| Sodium | 100 | Plastic | Nitric acid to pH<2 | 6 months |

The analytical methods recommended for use in determining the parameters listed in the LS&Co. *Recycle & Reuse Standard and Guidelines* are referenced in the table below. Equivalents of these methods are also acceptable (e.g. equivalent methods from the country's Bureau of Standards).

LS&Co. GER includes a list of international companies and their collaborative networks of certified laboratories. Refer to this list (GER) for analytical laboratories that are qualified to perform the analyses. Compliance with LS&Co.'s *Recycle & Reuse Standard and Guidelines* relies, in part, on recycled water testing results produced by laboratories. It is critical that the laboratories produce reliable, high quality data. When choosing a laboratory, refer to LS&Co. GER.

**Table 3: Suggested Analytical Methods**

| Parameter | Parameter Limit / Guideline for Facility Process (Laundry) Water | Testing Standards | |
|---|---|---|---|
| | | US EPA and Standard Methods | ISO |
| Sampling: | | | |
| pH, standard units | 6.0 – 9.0 | SM 2550B | ISO 10523 |
| 5-day Biochemical Oxygen Demand ($BOD_5$) | 10 mg/L | SM 5210 | ISO 5815-1, -2 |
| Total Suspended Solids (TSS) | 10 mg/L | SM 2540D | ISO 11923 |
| Fecal Coliform | 75% ND; 25 CFU/100 mL max | SM 9222D | ISO 9308-1 |
| Turbidity | 2 NTU | USEPA 180.1 or SM 2130B | ISO 7027 |
| Chlorine Residual | 1 - 4 mg/L | USEPA 300.1 or SM 4500-ClD | ISO 7393-3 |
| Total Dissolved Solids (TDS) | 2000 mg/L | SM 2540C | |
| Total Hardness | 90 mg/L | USEPA 130 or SM 2340C | |
| Chloride | -- | USEPA 300.6 or SM 4500 | ISO 10304 |
| Sodium | -- | USEPA 200.7, USEPA 200.8 or SM-3120B, SM-3125B | ISO 15586, ISO 11885 |
| Color | 5 CU or 150 ADMI | USEPA 110.1 or SM 2120E | |
| Iron | 0.1 mg/L | USEPA 200.7, USEPA 200.8 or SM-3120B, SM-3125B | ISO 15586, ISO 11885 |
| Manganese | 0.1 mg/L | USEPA 200.7, USEPA 200.8 or SM-3120B, SM-3125B | ISO 15586, ISO 11885 |
| "Other" Metals | See LS&Co. Global Effluent Requirements (GER) | | |

Notes:
ISO – International Standard Organization, complete list of water test methods, technical committee
SM – Standard Methods
USEPA – United States Environmental Protection Agency

## Reporting Guidelines

All facilities must submit laboratory reports twice per year in order to demonstrate compliance with the R&R Program.

## Submitting the Laboratory Report: Laboratory Guidelines (refer to GER)

LS&Co. GER includes a list of requirements which must be forwarded to all laboratories used in sampling and analysis for the purposes of compliance with the LS&Co. *Recycle & Reuse Standard and Guidelines*. Refer to LS&Co. GER. These LS&Co.-specific laboratory requirements help LS&Co. assure the quality of the reporting being received, and help consolidate reports from almost 150 laboratories globally.

## Submitting the Laboratory Report: Factory Guidelines

1. Reporting Deadlines – LS&Co. *Recycle & Reuse Standard and Guidelines* analysis results shall be submitted to the Sustainability Assessor according to the following schedule:
    a. By April 30th and October 1st of each year: original laboratory reports of the R&R Program parameters listed in Table 1 (pH, $BOD_5$, TSS, fecal coliform, turbidity, chlorine residual, TDS, iron, manganese, total hardness, sodium, chloride, chlorine residual, and color) that are applicable to any and all reuse application employed (laundry, landscape irrigation, cooling tower, sanitary toilet flushing) are to be submitted.
        i. Water quality reports are to be submitted twice per year as a supplement to the facility's GER water quality test result reports.
    b. All factories required to sample and analyze recycled water under the LS&Co. R&R Program shall meet these reporting deadlines.
2. Other reporting issues:
    a. Only the original laboratory report is acceptable to LS&Co. Factories are not to create and submit their own document for reporting.
    b. Factories shall keep an original laboratory report on file for review during the annual TOE Assessment or follow-up visit.
    c. Metal analyses require some lead time before the results can be available; factories should take this into account when scheduling sample and analysis in order to submit their reports on time.
    d. Factories shall test as frequently as necessary to maintain water quality levels, and retain all original reports on site, to be provided to an LS&Co. or third-party inspector upon inquiry or visitation.
    e. At all times, recycled water systems shall comply with the local requirements, regulations, and/or permits.

# Verification Protocol

In order to officially be recognized as a participating vendor in the R&R program, it is necessary to have a third party consultant verify compliance with the guidelines identified in this document. The verification process helps LS&Co. keep track of reduced water consumption through water recycling. Each facility is required to submit sampling documentation, completed by a third party laboratory, twice per year. An initial on-site audit must be conducted by a third party verifier during the first year to verify the facility's compliance with the R&R program. Annual reverification will be determined through submission of flow meter and concentration data, coordinated through the third party verifier. If the analytical and flow reports demonstrate compliance then the facility maintains their verification status. If a significant facility upgrade occurs, an onsite visit to confirm retention of compliant infrastructure is required. During on-site visits, the facility is required to escort LS&Co. personnel (or individuals designated by LS&Co.) to appropriate locations to inspect all onsite recycling treatment equipment, associated piping, and recycled water usage locations.

## Initial Verification

The initial verification of R&R Standard Compliance is outlined in Figure 10. Once a vendor has made any necessary upgrades to their facility, such as upgrades to WWTP, installation of flow meters, or implementation of preventative measures, then the vendor should contact a third party verifier, who will coordinate a site visit by one of their approved auditors. The auditor will inspect the laundry infrastructure and collect water samples for testing. If approved, the facility is considered R&R verified. The auditor will look to confirm that the facility is in compliance with the following:

- Current and valid permits are in place to utilize recycled water from all applicable governing agencies, if required
- Analytical data (twice per year by third party laboratory, in accordance with GER procedure) demonstrates compliance with local, state, provincial or federal recycled water regulations and requirements, as well as the R&R requirements identified in Table 1
  - Check sampling and preservation techniques and chain of custody
  - Check on-site laboratory has minimum equipment (DO meter, pH meter, and thermometer) and that they are in acceptable condition
  - Check laboratory analysis was completed by a certified laboratory
  - Entered into facility data management system, per the GER
  - Verify any effluent discharged from the facility meets the GER
- Log of DO for all stored recycled water in tanks, ponds or other impoundments onsite is up to date with adequate information (levels, dates, and times)
- Permitting changes
  - Current and valid permits from all applicable governing agencies for any upgrades to WWTP, if required
  - Updated Industrial Wastewater Emergency Plan, per the GER
  - Updated WWTP flow diagram, per GER
- Verify configuration for recycled water is appropriate
  - Secondary source (potable or fresh water) is available and can meet 100% of facility's needs in case demand cannot be met with recycled water
  - Piping configuration and flow meter installation
    - Flow meters should have adequate straight length piping before and after meter.

- Water meter readings are configured correctly to obtain accurate data for water use under R&R or Water<Less Programs
- Check storage areas
    - Designed to prevent ponding outside these areas
    - Minimum of 0.5 meters "freeboard" or vertical clearance from overflow pipes or connections with fresh water/potable water pipes
    - Check blending or holding tank has mixing equipment for aeration

- If recycled water is used for landscape irrigation:
    - Verify the initial salinity of the soil to ensure that additional sodium deposits from application of recycled water will not bioaccumulate to a level that is beyond that is permitted by the local government.
    - Verify recycled water is not being used where uncontrolled access is permitted.
    - Verify it is not used within 2 meters of domestic drinking water supply well (if spray irrigation).
    - Verify it is set back of 2 meters from property lines of public places (if spray irrigation).
    - Verify spraying does not occur when people may be nearby preparing or eating food.
        - Confirm any areas accessible to employees are only sprayed during times when employees are not present, or that the drip irrigation method is used.
- If recycled water is used for sanitary toilet flushing:
    - Verify it is only for restricted access toilets (controlled public access)
    - Verify it is not used for systems involving human contact (sink, bidets, other washing)
- Verify preventative measures are in place
    - Confirm there are signs indicating recycled water at each point of use.
    - PPE is available (gloves and goggles at a minimum) and are being used.
    - Check that piping is color coded and labeled to distinguish recycled water versus potable water.

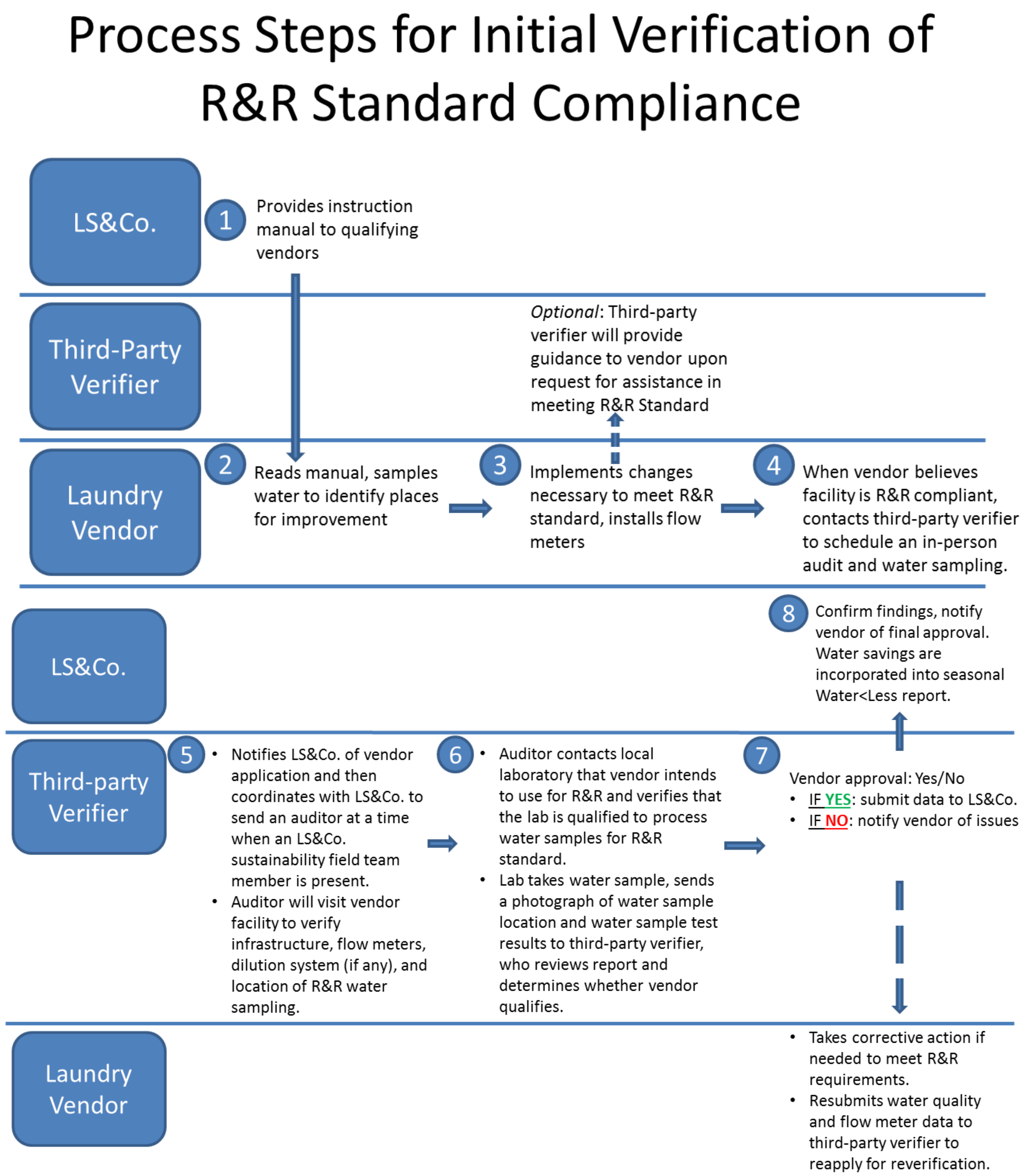



**Figure 10: Process Steps for Initial Verification of R&R Standard Compliance**

## Reverification

In order to maintain status as an R&R verified facility, water samples, flow meter data, and blending information (if applicable) must be provided to LS&Co. twice a year by April 30th and October 30th. The data submitted by April 30th should include data from October 1st through March 31st, and the data submitted by

October 30th should include data from April 1st through September 30th. The process of reverification will be managed by a third-party verifier as outlined in Figure 11.

In-person audits will not be required for reverification unless there are significant changes or upgrades to the water treatment system, in which case the vendor shall notify LS&Co. immediately.

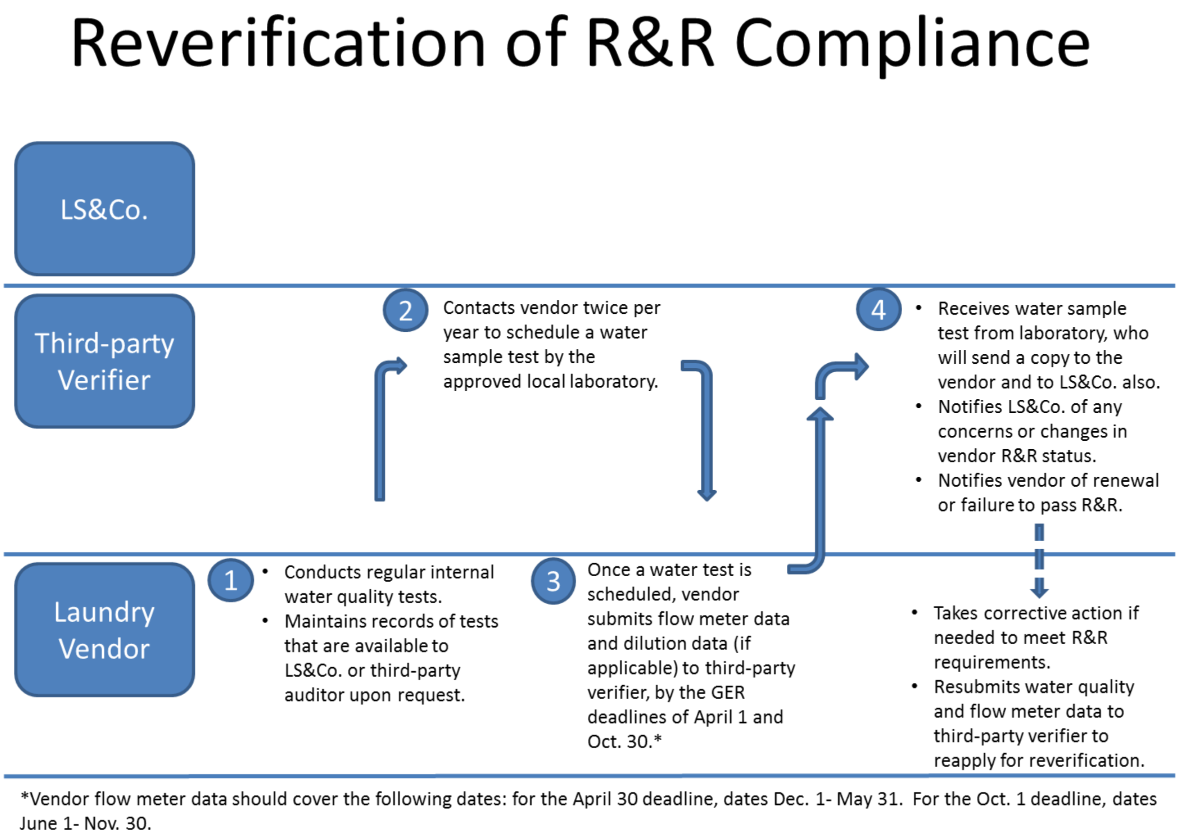



**Figure 11: Reverification of R&R Compliance**

# Case Study – Yida Facility in Zhongshan, China

LS&Co. has partnered with the Crystal Group to implement recycle and reuse in apparel manufacturing. Yida is a denim jeans manufacturing facility located in Zhongshan, China, that makes jeans for a variety of companies including LS&Co. The Crystal Group first implemented a Recycle and Reuse Program at the Yida facility around 2005 as part of a major environmental initiative. LS&Co. began to collaborate with the Crystal Group in 2012 in order to further develop standards for water recycling and reuse in the industry (Crystal Group, 2015).

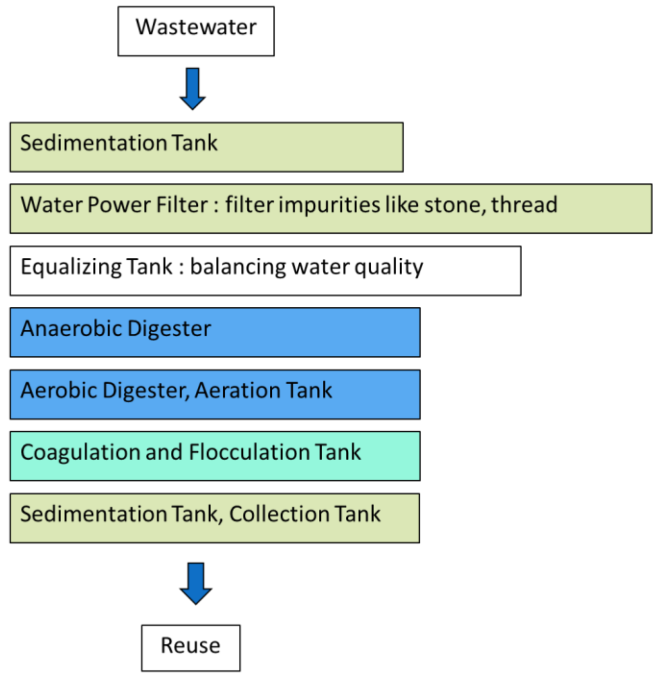



**Figure 13: Yida Wastewater Treatment Plant Simplified Block Flow Diagram (Crystal Group, 2012)**

The facility has a tertiary industrial wastewater treatment plant that consists of physical, biological, and chemical processes, which is depicted on a simplified block flow diagram in Figure 13. The treated wastewater from the WWTP does not require additional treatment to meet the reuse requirements. COD and $NH_3$ are measured daily using an on-line monitoring system. The facility collaborates with the Zhongshan Environmental Team of China Government to monitor the effluent water quality. The hardness, pH, temperature, TDS, and turbidity of the wastewater are also measured on a daily basis. Recycled water is also tested at an external laboratory twice per year, in fulfillment of LS&Co.'s R&R program requirements. Figure 12 shows an individual laboratory for the WWTP and the on-line monitoring system at Yida.

**Figure 12: Laboratory equipment and on-line monitoring system at Yida Facility. Left two pictures show water sent to Chinese Government for testing**

Approximately 90% of the wastewater treated on-site is reused; 70% used in production and 20% used for flushing toilets and landscape irrigation. Each laundry machine has a fresh water and a recycled water pipe, similar to Option 2 above. Yida uses either 100% recycled or 100% fresh water in their machines at a time due to limitations to accurately measure the volume of each water type blended at the machine-level.

Yida has implemented many of the preventative measures described in these guidelines in order to minimize potential for human contact with the recycled water. They have color-coded piping, where the fresh water pipes are blue and the recycled water pipes are green. They also have signs that say "Do Not Drink Recycled Water" and maintain records of control documents of their wastewater treatment operation.


**Figure 14: Preventative measures at the Yida Facility; Color coded piping shows fresh water (blue pipes) and recycled water (green pipes) connecting to each machine (Left) and "Do Not Drink" warning sign (Right)**

The Crystal Group has saved over 60 million liters of fresh water and made over 500,000 pairs of denim jeans with recycled water (Crystal Group, 2015). The Yida facility has been able to minimize consumption of fresh water through the R&R program and have achieved approximately 13.5% in savings, including the operational cost of the WWTP.

*LS&Co. encourages any laundry facility who has met the R&R Standard to submit photographs and information about your own R&R set-up to us, for inclusion in future manual editions. We want to learn from you, and share your learnings with other of our laundry partners so that we can improve collective water use across the supply chain.*

# Recommendations and Supplemental Resources

This manual has outlined the requirements of the R&R program. The appendices to this manual include supplemental resources and recommendations to help support facilities achieve and maintain verification with the R&R program. Table 4 provides a summary of the supplemental material, including what each section includes, how it relates to the requirements of the R&R program, and where it is located.

**Table 4: R&R Program Supplemental Resources and Recommendations**

| Recommendation/Guidance | Description | Related Requirement | Reference |
|---|---|---|---|
| Suggestions for Recycled Water Treatment and Blending | Guidance to help design wastewater treatment system to meet recycled water quality requirements as well as information on how to blend treated wastewater with potable or fresh water to meet limits.<br><br>These are recommendations only and the vendor can use an existing treatment system or another design as long as the treated wastewater meets the recycled water quality limits. | Recycled wastewater meets water quality limits (Table 1) | Appendix B |
| Importance of water quality parameters on textile quality, machinery, and health | Provides information on how the measured parameters impact product quality and human health | N/A – informative only | Appendix C |
| Wastewater treatment sampling guidance | Troubleshooting guide to help vendors adjust wastewater treatment in order to meet the R&R recycled wastewater water quality limits. Provides recommended sampling locations for each parameter.<br><br>LS&Co. requires sampling after the WWTP/blend tank for compliance with the R&R, but it is recommended that additional samples are taken more frequently to ensure the wastewater treatment facility is functioning properly. | Recycled wastewater meets water quality limits (Table 1) | Appendix D |

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## Glossary

**Aerobic Treatment:** A treatment method for wastewater in which the water is aerated to provide oxygen for the microorganisms to convert organic carbon to CO and new cells. This is a very common treatment for wastewater.

**Applicable Laws and Regulations:** Governing laws, regulations, and authorized agency guidance in both the Sending Country and Receiving Countries.

**Analytical Method or Test Method:** A documented technical procedure for measuring the parameters defined in the LS&CO. GER from wastewater samples collected at factories.

**Analytical Report:** A laboratory-generated document containing the results of analyses carried out on wastewater samples, along with other pertinent information relating to the sampling/ analysis exercise.

**Biochemical Oxygen Demand (BOD):** This is the measure of the organic polluting strength of wastewater. The BOD is determined by measuring the oxygen used by microorganisms in the biochemical oxidation of the organic matter, in a given volume of waste or natural water. Reported as milligram oxygen per liter (mg/l), essentially equivalent to parts per million (ppm) by weight in the case of liquid water.

**Biodegradability:** The susceptibility of a substance to decomposition by living organisms, mainly microorganisms.

**Biological Oxygen Demand5 or BOD5:** An indirect way of measuring the quantity of organic material present in wastewater that is utilized by bacteria.

**Blended Water:** Water blend developed from Recycled/Reclaimed Water and Fresh/Potable Water. The Recycled/Reclaimed Water must make up at least 20% of the blended water to be considered part of the R&R program.

**Chemicals:** "Chemicals" is a common term that describes many different solids, liquids and gases that are used to produce specific effects on other substances. For the purposes of a TOE assessment, "chemicals" include substances that may be present in all facilities such as paint, oil, degreasers, spot removers and solvents. It also includes specialist laundry and dyeing chemicals used in wet finishing facilities and mills, such as detergents, softeners, surfactants, oxidizers and bleaching agents. TOE requires that all chemicals at a facility site have Material Safety Data Sheets.

**COD (Chemical Oxygen Demand):** A measure of the polluting strength of wastewater (especially industrial effluents). COD is determined by measuring the oxygen used by a strong oxidizing agent to chemically oxidize the organic matter in a given volume of waste or natural water. Normally COD is higher than BOD is, as more inorganic and organic substances can be oxidized chemically than biologically. Reported like BOD, as mg/l.

**Compliance:** Following or meeting the obligations of a rule, agreement or guideline.

**Composite Sample:** A mixture of grab samples collected at the same sampling point at different times, formed either by continuous sampling or by mixing discrete samples. May be a "time-composite" (collected at constant time intervals) or "flow- proportional" (collected either as a constant sample volume at time intervals proportional to stream flow, or collected by increasing the volume of each grab sample as the flow increases, while maintaining a constant time interval between the grab samples).

**Detection Limit:** The minimum concentration of a substance that can be measured and reported with 99% confidence that the parameter concentration is above zero and is determined from analysis of a sample in a given matrix containing the parameter.

**Effluent:** wastewater that has been discharged from the laundry facility.

**Environment:** Surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation.

**External Monitor:** A third-party hired by LS&CO. or one of LS&CO.'s business partners to conduct TOE assessments, in place of an internal TOE assessor.

**Facility Headquarters:** The registered office of the company that owns the facility that is being TOE assessed.

**Facility Site:** The specific factory that is being TOE assessed, including workplaces and all facility land, structures and other improvements on the land owned or leased by the facility.

**Follow Up Assessment:** The assessment that usually follows an initial or annual TOE assessment. The TOE assessor conducts a follow up assessment if the factory had corrective actions to make based on discoveries in the initial or annual assessment.

**Fresh Water:** Water obtained directly from lakes, rivers, or deep wells and may not be suitable for drinking water.

**Global Sourcing and Operating Guidelines (GSOG):** The LS&CO. requirements that are applied to every contractor or supplier that manufactures or finishes product for LS&CO. The GSOG have 2 parts: the Country Assessment Guidelines and our Terms of Engagement.

**Grab Sample:** A single sample or measurement taken at a specific time or over as short a period of time as is feasible.

**Hazen:** The standard unit of color measurement that is measured spectrophotometrically.

**Independent Evaluation:** The use of an independent, third party to evaluate specific activities, behavior or facilities.

**Independent Monitoring:** A program or system in which an independent, third-party organization assumes the responsibility for monitoring specific activities, behavior or facilities.

**Indicator:** Something used to show the existence of a particular activity, behavior, substance or state of being.

**Industrial Wastewater:** Water or liquid-carried waste from wet processing of apparel.

**Initial Assessment:** First TOE assessment conducted at a specific facility site.

**Local Limits:** Specific limits on pollutant parameters developed by local country legislation, regional or municipal authorities.

**Material Safety Data Sheet ("MSDS"):** Provides detailed information on each hazardous chemical contained in a chemical product, including the proportion of each chemical, and the potential hazardous effects, physical and chemical characteristics, and recommendations for appropriate human protective measures. An MSDS does not identify whether a material is a hazardous waste.

**Non-compliance:** Violation or failing to follow the obligations of a rule, agreement or guidelines.

**Oxidation:** The addition of oxygen, removal of hydrogen, or the removal of electrons from an elements or compound. In wastewater treatment, organic matter is oxidized to more stable substances.

**Oxidizer:** A substance that gains electrons in a chemical reaction. Oxidizers are generally recognizable by their structures or names. They tend to have oxygen in their structures and often release oxygen as a result of thermal decomposition. Oxidizers often have prefixes (peroxides) and often end in "ate" (nitrate).

**Personal Protection Equipment (PPE):** Safety equipment worn by employees to protect against physical hazards. Examples of PPE: eyewear, face shields, ear plugs, hard hats, gloves, foot protection.

**pH:** An expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion condition. An exactly neutral solution has a pH value of 7.0.

**Potable Water:** Water that meets all local and federal drinking water standards.

**Pre-Treatment:** Any wastewater treatment process which takes place on site prior to the discharge of the wastewater to the municipal sewers leading to the POTW, usually consisting of screening and sludge conditioning and dewatering.

**Publicly Owned Treatment Works (POTW):** Publicly owned systems for treating liquid municipal sewage and industrial waste. May also be referred to as wastewater treatment plants and/or waste pollution control plants.

**Quality Assurance:** A series of planned, routine activities which a laboratory carries out to ensure that a product or service complies with the specified quality requirements.

**Quality Control:** A series of operating methods and activities which are used to satisfy compliance with the established quality requirements.

**Reclaimed Water:** Also "Recycled Water"; water treated for reuse from one of the following sources: (1) treated wastewater from facility's separate system (only industrial water), (2) treated wastewater from facility's combined system (industrial wastewater plus domestic wastewater), (3) treated wastewater from offsite privately or publicly-owned treatment works (POTW).

**Secondary Containment:** Apparatus installed around storage devices, such as tanks or containers, to prevent wastes or accumulated liquids from leaking into the soil, groundwater or surface water by capturing any leaks. Secondary containment devices include double-walls, liners, vaults, spill baths, Bund(ing) or Berms. Sometimes secondary containment is an area that is sloped to drain into a sump or holding area where materials are collected.

**Sludge:** Sludge is a term used to describe solids that are removed from wastewater after treatment. Sludge is a slurry of solids and liquid and may be thought of as one of three types: raw, biological or chemical.

**Solids:** The matter that remains a residue upon evaporation and drying at 103° to 105°C.

**Spill:** When a chemical product, waste or material is released from its proper container into an area where it was not intended to be.

**Standard:** A technical document stating the accepted rules for conducting a specific analytical test.

**State Entities:** Agencies or organizations that are sponsored or managed by the government and/or act on behalf of the government.

**Terms of Engagement (TOE):** The LS&CO. Business Partner Terms of Engagement are part of the LS&CO. Global Sourcing and Operating Guidelines (GSOG) that apply to individual companies that supply LS&CO. These guidelines deal with issues that are substantially controllable by the individual business owners, e.g., workplace conditions and hiring practices. The other part of the GSOG is the Country Assessment Guidelines.

**Total Color Units:** Uses a visual comparator and numerical units are identical with Hazens

**Total Hardness:** Measured as $CaCO_3$

**Total Solids:** The combined total of dissolved solids and suspended solids.

**Total Suspended Solids (TSS):** Particulate matter contained in a water or wastewater samples.

**Verification Assessment:** An assessment that takes place in addition to the Annual Assessment, with the aim of verifying that the information in the TOE report accurately represents the conditions in the factory assessed.

**Waste Water:** Process water that contains chemicals or additives generated throughout manufacturing processes.

# Appendix A

# Reference Standards & Guidelines

## Reference standards & guidelines used for development of the LS&Co. Global Reuse Guidelines and Standards

The following list of references was used to develop the R&R standards listed in Table 1:

1. LS&Co. Finishing specialist (survey was send out to Frank Garcia, Debra Laney, Stacy Laney, Nelson Leung, Bill Tam,) what are the quality of water they desire to see for washing process.
2. Pilot study of two laundry facilities in US currently permitted to utilize recycling water for washing process.
3. LS&Co. Regional Sustainability member review.
3. Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) (2006)
4. United States Environmental Protection Agency, Guidelines for Water Reuse (2004)
5. World Health Organization, Guidelines for the Safe Use of Wastewater, Excreta, and Greywater (2006)
6. From USEPA Guidelines (2004),
   Arizona, California, Cyprus, European Commission Bathing Water Criteria, Florida, France, Germany, Hawaii, Japan, Israel, Italy, Kuwait, Nevada, Oman, South Africa, Spain (Canary Islands), Texas, Tunisia, United Arab Emirates, United Kingdom Bathing Water Criteria, Washington WHO.

# Appendix B

# Suggested Guidelines for Recycled Water Treatment and Blending

## Suggestions for Recycled Water Treatment and Blending

In order to qualify and implement the R&R program, the water to be recycled must be tested and compared to the parameter limits for the desired use, as defined in Table 1. If the water to be recycled does not meet the parameter limits, then additional treatment will be required before the water can be reused within the facility or the recycled water can be blended with fresh water.

## Recycled Water Treatment

The appropriate treatment process will depend greatly on the facility's source water and operations, wastewater characteristics, and intended wastewater quality (where it will be reused). The table below presents typical pH, COD, and BOD values for various generation sources of process and wash wastewater. It is recommended that a third party engineering consultant conducts a comprehensive investigation of the facility operations, source water and effluent wastewater characteristics, and potential reuse applications to determine feasible options. Then each facility can select the most appropriate treatment and implement an appropriate solution.

**Typical Process and Wash Wastewater (DOE, 2008)**

| Source of wastewater generation | Parameters* | | |
|---|---|---|---|
| | pH | COD (mg/L) | BOD (mg/L) |
| **Process Wastewater** | | | |
| Desizing | 5.83-6.50 | 10000-15000 | 1700-5200 |
| Scouring | 10-13 | 1200-3300 | 260-400 |
| Bleaching | 8.5-9.6 | 150-500 | 50-100 |
| Mercerizing | 8-10 | 100-200 | 20-50 |
| Dyeing | 7-10 | 1000-3000 | 400-1200 |
| **Wash Wastewater** | | | |
| After beaching | 8-9 | 50-100 | 10-20 |
| After acid rinsing | 6.5-7.6 | 120-250 | 25-50 |
| After dyeing (hot wash) | 7.5-8.5 | 300-500 | 100-200 |
| After dyeing (acid & soap wash) | 7.5-8.64 | 50-100 | 25-50 |
| After dyeing (final wash) | 7-7.8 | 25-50 | |
| Printing washing | 8-9 | 250-450 | 115-150 |
| Blanket washing of rotary printer | 7-8 | 100-150 | 25-50 |

* Parameters – which are average general processing conditions, across the industrial practices. Other parameters were not considered, due to high deviations. This deviation is mainly due to quality of input chemicals and processing conditions.

There are many important considerations when designing or upgrading a wastewater treatment plant to handle wastewater from various wet textile processing operations. A well-controlled operation with proper checks gives better reusable water. Some considerations are:

- For biological treatment systems, care needs to be taken to ensure that parameters such as temperature, pH are maintained below the bacteria inhibition levels. Care also needs to be taken to ensure that the biological inhibition chemicals, such as antimicrobial finishes and toxic chemicals, do not enter directly into the process water without dilution.
- Plants with washing operations only may have a simple primary treatment, aeration and PSF & ACF filters. TSS and TDS of the recycled water needs to be tested before using the water for processing.

- For the treatment plants that include membrane processes, it is important to ensure proper pretreatment for suspended solids removal prior to the membrane process, and proper membrane maintenance. Feed water to membrane systems should be monitored for TSS and BOD and maintained within the required levels to prevent membrane fouling.

Typical processes for an onsite treatment are described below.

1. Potential treatment processes to achieve the parameter limits summarized in Table 1 include secondary treatment, filtration, and disinfection.
    a. Secondary treatment processes include aerobic biological processes, such as extended aeration, activated sludge, trickling filters, and rotating biological contactors. Stabilization ponds may also be included in the secondary process. Secondary treatment should produce wastewater with $BOD_5$ and TSS concentrations less than 10 mg/L.
    b. Filtration involves passing wastewater through undisturbed soils or filter media such as sand, cloth, or anthracite, or through microfilters. Filtration is required to reduce suspended solids and turbidity.
    c. Disinfection means the destruction, inactivation, or removal of pathogenic organisms and may be achieved by chlorination, ozonation, or other chemical disinfectants, or through membrane processes. Ozonation and membrane processes have the added benefit of reducing color, and potentially iron and manganese. UV radiation is also a common disinfection technique. However, the effectiveness of UV radiation is dependent on the absorbance (or transmittance) of the wastewater, which is often impacted by high TSS and TDS, high organics, metals and dyes.
2. If, after secondary treatment, filtration, and/or disinfection, treated wastewater characteristics contain concentrations greater than the levels listed in Table 1 additional treatment will be required. Advanced treatment techniques are summarized in the table and description paragraphs below.

## Potential Advanced Treatment Techniques

| **Parameter** | **Treatment Techniques** [1] |
|---|---|
| *If, after secondary treatment, filtration, and disinfection, concentrations are greater than Table 1 limits, the following treatment techniques may be appropriate.* | |
| pH | Neutralization through addition of acid or base (depending on pH)<br>Ion exchange |
| $BOD_5$ | Secondary treatment if BOD objective is >30<br>Secondary treatment with filtration if BOD objective is <30 |
| TSS | Secondary treatment if TSS objective is >30 mg/L<br>Secondary treatment with filtration if TSS objective is <30 mg/L |

| Parameter | Treatment Techniques [1] |
|---|---|
| Fecal Coliform | Secondary treatment with disinfection |
| Turbidity | Additional Filtration, filtration with coagulants<br>Electrodialysis Reversal (EDR)<br>Membrane Bioreactor (MBR) |
| Chlorine Residual | Chlorination / Dechlorination |
| Adsorbable Organic Halides | Primary treatment<br>Secondary treatment with activated sludge process<br>Chemical treatment (advanced oxidation process/ozone treatment) |
| Metals | Precipitation<br>Ion Exchange<br>Carbon Adsorption<br>Reverse Osmosis |
| TDS | Ion Exchange<br>Nanofiltration<br>Reverse Osmosis<br>Electrodialysis Reversal (EDR) |
| Iron | See Metals above |
| Manganese | See Metals above |
| Total Hardness | Ion Exchange<br>Nanofiltration<br>Reverse Osmosis<br>Electrodialysis Reversal (EDR) |
| Sodium | Ion Exchange<br>Reverse Osmosis<br>Electrodialysis Reversal (EDR) |
| Chloride | Ion Exchange<br>Reverse Osmosis<br>Electrodialysis Reversal (EDR) |
| Color | Coagulation & Sedimentation<br>Carbon Adsorption<br>Filtration<br>Advanced oxidation |

[1] Generally listed in increasing initial costs from low to high

## Advanced Treatment Processes

The following paragraphs briefly describe advanced treatment techniques that could be applied to design or upgrade to a WWTP to meet R&R standards (Tchobanglous, et al., 2003):

**Neutralization through acid or base** provides pH adjustment. A number of different chemicals are available and the choice will likely depend on cost and suitability for a particular application. Some common bases used to raise the pH for acidic wastewaters include calcium carbonate, calcium hydroxide (lime), sodium bicarbonate, sodium carbonate (soda ash), and sodium hydroxide (caustic soda). Some common acids used to lower the pH for basic wastewaters include carbonic acid, hydrochloric acid, carbon dioxide, and sulfuric acid.

**Ion exchange** is a process that uses ions on an insoluble exchange material to displace ions of a different species in solution. The most common form of ion exchange is water softening, where sodium ions from a cationic-exchange resin replace calcium and magnesium ions in the treated water to reduce hardness. Naturally-occurring (zeolites) and synthetic resins are available ion-exchange materials and the process can be run in batch or continuous mode. In a batch process, the water is stirred with the exchange material in a reactor until the reaction is complete. The spent exchange material is removed by settling and can usually be regenerated and reused. In a continuous process, the exchange material is in a bed or packed column and the water is passed through it. Typically, the exchange material is in a packed column and the wastewater enters through the top.

**Precipitation** is one of the most common techniques used for removing heavy metals from wastewater. A precipitant is added, usually with lime or caustic soda to bring the wastewater to the minimum pH required for solubility. Common precipitants include sulfide ($S^{2-}$) and hydroxide (OH). Metals that can usually be precipitated as hydroxides or sulfides include arsenic (As), barium (Ba), cadmium (Cd), copper (Cu), mercury (Hg), nickel (Ni), selenium (Se), and zinc (Zn). Residual wastewater concentrations after precipitation depend on temperature, organic content and other constituents in the wastewater. Pilot testing is recommended. This process produces a concentrated solid waste. Appropriate disposal options of the solid waste will depend on local regulations.

**Carbon adsorption** is primarily used to remove refractory organic compounds. For example, aromatic solvents such as benzene, chlorinated aromatics, pesticides, and high molecular weight hydrocarbons such as dyes and gasoline. However, it can also be used to remove residual amounts of inorganic compounds such as sulfides, nitrogen, and heavy metals. Additionally, it removes taste and odor compounds. Carbon adsorption can occur using granular activated carbon (GAC) in a fixed-bed or expanded-bed reactor, or with powdered activated carbon (PAC) through application in a contact basin often with a coagulant (such as polyelectrolyte) to remove the fine PAC particles.

**Coagulation and sedimentation** are processes that use chemical additives to induce coagulation and binding, and settling or sedimentation. Coagulants, such as ferric chloride, polymers, or aluminum salts, have a positive charge which neutralize the negative charges of suspended solids in the wastewater and allow binding of particles (sometimes called 'flocculation'). The process may also require mixing to assist the binding process. As the particles bind, the formation becomes heavier and settles out. The settling is termed sedimentation. The type of coagulant, length of time for settling, and need for mixing is dependent on the particles to be coagulated, temperature, other constituents in the wastewater, and desired wastewater concentrations. Pilot testing is recommended.

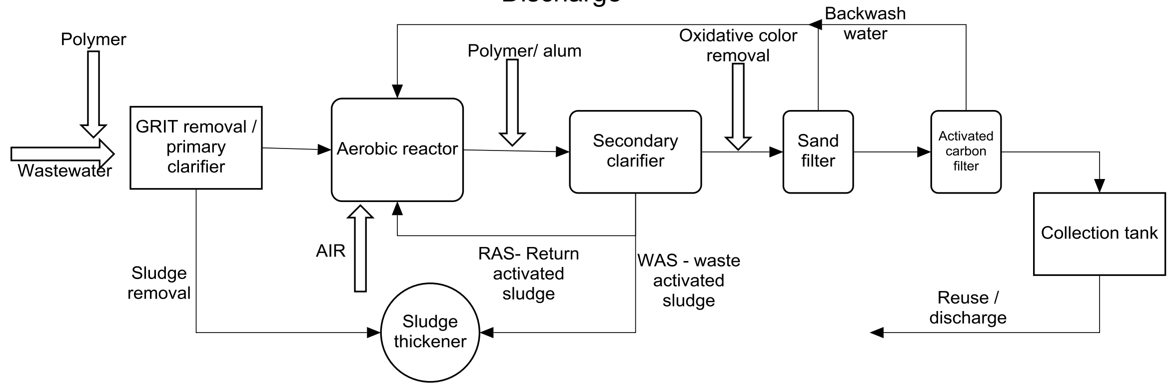
**Reverse osmosis (RO)** is a process that uses pressure to force water through a semi-permeable membrane. The membrane allows water to pass through faster than dissolved salts, so the "permeate" has reduced salinity. The salts rejected by the membrane are carried out in a "concentrate" stream. For a wastewater system, the permeate may consist of as much as 90 percent of the feedwater, in which case the concentrate would be about 10 percent, and the salinity of the concentrate would be almost 10 times as high as the feedwater. Application of this process may require additional pretreatment, such as filtration or chemical addition, to reduce the potential for fouling and/or scaling. In addition, this process creates a concentrated waste stream that will require disposal. Disposal options employed in the US include deep ocean discharge, deep-well injection, evaporation ponds, and land application, among others. Appropriate disposal options will depend on local regulations, and may often require blending with less concentrated streams.

**Nanofiltration** is a variant of reverse osmosis that does not reject the salts as thoroughly. Monovalent ions such as sodium and chloride are rejected poorly (perhaps 50 to 90 percent rejection), while divalent ions, such as hardness and sulfate, are well rejected. For this reason, nanofiltration is sometimes termed membrane softening. Application of this process may require additional pretreatment, such as filtration or chemical addition, to reduce the potential for fouling and/or scaling. In addition, this process creates a concentrated waste stream that will require disposal. Disposal options employed in the US include deep ocean discharge, deep-well injection, evaporation ponds, and land application, among others. Appropriate disposal options will depend on local regulations, and may often require blending with less concentrated streams.

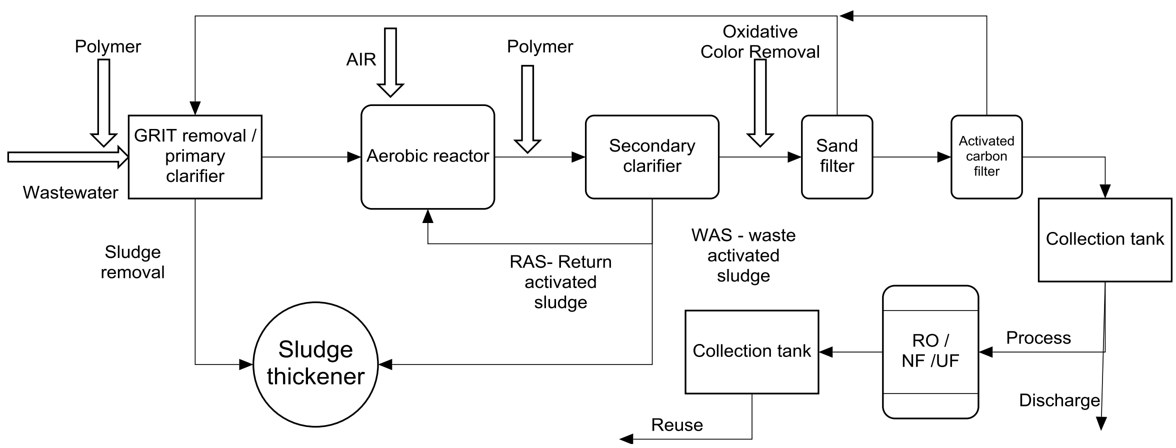
**Electrodialysis reversal (EDR)** is a membrane that uses electrical potential to draw dissolved ions through ion selective membranes. Cation (positive ions) and anion (negative ions) selective membranes are arranged alternately in stacks of up to 600. Water is fed into alternate channels, and a voltage is applied across the stack. The ions are drawn out of the feed channels and into intervening concentrate channels, reducing the salinity of the feedwater and increasing the salinity of the concentrate. EDR has a benefit in wastewater use because water does not go through the membranes, so there is less potential for fouling from the solids typically found in wastewater. In addition, EDR membranes (unlike RO membranes) are chlorine tolerant, which can help reduce biofouling when treating wastewater. Maximum recovery in an EDR system can be as high as 95%. Additional pretreatment may be required for EDR, such as filtration or chemical addition, to reduce the potential for fouling and/or scaling. In addition, this process creates a concentrated waste stream that will require disposal. Disposal options employed in the US include deep ocean discharge, deep-well injection, evaporation ponds, and land application, among others. Appropriate disposal options will depend on local regulations, and may often require blending with less concentrated streams.

**Example WWTP Diagrams:**
The following diagrams depict various WWTP configurations, depending on whether simple or advanced treatment is required and whether full or partial reuse is desired.

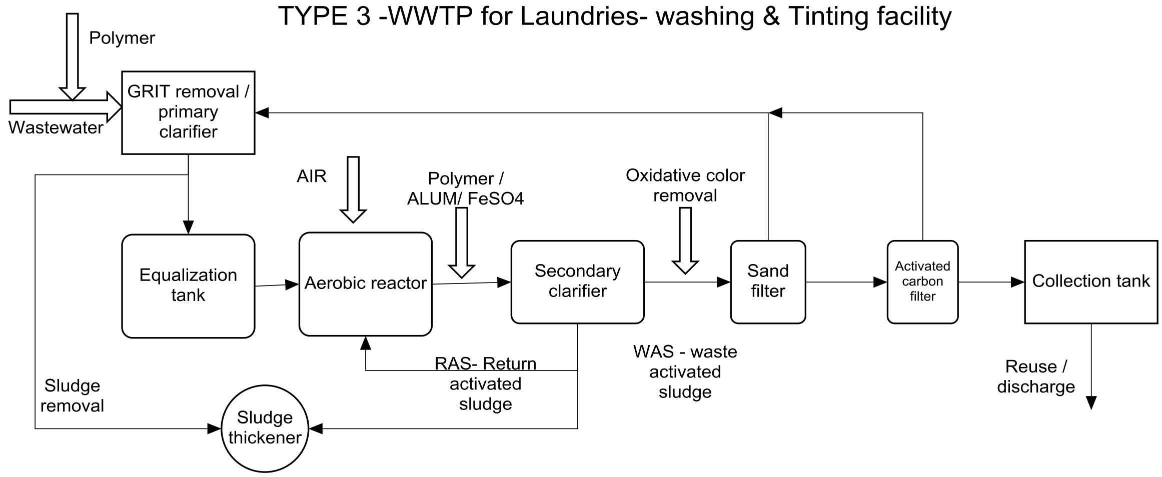
## TYPE1 - Simple WWTP For Laundries - Reuse* / Discharge



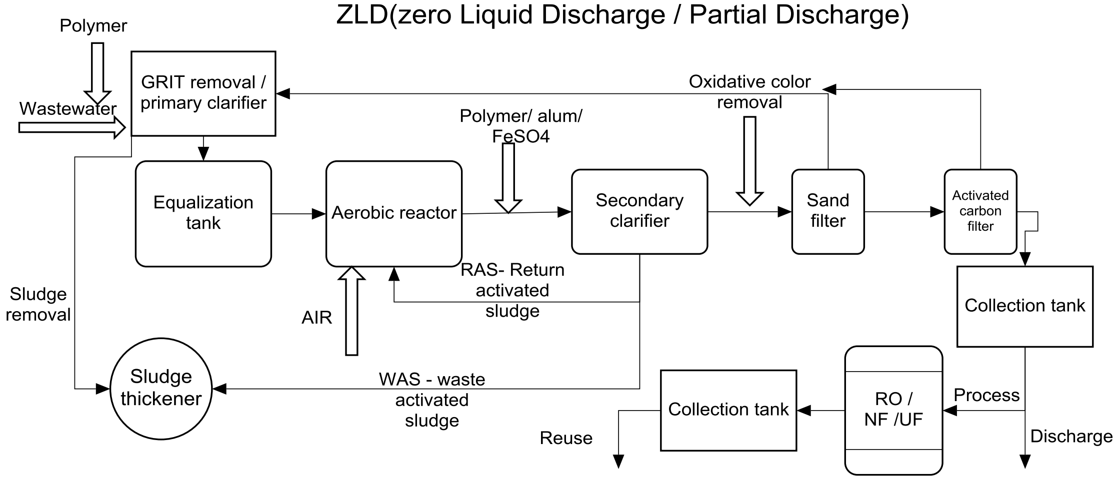

## TYPE 2 -Simple WWTP for Laundries- with ZLD(Zero Liquid Discharge / partial Discharge)



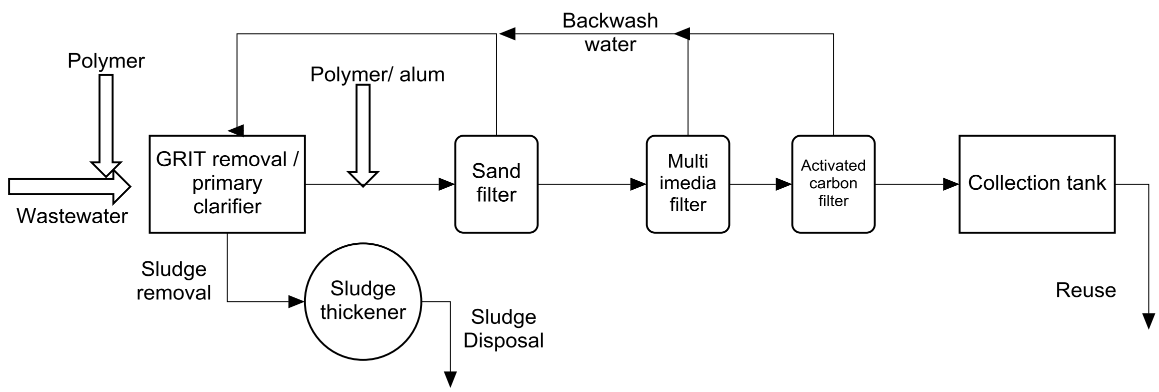

## TYPE 3 -WWTP for Laundries- washing & Tinting facility



TYPE4 -WWTP for Laundries- washing & Tinting facility
ZLD(zero Liquid Discharge / Partial Discharge)




TYPE 5 -Simple WWTP for Laundries with softener application only




## Recycled Water Blending

Alternatively, if a facility does not wish to invest in further treatment of the treated effluent, the water to be recycled can be blended with potable or fresh water to obtain a new stream. The percentage of recycled water versus potable or fresh water is largely dependent on the recycled water quality and the facility's potable or fresh water source water quality. If 20% or more of the blended stream is recycled water, then it is considered part of the R&R program. The blended stream must also meet the LS&Co. reuse standards, as well as all applicable government requirements, in order to be used within the process. Recommendations on how to configure piping and flow meters for blending of recycled water and fresh water can be found in the Implementation Recommendations section above.

The table below provides an example calculation to show how the quality of recycled water can vary depending on the percentage used in the blended water stream. The example assumes a fresh water concentration of 500 mg/L TDS. Since the R&R standard for TDS is 2000 mg/L, if 100% of the blended water is recycled water, then the recycled water TDS concentration can be a maximum of 2000 mg/L. As the percentage of recycled water in the blended stream decreases, the TDS concentration in the recycled water can increase, as long as the fresh water concentration remains the same and the blended water stream TDS concentration is 2000 mg/L or less. Blending water provides opportunities to reuse water even if the treated, undiluted wastewater does not meet the R&R standards. Additionally, blending water could be used to achieve a higher water quality than the R&R standard. This is particularly useful for some of the lighter finishes, as the recycled water may cause quality issues for the product, such as staining, and higher quality water may be required for rinsing.

**CAUTION:** This approach requires an accurate characterization of the fresh water to ensure that water quality parameters in the incoming fresh water do not exceed the R&R limits. For example, the level of naturally occurring iron in fresh water can be higher than that in the recycled water and could cause staining problems. It is recommended that an engineer is utilized to determine what the appropriate blend ratio should be in order to meet R&R standards.

**Example Blending Calculation - TDS (mg/L)**

| Water Type | Fresh Water | Recycled Water | Blended Water |
|---|---|---|---|
| 100% Recycled Water | 500 | 2000 | 2000 |
| 75% Recycled Water | 500 | 2500 | 2000 |
| 50% Recycled Water | 500 | 3500 | 2000 |
| 25% Recycled Water | 500 | 6500 | 2000 |
| **R&R Standard** | | | **2000** |

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# Appendix C

# Impacts of Parameters on Textile Quality, Machinery, and Health

## Impacts of Parameters on Textile Quality, Machinery, and Health

The recycled water must meet the limits identified in Table 1 for many health and environmental reasons, such as the potential impacts on textile quality, machinery, and human health. Potential impacts for each water quality parameter are listed in the following tables. It is important to note that many of the potential health impacts are risks associated with the parameter in drinking water. **The recycled water is NOT to be used for drinking water.** This information has been included **for information only** and to stress the importance that the recycled water should not be connected to a potable water source and that there should be no human contact with the recycled water. For information on testing garments to meet product quality standards, please see the quality testing manual. All products developed using R&R water must meet LS&Co. quality standards and the GER.

### Impact of pH on Textile Quality, Machinery, and Health

| | |
|---|---|
| **Impact on quality parameters** | • pH < 3.00 –Loss in fabric strength (tear strength (ASTM 5034, 1424, 3786)) (Thygesen, et. al, 2007), effect on softness, poor color fastness to rubbing (AATCC 8), allergic to skin.<br>• pH > 9.00 –Poor fabric strength, poor durability of pressing rating (DP rating), poor softness rating, poor color fastness to water , wet rubbing fastness (AATCC8), lab results for color fastness , wet/ dry rubbing fastness inconsistency, poor leveling in direct dyeing/ reactive dyeing / vat dyeing and sulphur dyeing (Oktav Bulut and Akçali, 2013; Fergusson, 2008). |
| **Impact on wet processes** | • Washing – stain marks due to corrosion based metal marks (Shamey and Hussein, 2005)<br>• Dyeing – poor dye yield (Shamey and Hussein, 2005)<br>• Finishing – stain marks and softener breakups<br>– Pipe lines corrosion/damage to metal pipelines, damage to pump valves, damage to gunmetal/stainless steel (314,306 grades) impellers, rubber gaskets & liner in valves and joints, damage to level indicators of the machine (WHO, 2003). |
| **Impact on health** | • Exposure to extreme pH values may result in irritation to the eyes, skin, and mucous membranes.<br>• pH values greater than 11 have been associated with eye irritation and exacerbation of skin disorders<br>• pH values of 10–12.5 have been reported to cause hair fibers to swell.<br>• Gastrointestinal irritation may occur if solutions with high or low pH are ingested.<br>• Ingestion of solutions with pH below 4 has been reported to cause redness and irritation of the eyes, the severity of which increases with decreasing pH.<br>• Ingestion of solutions with pH below 2.5 may cause damage to the epithelium of esophagus (from throat to stomach), which is irreversible.<br>• pH can have an indirect effect on health because it may affect the degree of corrosion of metals and disinfection efficiency of drinking water. (WHO, 2003) |

### Impact of TSS on Textile Quality, Machinery, and Health

| | |
|---|---|
| **Impact on quality parameters** | High TSS gives:<br>• rough finish<br>• poor color fastness home laundering (AATCC 61) (Shamey and Hussein, 2005)<br>• poor color fastness to rubbing (AATCC 8) (Shamey and Hussein, 2005)<br>• inconsistent quality of processing – patchy dyeing in reactive dyeing, Vat dyeing , |

| | |
|---|---|
| | indigo dyeing & poor color in disperse dyeing, staining in dyed material (Günay, 2011) |
| **Impact on wet processes** | • Waterline corrosion inside the pipe line (USDOT, 2011)<br>• Frequent failure in mechanical seals (Grundfos, 2011)<br>• Poor garment finishing (Shore, 1995)<br>• Repeated back wash PSF filter (Dow)<br>• RO Membrane damage (in case of TSS with Amorphous silica) (Nitto and Hydraunautics, 2013) |
| **Impact on health** | • Interfere with effective drinking water treatment, particularly coagulation, filtration, and disinfection.<br>• More oxidizing agent is required to effectively disinfect turbid water.<br>• Presence of suspended solids can positively impact water because they help absorb or make complexes with toxic chemicals, such as pesticides and metals, which make the toxics less available to be absorbed by living organisms. (KDEP, 1996) |

**Impact of TDS on Textile Quality, Machinery, and Health**

| | |
|---|---|
| **Impact on quality parameters** | • Reduced degree of whiteness (New Cloth Market-A)<br>• Loss of tensile strength of the fiber (ASTM 3822) & fabric (ASTM D5034,D 5035, D2261 & D 1424) and "pinhole" damage (Menezes and Choudhari, 2011)<br>• Harsh surface<br>• Uneven softness |
| **Impact on wet processes** | • TDS caused by Ca & Mg ions react with alkali during scouring process to form a waxy substance, which is referred to "lime soap deposits" settles on surface of fabric (Rucker and Smith, 1988)<br>• Re-deposition of dirt and insoluble soap on the fabric being washed, during bleaching using hydrogen peroxide, reduced degree of whiteness (Rucker and Smith, 1988)<br>• Loss of tensile strength of the fiber and "pinhole" damage (Uddin and Atiquzzaman, 2014)<br>• Desizing washing affects solubility of anionic dyes causing them to aggregate or precipitate onto the fibers. They typically remain on the fiber surface as particulate deposits. (Uddin & Atiquzzaman, 2014) (Khalil and Sarkar, 2014) |
| **Impact on health** | • There are no significant health hazards reported for TDS up to 2000 mg/L except the taste of the water changes, due to presence carbonate salts. |

**Impact of BOD on Textile Quality, Machinery, and Health**

| | |
|---|---|
| **Impact on quality parameters** | • There are no known impacts of BOD on quality of fabrics or textile material.<br>• In case of High BOD with phenol, then fastness properties like fastness to home laundering (AATCC61), wet rubbing (AATCC 8) will be affected (Lewin, 2006). |
| **Impact on wet processes** | • There are no known impacts of BOD on wet processing (Ramesh Kumar and Saravanan, 2010). |

| | |
|---|---|
| **Impact on health** | • There are no studies on the health hazards of the BOD, but high BOD values may affect aquatic life. If effluent with high BOD levels is discharged into a stream or river, it will accelerate bacterial growth in the river and consume the oxygen levels in the river and may cause eutrophication. The oxygen may diminish to levels that are lethal for most fish and many aquatic organisms. As the river re-aerates due to atmospheric mixing and as algal photosynthesis adds oxygen to the water, the oxygen levels will slowly increase downstream (Northeast Georgia Regional Development Center, 2001). |

**Impact of Total Hardness on Textile Quality, Machinery, and Health**

| | |
|---|---|
| **Impact on quality parameters** | • Bronziness (Chakraborty, 2014; New Cloth Market-B)<br>• Dye spots/resist spots/stains/blotches/filtering/dark colored areas<br>• Poor washing fastness as per AATCC 61, Poor light fastness (AATCC16) (Park and Shore, 2004) |
| **Impact on wet processes** | • **Desizing/enzymatic finishing of garments** - Deactivate enzymes and makes it in-soluble some size materials like starch and PVA. The enzyme finish of the garments also is affected due to the reduced enzyme activity.<br>• **Scouring** - Combine with soap, precipitate metal-organic acids. Produces yellowing of off-white shades; reduce cleaning efficiency and water absorption.<br>• **Bleaching** - Decompose bleach baths.<br>• **Mercerizing** - Form insoluble metal oxides, reduce absorbency and luster.<br>• **Dyeing** - Combine with dyes changing their shades, in-solubilize dyes, cause stripy looking dyeing, reduce dye diffusion and hence results in poor washing and rubbing fastness. Dusting and white patches appear if the hardness is very high.<br>• **Finishing** - results in poor washing (AATCC 61), poor light fastness (AATCC16) and rubbing fastness (AATCC8). (Park and Shore, 2004) |
| **Impact on health** | • The WHO says that "there does not appear to be any convincing evidence that water hardness causes adverse health effects in humans". In fact, the United States National Research Council has found that hard water can actually serve as a dietary supplement for calcium and magnesium.<br>• Some studies have shown a weak inverse relationship between water hardness and cardiovascular disease in men, up to a level of 170 mg calcium carbonate per liter of water. The WHO has reviewed the evidence and concluded the data was inadequate to allow for a recommendation for a level of hardness. Recommendations have been made for the maximum and minimum levels of calcium (40–80) and magnesium (20–30) in drinking water, and a total hardness expressed as the sum of the calcium and magnesium concentrations of 0.7- 1.54. Other studies have shown weak correlations between cardiovascular health and water hardness |

**Impact of Turbidity on Textile Quality, Machinery, and Health**

| | |
|---|---|
| **Impact on quality parameters** | • May cause dullness in white and light shades.<br>• Cloudy dyeing, haziness in dyeing /dingy looking dyeing. (Park and Shore, 2004) |
| **Impact on wet processes** | • Causes unevenness/silt formation in yarn dyeing, finishing.<br>• Finished fabric may have a dingy look. (Park and Shore, 2004) |
| **Impact on health** | • Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern.<br>• Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne |

| | |
|---|---|
| | disease outbreaks, which have caused significant cases of gastroenteritis throughout the United States and the world.<br>• Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa. The particles of turbidity provide "shelter" for microbes by reducing their exposure to attack by disinfectants. Microbial attachment to particulate material or inert substances in water systems has been documented by several investigators and has been considered to aid in microbe survival. Fortunately, traditional water treatment processes have the ability to effectively remove turbidity when operated properly. (Interior Health, 2006) |

**Impact of Chlorine Residual on Textile Quality, Machinery, and Health**

| | |
|---|---|
| **Impact on quality parameters** | • Streak marks<br>• Localized bleaching marks (Perkins, et al., 1995)<br>• Poor color light fastness AATCC 16, (Perenich, et al., 1991) |
| **Impact on wet processes** | • Dyeing (Perkins, et al., 1995)<br>• Corrosion of machines (THIES GmbH & Co. KG-Coesfeld, 2002)<br>• Presence of AOX<br>• Impact on effluent and effluent treatment. |
| **Impact on health** | • In humans and animals exposed to chlorine in drinking-water, no specific adverse treatment-related effects have been observed.<br>• IARC has classified hypochlorite in Group 3 (WHO, 2008) |

**Impact of Iron on Textile Quality, Machinery, and Health**

| | |
|---|---|
| **Impact on quality parameters** | • Stains in fabric with catalytic degradation<br>• Pin holes in white fabric<br>• reduction in fabric tear strength (ASTM 5034, 1424, 3786)<br>• dullness in dyed fabric, poor lightfastness (AATCC16) |
| **Impact on wet processes** | • In dyeing operations, iron may form complexes with acid dyes, rendering them inactive and resulting in discoloration, color changes and dulling of shades.<br>• The presence of iron in concentrations above 1.0 during bleaching operations produces a yellowing effect. |
| **Impact on health** | • As a precaution against storage in the body of excessive iron, in 1983 JECFA established a PMTDI (***Provisional Maximum Tolerable Daily Intake***) of 0.8 mg/kg of body weight, which applies to iron from all sources except for iron oxides used as coloring agents and iron supplements taken during pregnancy and lactation or for specific clinical requirements.<br>• An allocation of 10% of this PMTDI to drinking-water gives a value of about 2, which does not present a hazard to health.<br>• The taste and appearance of drinking-water will usually be affected below this level.<br>• No guideline value for iron in drinking-water is proposed. (WHO, 2008) |

**Impact of AOX on Textile Quality, Machinery, and Health**

| | |
|---|---|
| **Impact on quality parameters** | • There are no reported impacts of AOX on quality parameters on finished textile quality. (CES) |
| **Impact on wet processes** | • There are no reported problems by the dissolved oxygen, but this will have an effect on the treatment plants. The behavior of Dissolved organic Compounds during Soil |

| | |
|---|---|
| | Aquifer Treatments of tertiary wastewater demonstrates that refractory compounds are partially degraded due to AOX (Pi, et al., 2004). |
| **Impact on health** | • Some AOXs are toxic to fish and aquatic organisms - even at low concentrations. Many are persistent and have a tendency to accumulate in the environment which causes concern at a regional (if not global) level.<br>• Exposure of AOXs to humans can occur through eating contaminated food - and the fact that AOXs can concentrate up the food chain means that humans could be exposed to dangerous levels. The type and severity of adverse effects depend on the AOX in question. Some (such as dioxins) are known to be very toxic. In the UK (including Scotland) releases of AOX are controlled through the Pollution Prevention and Control (PPC) regulations. Chlorinated AOXs have been on the European Commission's "black list" of toxic substances since 1976. (Drewes and Jekel, 1998) |

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# Appendix D

# Wastewater Treatment Sampling Guidance

## Sampling Guidelines

### Guideline Tables and Diagrams

The sampling guidelines section includes information for each R&R water quality parameter. A guidelines table for each parameter includes important information, as listed below. While it is only required to provide documentation of sampling twice per year, it is recommended that parameters are monitored internally more frequently. This frequency ranges from once per shift to once per week, and varies by parameter.

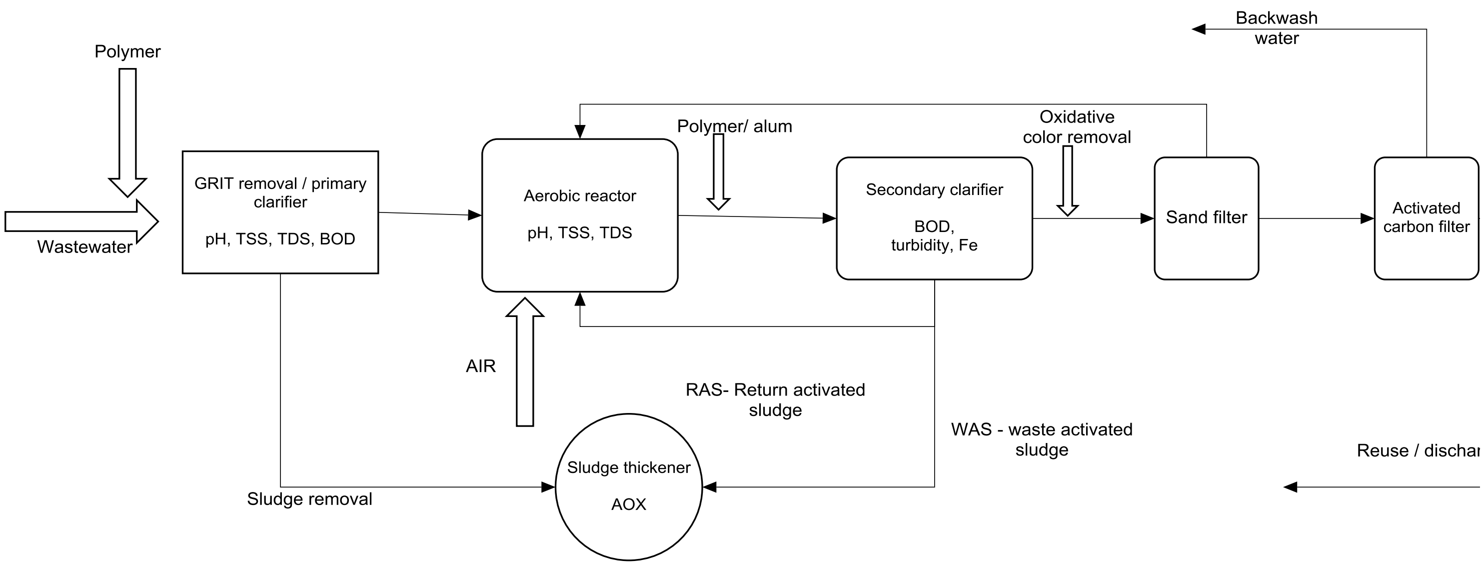
- Guideline tables include the following information:
  - Parameter limit (as found in Table 1)
  - Recommended frequency of internal testing
  - Instrumentation to be used for measurement
  - Recommendations for achieving the parameter for recycled water
  - Precautions to follow for safety and quality

A reference table is included for some parameters, which summarizes interim measurements expected under average operational conditions that likely allow the parameter limit to be satisfied at the end of treatment. This serves as an example and actual operation may need to be adjusted to achieve the parameter limit.

Each WWTP is unique and may consist of different treatment processes. As an example, two schematic diagrams are included to indicate recommended sampling points, which suggest various points in the treatment process that certain parameters should be tested in order to achieve compliance of the recycled water stream. There is a simple WWTP for when there is no high TDS discharge activity and an advanced WWTP for when there is high TDS discharge activity. It is possible for both WWTP schematics to become zero liquid discharge (ZLD) plants if 100% of the treated wastewater can be recycled for use within the facility and all other waste streams disposed of within the facility.

- Two WWTP schematic diagrams
  - Simple WWTP: processes for the minimal treatment, where there is no high TDS discharge activity (like dyeing (reactive, VAT, ETC))
    - Collection and primary clarifier- used for collecting the wastewater including grit removal
    - Aerobic reactor (aerobic digester/aeration tank /biological reactor, etc)
    - Secondary clarifier
      - Sludge removal (sludge thickener)
    - Sand filter (pressurized sand filter)
    - Activated carbon filter (ACF)
    - Collection tank – for process water
  - Advanced WWTP: processes for the minimal treatment, where there is high TDS discharge activity (like dyeing (reactive, VAT, ETC))
    - Equalization tank
    - Aerobic reactor (aerobic digester/ aeration tank /biological reactor, etc)
    - Secondary clarifier
      - Sludge removal (sludge thickener)
    - Sand filter (pressurized sand filter)
    - Activated carbon filter (ACF)
    - Collection tank – for process water
    - Reverse osmosis (RO), nanofiltration (NF), or ultrafiltration (UF)

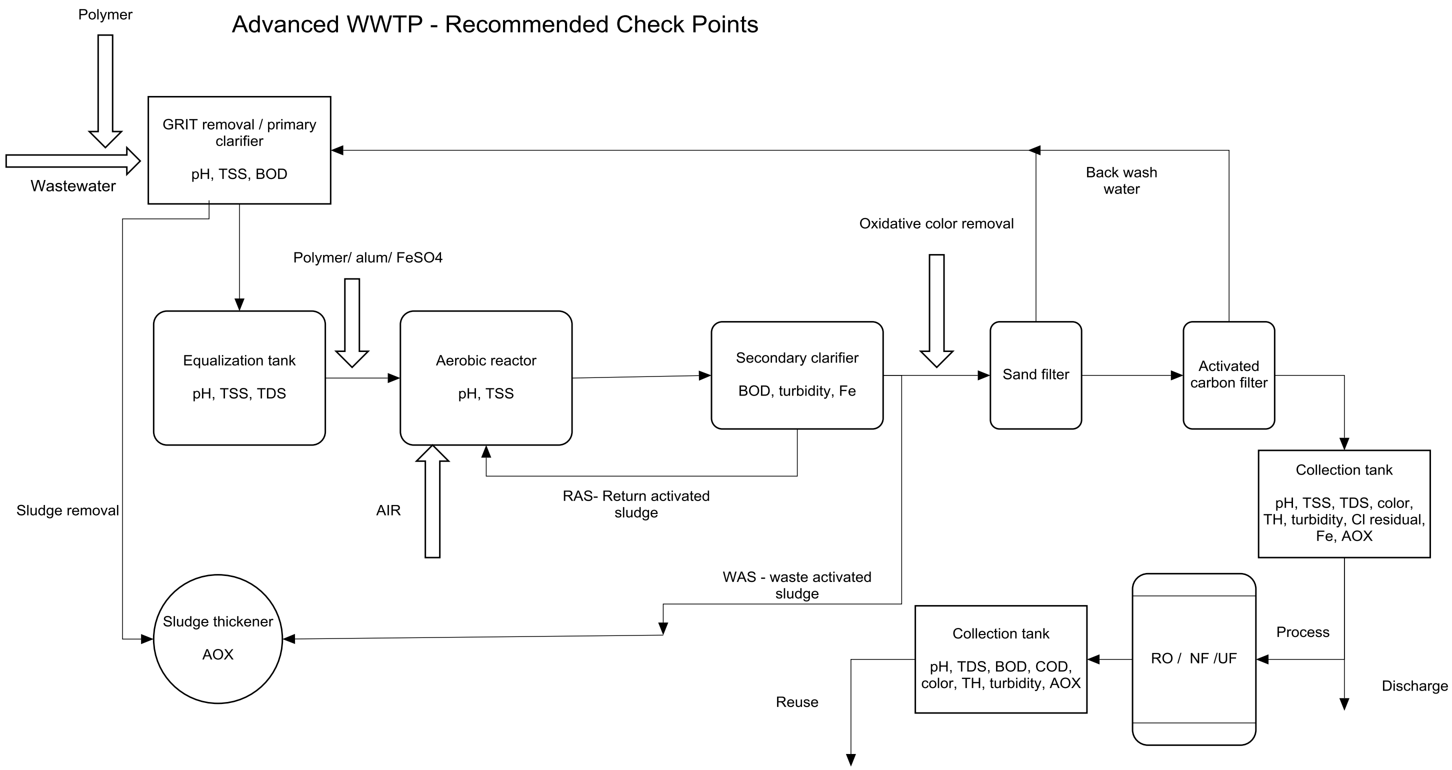
## Simple WWTP - Recommended Check Points




This table summarizes the information depicted on the simple WWTP diagram.

| Treatment Process | Recommended Parameters to Sample |
|---|---|
| Grit Removal/Primary Clarifier | pH, TSS, TDS, BOD |
| Aerobic Reactor | pH, TSS, TDS |
| Secondary Clarifier | BOD, turbidity, Fe |
| Collection Tank | pH, TSS, TDS, BOD, color, TH, turbidity, Cl residual, Fe, AOX |
| Sludge Thickener | AOX |

Advanced WWTP - Recommended Check Points




This table summarizes the information depicted on the advanced WWTP diagram.

| **Treatment Process** | **Recommended Parameters to Sample** |
|---|---|
| Grit Removal/Primary Clarifier | pH, TSS, BOD |
| Equalization Tank | pH, TSS, TDS |
| Aerobic Reactor | pH, TSS |
| Secondary Clarifier | BOD, turbidity, Fe |
| Collection Tank (prior to RO/NF/UF) | pH, TSS, TDS, color, TH, turbidity, Cl residual, Fe, AOX |
| Collection Tank (after RO/NF/UF) | pH, TDS, BOD, color, TH, turbidity, AOX |
| Sludge Thickener | AOX |

**Sampling Guidelines for pH**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **6.0 - 9.0** | **6.0 - 9.0** | **6.0 - 9.0** | **6.0 - 9.0** |
| **Recommended frequency of tests** | **Once in a shift (at least) – three times a day** | | |
| **Instrumentation** | **Quick tests – pH papers/ pH meters**<br>**Analysis** - SM 2550B or ISO 10523 | | |
| **Test paper /instrument Product code / photo** | **1.09535.0001 (Merck)** |  |  |
| **How to achieve the parameter in WWTP process** | The pH of water can be adjusted high and low by the addition of an alkali or an acid respectively. Acidic reagents commonly used are carbon dioxide (a gas which forms carbonic acid in water), hydrochloric acid, nitric, acetic acid or sulphuric acid. The reagent is usually added in dilute form using a dosing pump controlled by a pH monitor.<br><br>**<u>Precautions</u> –**<br>The adjustment of pH in water will inevitably increase the salinity of the water through the addition of ions such as sodium, carbonate, hydroxyl, sulphate or chloride. Reagents should be chosen to minimize secondary effects. For certain purposes, the pH of the water will need to be stabilized to within a chosen range by the addition of buffering reagents. Sodium acetate / acetic acid buffer | | |

| LIMITS OF ACHIEVABILITY * - pH | Inlet | Outlet |
|---|---|---|
| Primary – washing | 8-9 | 7-8 |
| Primary – dyeing | 9-10 | 7-8 |
| Equalization tank | 7-10 | 7-8 |
| Aeration tank | 7-8 | 7-8 |
| Secondary clarifier | Collection tank | 7-8 |

**Sampling Guidelines for Total Suspended Solids (TSS)**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **10** | **30** | **100** | **30** |
| **Recommended frequency of tests** | **Once in a shift (at least) – three times a day** | | |
| **Instrumentation** | **Quick tests – filter paper / weighing balance**<br>**Analysis** - SM 2540D or ISO 11923 | | |
| **Test paper /instrument Product code / photo** | **Filter paper and balance** | |  |
| **How to achieve the parameter in WWTP process** | Removal of suspended solids normally requires an effective coagulation and flocculation process, followed by deep-bed or multimedia filtration as the particles involved are usually colloidal at this stage.<br>Coagulants like aluminum sulphate or ferric chloride are conventionally used, with small dose of polyelectrolytes added to assist in flocculation. This small dose of polyelectrolytes may be | | |

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| | sufficient to promote flocculation of the particles for removal by settlement and filtration. Polyelectrolytes are chosen for the application on the basis of jar tests.<br>Multimedia filters of anthracite, garnet and silica sand are commonly used, although there is a growing tendency to use membrane processes such as microfiltration or ultrafiltration in more critical applications.<br>**Precautions –**<br>The processes require careful design and skilled monitoring and control. Filter backwash water may cause disposal difficulties. |

| LIMITS OF ACHIEVABILITY * - TSS | Inlet % | Outlet - % |
|---|---|---|
| Primary – washing | X | ( X – 85% )% |
| Primary – dyeing | X | ( X – 75% )% |
| Equalization tank | X | ( X – 10 % )% |
| Aeration tank | X | ( X – 90 % )% |
| Secondary clarifier | X | ( X – 90 % )% |
| PSF & ACF | X | ( X – 99 % )% |
| Collection tank | X | X |

**Sampling Guidelines for Total Dissolved Solids (TDS)**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **2000** | **1000** | **500** | **NL** |
| **Recommended frequency of tests** | **Once in a shift (at least) – three times a day** | | |
| **Instrumentation** | **Quick tests – filter paper / weighing balance**<br>**Analysis -** USEPA 160.1 or SM 2540C | | |
| **Test paper /instrument Product code / photo** |   | **Item# 561683 –Aqua Check** |  |
| **How to achieve the parameter in WWTP process** | Although some salts, such as those of calcium, magnesium, sulphate and certain heavy metals can be removed by chemical precipitation, most of the inorganic salts dissolved in water can only be removed by evaporative crystallization or by highly sophisticated physical chemical separation technologies. Desalination technologies used for reducing the TDS in water are selected for their cost effectiveness in treating different ranges of TDS.<br>1) De-Mineralization in a mixed-bed ion exchange column for the feed TDS concentration does not exceed 2000.<br>2) Ion exchange processes are also used for the production of ultrapure water.<br>3) Membrane processes such as reverse osmosis or electro-dialysis is applied where the TDS concentration is in the range of 2000 - 3500.<br>4) Distillation / evaporation is cost effective where the TDS Concentration exceeds approximately 10000.<br>5) Agitated thin film dryer and evaporators are the latest development for TDS concentration exceeds approximately 10000. | | |

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| | **Precautions** – All large-scale processes require high levels of design, operation and maintenance skills. Further, all processes produce a concentrated waste stream of salts removed from the water and can cause disposal difficulties. The choice of an appropriate treatment technology depends on many factors and some processes may cause corrosion and Material of construction should be properly selected. Expert advice should be sought when selecting a treatment process. |

| LIMITS OF ACHIEVABILITY * - TDS | Inlet % | Outlet - % |
|---|---|---|
| Primary – washing | X | ( X – 15% )% |
| Primary – dyeing | X | ( X – 15% )% |
| Equalization tank | X | ( X – 5 % )% |
| Aeration tank | X | ( X – 5 % )% |
| Secondary clarifier | X | ( X – 5 % )% |
| PSF & ACF | X | (X – 5% ) % |
| Membrane process/ distillations | X | (X-98%) % |

**Sampling Guidelines for Biochemical Oxygen Demand (BOD)**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **10** | **30** | **10** | **30** |
| **Recommended frequency of tests** | **One time daily ( minimum) ( takes five days to complete analysis)** | | |
| **Instrumentation** | **Quick tests – biochemical oxygen demand (BOD) biosensor with a novel microbial membrane/ LDO technology by Hach to measure BOD**<br>**Analysis** - SM 5210 or ISO 5815-1, -2 | | |
| **Test paper /instrument Product code / photo** | **MACHEREY-NAGEL GmbH & Co. KG** |  |  |
| **How to achieve the parameter in WWTP process** | The Secondary treatment is carried out to reduce BOD, phenol and oil contents in the wastewater color and some extent COD. This can be biologically done with microorganisms under aerobic or anaerobic conditions.<br>Aerated lagoons, trickling filter and activated sludge systems are among the aerobic system used in the secondary treatment. Anaerobic treatment is mainly used to stabilize the generated sludge.<br>Aerated lagoons are one of the commonly used biological treatment processes. This consists of a large holding tank lined with rubber or polythene and the wastewater from primary treatment is aerated for about 2-6 days and the formed sludge is removed.<br>Aeration tank with activated sludge process, after equalization tank is used to reduce the BOD levels. The BOD removal efficiency is up to 99% and the phosphorous removal is 15-25% in primary, equalization, aeration tank and secondary clarified type of setup. | | |

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| | **<u>Precautions</u>** –<br>1) In case of the biological treatment where bacteria culture is present after the equalization tank as the first process, care needs to be taken to ensure that the parameters such as temperature and pH need to be maintained below the bacteria inhibition parameters.<br>2) Care also need to be taken to ensure that the bacteria inhibition chemicals such as antimicrobial finishes, chemicals with very low EC 50 values (between 0.1-10) should be avoided to enter directly in to the process water without dilution.<br>3) For plants with washing operations only, may have a simple primary treatment, aeration and PSF & ACF filter. In this case TSS and TDS of the product water need to be tested before using for processing. A better blower with adequate aeration capacity at the aeration tank many reduce the total TSS, COD & BOD close to norms level. A well-controlled operation with proper checks gives better reusable water. |

| LIMITS OF ACHIEVABILITY * - BOD | Inlet % | Outlet - % |
|---|---|---|
| Primary – washing* | X | ( X – 90% )% |
| Primary – dyeing | X | ( X – 75% )% |
| Equalization tank | | |
| Aeration tank | X | ( X – 90 % )% |
| Secondary clarifier | X | ( X – 66 % )% |
| PSF & ACF | X | ( X – 99 % )% |
| Collection tank | X | X |

**(USEPA, 2002)**

**Sampling Guidelines for Color**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **5 Hazens** | **NL** | **NL** | **40 Hazens** |
| **Recommended frequency of tests** | **Once in a shift (at least) – three times a day** | | |
| **Instrumentation** | Quick tests – spectrophotometrically (The standard unit of color measurement is the Hazen unit (HU).) or using a visual comparator- (True color is often quoted as True Color Units, or TCU) however, the numerical values are identical.)<br>Analysis - USEPA 110.1 or SM 2120E | | |
| **Test paper /instrument Product code / photo** | |  | |
| **How to achieve the parameter in WWTP process** | For the residual concentrations which are marginally above specified levels ( more than 5 Hazens), the treatment methods include:<br>1. Oxidation (example Chlorination), followed by an activated carbon filtration step may be beneficial.<br>2. Membrane processes (Reverse osmosis/ Nanofiltration). | | |

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| | 3. Color removal is a complete integrated treatment process involving, pretreatment, activated sludge process, secondary clarifier and tertiary clarifier, if required with oxidation.<br><br>**<u>Precautions</u> –**<br>1. In many cases, a combination of treatment processes will be needed to achieve the water quality required. The strong oxidizing agents mentioned above are hazardous if handled carelessly. |

- *Average Hazens in Tap water used (Brandon, et al., 1978) – measure in Pt-Co scale which is similar to Hazen scale (ASTM 1209)*

| LIMITS OF ACHIEVABILITY * - Color | Inlet % | Outlet - % |
|---|---|---|
| Primary – washing* | X | ( X – 10% )% |
| Primary – dyeing | X | ( X – 15% )% |
| Equalization tank | | |
| Aeration tank | X | ( X – 81 % )% |
| Secondary clarifier | X | ( X – 89 % )% |
| PSF & ACF | X | ( X – 70 % )% |
| Collection tank | X | X |

**Sampling Guidelines for Total Hardness (TH)**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **90 mg/L** | **NL** | **130 mg/ l** | **NL** |
| **Recommended frequency of tests** | **Once in a shift (at least) – three times a day** | | |
| **Instrumentation** | **Quick tests – test papers**<br>**Analysis** - USEPA 130 or SM 2340 | | |
| **Test paper /instrument Product code / photo** |  | |  |
| **How to achieve the parameter in WWTP process** | Processes routinely employed in the treatment for water hardness are<br>a.) Base exchange softening ( resin based ion exchange) to replace the calcium and magnesium in the water with non-hardness forming sodium in Ion-exchange columns and regenerated with a sodium chloride brine.<br><br>**<u>Precautions</u> –**<br>The process usually needs to be closely monitored because the consequences of incomplete softening can be severe.<br>a.) De-Mineralization in mixed bed ion exchange columns are used to remove all hardness-forming ions where particularly low salinity water is required.<br>b.) Desalination techniques like membrane (RO, NF, UF) treatment or distillation are also employed. However, problems of scaling may occur due to the hardness forming salts and impair proper functioning of the equipment.<br>c.) All the processes need skilled operation and control. They produce a | | |

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| | concentrated waste stream which may cause disposal difficulties. |

**Sampling Guidelines for Turbidity**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **2 NTU** | **NL** | **NL** | **NL** |
| **Recommended frequency of tests** | **One time daily ( minimum)** | | |
| **Instrumentation** | **Quick tests – Tintometer / photometric analyzer**<br>**Analysis -** USEPA 180.1 or SM 2130B / ISO 7027 | | |
| **Test paper /instrument Product code / photo** | |  |  |
| **How to achieve the parameter in WWTP process** | Removal of turbidity normally requires an effective coagulation and flocculation process followed by deep-bed or multimedia filtration, since the particles involved are usually colloidal in nature. Coagulants like aluminium sulphate or ferric chloride are conventionally used, with small doses of polyelectrolytes added to assist in flocculation. In many water qualities, small doses of polyelectrolytes alone may be sufficient to promote flocculation of the particles for removal by settlement and filtration. Polyelectrolytes are chosen for the application on the basis of jar tests. Multimedia filters of anthracite, garnet and silica sand are commonly used, although there is a growing tendency to use membrane processes such as microfiltration or ultrafiltration in more critical applications.<br><br>**<u>Precautions</u> –**<br>The processes involved require careful design and skilled monitoring and control. Filter backwash water may cause disposal difficulties. | | |

**Sampling Guidelines for Chlorine Residual**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **1 -4 mg/ l** | **1-2 mg/ l** | **1-4 mg/ l** | **1-4 mg /l** |
| **Recommended frequency of tests** | **One time daily ( minimum)** | | |
| **Instrumentation** | **Quick tests – chlorine analyzer**<br>**Analysis -** USEPA 330.1 or SM 4500-ClD / ISO 7393-3 | | |
| **Test paper /instrument Product code / photo** | **91317 - MACHEREY-NAGEL GmbH & Co. KG** |  |  |

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| **How to achieve the parameter in WWTP process** | 1. Free chlorine is normally removed through granular activated carbon media filter by adsorption.<br><br>**<u>Precautions</u> –**<br>The selection of activated carbon grade based on the activity level i.e. surface area. Activity level is often expressed as total surface area per unit weight, usually in square meters per gram. This total exposed surface will typically be in the range of 600-1200 $m^2/g$. Toward the higher end of this range, one might better visualize one pound, about a quart in volume, of granular activated carbon with a total surface area of 4046.86 $m^2$ |

**Sampling Guidelines for Iron**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
|---|---|---|---|
| **0.1 mg /l** | **5 mg /l** | **0.5 mg /l** | **0.3 mg /l** |
| **Recommended frequency of tests** | **One time daily ( minimum)** | | |
| **Instrumentation** | **Quick tests – Iron test papers/ analyzers**<br>**Analysis -** USEPA 236.2 or SM 3500 / ISO 15586 / ISO 11885 | | |
| **Test paper /instrument Product code / photo** | |  |  |
| **How to achieve the parameter in WWTP process** | 1. Iron is commonly removed from water using an oxidizing process which converts the iron into an insoluble oxide removable by filtration. The following treatment approaches are commonly used,<br>1) Neutralization with acids<br>2) Aerated by devices such as fountains, cascades or mechanical aeration followed by settlements.<br>3) Chemical oxidization by dosing with chlorine / hydrogen peroxide / ozone or other strong oxidants. Chlorine is commonly used as the chemical oxidant. Post-treatment of high level residual chlorine should be accurate as this can interfere with the quality of the water.<br><br>**<u>Precautions</u> –**<br>For the optimization of treatment processes it is important to determine both the total and dissolved iron species and their relative concentrations.<br>Removal of iron using aeration techniques, followed by settlement of iron oxide particles needs to be closely controlled and monitored because the consequences incomplete treatment may be severe. | | |

**Sampling Guidelines for Dissolved Oxygen (DO)**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
| --- | --- | --- | --- |
| **2.5- 5 mg /l (recommended)** | **N/A** | **N/A** | **N/A** |
| **Recommended frequency of tests** | **Three time daily ( minimum) / once in two hours ( recommended)** | | |
| **Instrumentation** | **Quick tests – DO analyzers**<br>**Analysis – Winkler method by titration.** | | |
| **Test paper /instrument Product code / photo** | |  |  |
| **How to achieve the parameter in WWTP process** | Increasing the aeration tank's blower activity, can increase the Dissolved Oxygen in water. Ionization is alternative best method.<br><br>**<u>Precautions</u>** – In case of the biological treatment where bacteria culture is present after the equalization tank as the first process, care need to be taken to ensure that the parameters such as temperature, pH need to be maintained below the bacteria inhibition parameters. Care also need to be taken to ensure that the bacteria inhibition chemicals such as antimicrobial finishes, chemicals with very low EC 50 values (between 0.1-10) should be avoided to entre directly in to the process water without dilution. | | |

**Sampling Guidelines for Adsorbable Organic Halides (AOX)**

| Facility Process (Laundry) | Landscape Irrigation | Cooling Towers | Sanitary Toilets |
| --- | --- | --- | --- |
| **0.5** | **N/A** | **N/A** | **N/A** |
| **Recommended frequency of tests** | **once in a day** | | |
| **Instrumentation** | **Quick tests** - Microcoulometry is the reference method for the determination of total organic halogen content in AOX<br>**Analysis** - Method 1650 rev C EPA or ISO 9562:2004 | | |
| **Test paper /instrument Product code / photo** |  | | |
| **How to achieve the parameter in WWTP process** | AOX is removed with aeration followed by activated sludge process or can be oxidized by chemical treatment (advanced oxidation process / ozone treatment).The major AOX removal happens in Primary and secondary clarifier. | | |

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| | **<u>Precautions</u>** – <br>The AOX removal mainly depends on the removal of Dissolved Organic Compounds. (DOC) from wastewater. Poorly degradable DOC does function as a co-substrate in AOX-co-metabolism and it is likely that further AOX-degradation will not occur until the concentration of DOC are not reduced. |

## References


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