INDITEX

# Supporting Guide for Sustainable Manufacturing for Green to Wear products

Environmental Sustainability Standard for Pre-treatment, Dyeing, Printing, Finishing and Washing Mills

Cover photo from Arup

August 2015

INDITEX
www.inditex.com

# Introduction and objective

## Inditex, the sustainability of the Supply chain and the Green to Wear standard

As part of the 2011-2015 Inditex Sustainable Strategic Plan, the company has continued making progress to integrate sustainability in the Group's supply chain.

The Inditex Code of Conduct for Manufacturing, reinforced the monitoring of the supply chain, strengthening, also, Inditex's specific environmental code (the Green Code) defining minimum requirements to be complied by suppliers.

Among other initiatives Inditex is working on the goal of 'zero discharge' of hazardous chemicals linked to manufacturing processes by 1 January 2020 including evaluation and advise to a hundred suppliers on the use and management of water.

Inditex is also supporting the cleaner production projects in Bangladesh, PaCT, working with the IFC and other partners to improve the water and energy use of Washing/Dyeing/ Finishing processes of mills.

Based on these audits, benchmarking studies, and collaboration with institutions as well as the experience of organization such as Natural Resources Defense Council, Inditex has created **Green to Wear (GtW)**. GtW is Inditex's own environmental methodology and evaluation system to categorize suppliers based on their environmental performance on a scale A to D (see Annex I). The GtW labeling process informs Inditex internal buyers while helping suppliers to improve the sustainability of their textile wet processes.

## Objective of the guide

Inditex has been carrying out an ambitious program of environmental audits with focus on textile mills management process, water and energy consumption, waste and wastewater. The tool used for communication with the mills audited and the gathering of information is a detailed questionnaire covering all the mentioned environmental areas. This guide explain the concepts covered in these auditing questionnaires.

The first objective of the guide is to help the auditors comprehend what systems will be found on site, their main characteristics, purpose and any features to inspect. This guide is focused on the main energy generation and distribution systems as well as wastewater treatments found in the wet processes of textile mills. Auditors are trained in the textile process but could be non-experts in energy and water discharge treatment aspects of the mills. The purpose is to provide them with basic information on the energy and water systems to be audited and background of the questions included in the questionnaire. Thus, once these environmental aspects are explained, auditors will find information about the related GTW indicators and guidelines on how to check them on site.

The second objective is to highlight some of the best practices already identified in the wet processes of mills. The outcome of the energy and water consumption audits should be recommendations on system enhancements and general management good practices.

The third objective is to provide justification and background to the evaluation and labelling process that Inditex is carrying out.

Due to the variety of processes carried out in each factory and the subsequent wide disparity of energy and water consumption data for the different factories audited and specially the difficulty to collect accurate and reliable information it does not seem prudent at this stage to establish quantitative labelling thresholds. Alternatively qualitative assessment, descriptions of good practices and a number of key indicators and proxies are identified in GtW allowing Inditex to categorize (A to D) the suppliers based on their water and energy environmental performance.

GtW is also aiming to provide guidance to the customers about products manufactured with less environmental impact processes. Products manufactured in suppliers ranked by GtW as an 'A' or 'B' and using Best Available Technologies (BAT) can be labeled A+ or B+ respectively as 'less environmental impact products'.

## Who is it for?

This guide has been designed for the auditor carrying out the assessments of textile factories. All the systems and equipment types found within the questionnaire have been described in a simple manner, such that energy and water treatment non-experts auditors can obtain a basic understanding of each equipment or system purpose and its main components, as well as comprehend the purpose of each question included in the questionnaire.

## What part of the textile industry supply chain?

The questionnaire and guide is oriented towards energy, water treatment systems and equipment found in the textile mills's wet processes (mainly Pre-treatment, Dyeing, Printing, Finishing and Washing). The guide focuses on the supply and distribution of energy (in the form of electricity, steam, compressed air and hot water) as well as the water treatment plan (ETP) and associated equipment.

The guide does not provide guidance of the textile process and machinery. However, parts of the questionnaire identify key process and parameters also influencing water and energy performance such as the liquor ratio (identified as key parameter). The audits' questionnaire also allows for gathering and recognition of other good practice influencing energy such as wash off exchangers, humidity analysers in stenters or load adapted laundry programs as well as BATs such as Ozone for garment finishing.

# Supporting Guide for Sustainable Manufacturing for Green to Wear products

Environmental Sustainability Standard
for Pre-treatment, Dyeing, Printing, Finishing
and Washing Mills

Green to Wear · Supporting guide

# Energy and water use assessment

# Energy and water use assessment

Green to Wear
Supporting guide

# Energy and water consumption

The term 'annual energy consumption' refers in the questionnaire to the total energy use in a factory over a period of a year, and it generally includes more than one energy source, or fuel type. For example, a facility can consume energy from grid electricity, diesel, natural gas, on-site renewable, etc. Common energy sources frequent in the textile factories audited are discussed further below.

## Energy sources

### Fossil fuels

Fossil fuels are a type of non renewable energy source; they are formed from the remains of living organisms by the effect of heat and pressure through millions of years. The available quantity on the earth is limited and their use produces green house gas emissions.

- **Natural gas:** Natural gas is a nearly odourless, colourless gas that accumulates in the upper parts of oil and gas reservoirs. The composition of natural gas depends on its geographical source, but it consists predominantly of methane. It is generally delivered by pipeline or in gas cylinders. For safety purposes, odorants (e.g. mercaptans) are added to natural gas to give it detectable smell.

Heating values for natural gases vary from 34 to 45 MJ/m³. Natural gas is used in some of the textile factories audited also to produce Electricity. Heating values for natural gases vary from 34 to 45 MJ/m³.

- **Diesel/Fuel oil:** Fuel oils are refinery products obtained from crude petroleum. Fuel oils are broadly classified as

distillate fuel oils (lighter oils) and residual fuel oils (heavier oils). Distillate fuel oils, such as diesel, are the ones commonly used in industrial applications. It is generally delivered by fuel trucks into fuel tanks. Heating values for fuel oils vary from 25 to 40 MJ/l.

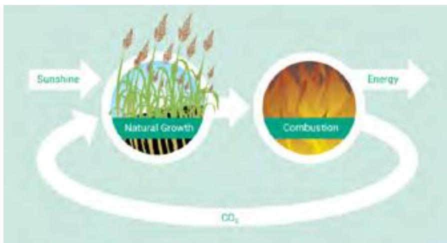
- **Coal:** Coal is a solid fossil fuel extracted from open pit or underground mines. Chemically, coal consists of carbon, hydrogen, oxygen, nitrogen, sulfur, and a mineral residue, ash. The characteristics of coal that determine classification and suitability for given applications are the proportions of: volatile matter, fixed carbon, moisture, sulfur and ash. Heating values for coal vary from 20 to 30 MJ/kg. Coal is found in the textile factories audited mainly in China.

### Renewable Energy

Renewable energy refers to energy sources which are naturally replenished on a human timescale. They do not get exhausted, unlike energy from fossil fuels. The renewable energy sources typically found in factories are:

- **Biomass:** Biomass is biological material from living or recently living organisms. The main recommended sustainable biomass sources are:

  - Energy crops that do not compete with food crops for land; high yield crops grown specifically for energy applications
  - Agricultural residues: residues from agriculture harvesting or processing, such as wheat straw or corn stover
  - Sustainably-harvested wood and forest residues
  - Industrial waste such as waste from food or wood processing




Biomass consists of organic, plant-based material that throughout its lifetime absorbs carbon dioxide from the atmosphere to convert into carbohydrates, through the process of photosynthesis. When biomass is burned, the trapped carbon is released back into the atmosphere as carbon dioxide. Emissions are taken up again by subsequent plant growth within a relatively short time, thereby maintaining a closed carbon cycle with no net increase in atmospheric carbon dioxide levels. For this reason biomass is considered both a renewable resource as well as a carbon-neutral resource. However, the embodied energy and carbon of manufacturing and transporting some types biomass needs to be considered.

In stark contrast, the burning of fossil fuels (such as coal, fuel oil or natural gas) leads to a net increase in carbon to the atmosphere, carbon that has been 'out' of the natural carbon cycle for millions of years.

Heating values for biomass vary from 12 to 18 MJ/kg. Biomass is found in the textile factories audited mainly in India and surrounding countries. In order to have the qualification of sustainable biomass this guide considers the biomass types indicated above.

Regarding to biomass consumption in the manufacturing processes, it is worth mentioned that Inditex's forest product policy gives preference to forest products with high-recycled content, and/or post-consumer waste, and encourages suppliers to continuously maintain, improve and expand the availability of such products.

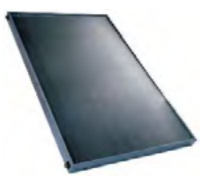
Whenever products with high-recycled content and/or post-consumer waste are not available, Inditex gives purchasing preference to forest products sourced from sustainably managed plantations, or forests certified to an independent third-party forest standard.

More information on www.inditex.com/es/sustainability/environment/biodiversity

- **Solar thermal:** Solar thermal or solar hot water systems work by absorbing thermal energy from the sun and transferring the collected heat to a distribution fluid, which is generally water. Ideally, systems should be roof-mounted and oriented to face the sun (according to the latitude and hemisphere).

There are three main types of solar heating collectors that are suitable for mounting in buildings:

- Flat-plate collectors: A sheet of black metal that absorbs the sun's energy. Water is fed through the system in pipes which conduct the heat to the water.



- Evacuated tubes :A series of parallel glass tubes grouped together. Each glass tube contains inside an absorber tube, which absorbs the sunlight. The glass tubes are subjected to vacuum to reduce the heat losses within the tube. Water flowing through the absorber tube or header (depending on the specific product) is then heated.

- Solar matting: A range of extruded hollow sections of flexible black material that can be used for solar collection. Water passes through the hollow tubes, absorbing the heat from the sun.

- **Solar photovoltaic:** Solar photovoltaic systems convert sunlight directly into electricity. Photovoltaic materials are usually solid-state semiconductors which generate electric current when exposed to light. Ideally, systems should be roof-mounted and oriented to face the sun (according to the latitude and hemisphere).

The two main types of crystalline PV cells are:

- Monocrystalline Silicon PV: 13-17% efficiencies (below, left)
- Polycrystalline Silicon PV: 11-15% efficiencies (below, right)

- **Wind power:** Wind turbines harness the power of the wind and use it to generate electricity. They use large blades to catch the wind. When the wind blows, the blades convert the wind's kinetic energy into rotational mechanical energy through the turbine blades' shape that creates lift. The spinning rotor of the turbine is connected to an electric

# Energy and water consumption

generator, so when the wind blows, electricity is generated. The stronger the wind, the more electricity is produced.

There are two types of micro-wind or small-wind turbines:

- Pole mounted: free standing and erected in a suitably exposed position (below, left). They offer capacities of around 1kW to 100kW

- Building mounted: smaller, installed on the roof where there is a suitable wind resource (below, right). Often around 1kW to 6kW. Building mounted wind turbines rarely make financial sense, since their location results in turbulent and unsteady gusts of wind, rather than the preferred steady and laminar flow that wind turbines need to generate energy. Their capital costs per kw could be 3-5 times more expensive than large wind turbines. Typically they are installed more for aesthetic and demonstrative reasons than financial ones.

### External district heating

A district heating scheme comprises a network of insulated pipes used to deliver heat, in the form of hot water or steam, from the point of generation to the end user. As a result, individual buildings served by a district energy system do not need their own heat production systems.


One of the main benefits of District Heating systems is that all the heat for the buildings/factories connected to the network is produced centrally. This can both increase the efficiency of the generation system as well as result in a benefit from a diversity factor (factories and residential uses will usually demand heat at different times of the day). Central systems can also employ more stringent emission controls, than individual buildings or factories, reducing pollution. Their major disadvantage is the energy loss from the distribution pipes and the energy required to pump that energy long distances to the end user.

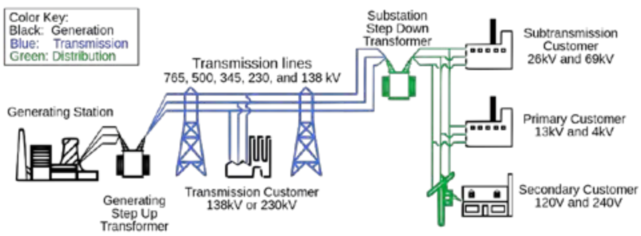
On the other hand, for the end user a district heating system require less maintenance and equipment needed. Fuel does not need to be stored, handled or burned on site, although their influence on the controllability of the system is generally also reduced. When relying in a district heating system, it is recommended that clauses in the utility contract to protect against possible failure in the distribution/generation systems are included.

Open steam district heating systems have the advantage of not requiring pumps, since there is only a supply pipe with no return and the pressure of the steam drives the steam´s movement (no additional prime mover is required). The distribution piping range is quite low: 1 to 3 miles for older systems (newer systems can achieve longer ranges with improved insulation). As other disadvantages, steam systems need steel pipes, which are more expensive and can corrode. Also, water must be conditioned to prevent mineralization. If condensate is not returned, water and energy will be wasted. There is high heat loss with steam distribution (15-45 percent). Maintenance costs for steam systems are higher than for hot water systems. There are stringent codes that steam systems must comply with, as steam is not as safe as hot water.

Hot water district heating systems require a more complex system, with two pipes, supply and return, and associated pumps to drive the system. However, they allow for an extended distribution piping range: up to 70 miles in some cases. Plastic pipes can be used and are less expensive and free from corrosion. Water does not need to be conditioned and in closed loop systems, water is not wasted. There is a reduced heat loss during distribution (5-15 percent). These systems have lower maintenance costs than steam systems.

### Grid electricity

An electricity grid is an interconnected network for delivering electricity from suppliers to consumers. It consists generally of the following main components: generating stations that produce electrical power (thermal, hydro power, nuclear, wind plants, etc); high-voltage transmission lines that carry power from distant sources to demand centres or big consumers; and substations that reduce the voltage to connect to individual customers through the distribution lines.




**Consumption and power rate:** The price of the energy purchased from the utility provider generally is made up of two components: a fixed charge (or power rate), dependent on the contracted capacity; and a variable charge (or consumption rate), dependent on the amount of energy consumed.

The contracted capacity is the maximum power demand, measured in kW or MW, available at any given time, in which the utility provider agrees to deliver to the purchaser. This component is calculated as $\$/kw_{contracted}$ and is independent of the energy consumption.

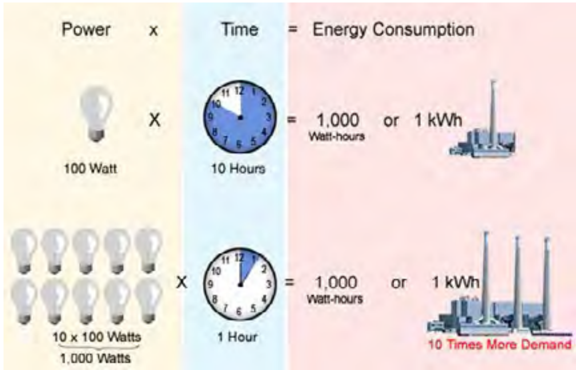
The contracted power must be adjusted and optimized to meet the actual power demand. If the power use is higher than the contracted power, there will be economic penalties for exceeding the contracted power consumption. On the contrary, if the contracted power is higher than the power actually needed, the user is paying a higher rate for an extra capacity which is not needed.

The consumption rate has a variable price dependent on the amount of energy consumed. The energy consumed is the total quantity of electricity used, measured in kWh.

Kilowatts (kW) measure the instantaneous power demand, i.e. the rate at which energy is delivered or used, at any point in time. Kilowatt-hours (kWh measure the total amount of energy used over time. You can see an examples below that may help understand the difference between power and energy consumption. (Source: http://www.think-energy.net/)

Example: A single 100W light bulb switched on for 10 hours consumes 1,000 watt-hours (1 kWh). The entire time it is on, it requires 100 W (0.1 kW) from the utility. That means the utility must have that 0.1 kW ready whenever the customer turns the lamp on.

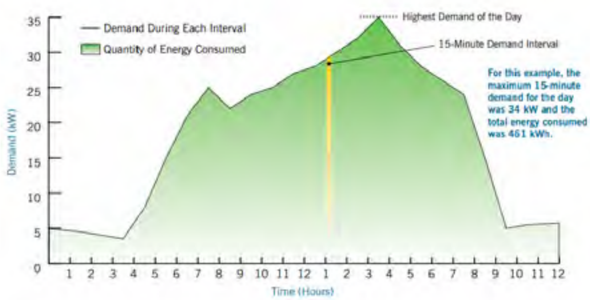
Similarly, ten (10) 100W light bulbs burning for 1 hour consume 1,000 watt-hours (1 kWh), but the serving utility must now be prepared to provide ten times as much 'capacity' at any time, in response to the possible demand of the 10 light bulbs operating all at once.




In both examples the consumption is the same, 1kWh. However in the second case, the utility has to have 10 times more generating capacity to provide the second customer's high demand for power compared to the first case.

**Energy bill monitoring:** Electricity meters continuously measure the number of kWh consumed. At the end of each billing period (typically one month), a kWh reading is obtained from the meter. The previous month's reading is then subtracted from the new reading to determine kWh consumption. In some cases, the meter registers only a portion of the kWh used, and a multiplier is used to determine actual usage. The multiplier, if applicable, is shown on your billing statement.

Meters at most businesses, in addition to electrical energy usage (kWh), also measure power demand (kW), the average rate at which kilowatt-hours are used during a certain time interval, usually 15 minutes. At the end of the billing period, a maximum kilowatt demand reading is obtained and the demand register is then reset so it can start to measure the maximum demand for the following month.




**Daily demand and consumption data**
*Source: Duke Energy*

It is important to register and monitor energy bills to analyse the consumption profile of the factory. Reliable energy and production data is critical to accurately evaluate an energy

# Energy and water consumption

efficiency opportunity. Energy consumption data can be compared monthly or from one year to another to detect equipment or process failures in case of unexpected variations. Also, energy consumption ratios enable benchmarking and comparison amongst manufacturers. Based on energy consumption and production data, a kWh/garment value can be obtained and the final product can be assessed with a life cycle approach. For further information see specific section on Metering in the Management and processes chapter of this guide.

GtW Indicator

**Best in class A**
Check if the mill has monitoring track records of its water and energy consumption

## Energy use efficiency in mills

Control over the textile processes and the machines are equally important to achieve an efficient use of energy in the facility. Some working practices that help to reduce the total energy consumption are:

### Controlling the moisture content during drying

The use of new mangle rollers to squeeze out more water can achieve moisture levels of 70%. Reducing moisture prior to drying provides considerable savings in energy and also increases productivity.

As well as this, fabrics are frequently over-dried during drying processes. Any drying beyond the ambient moisture level means a waste of energy. The use of moisture meters for stenters ensures that fabric is not dried beyond that level, thus reducing energy consumption and drying costs by up to 37%.

GtW Indicator

**Good performance B**
Check that driers in the mill have automated control system (including moisture measuring) and heat recovery on stenters

### Recording downtime

Downtime records for machinery (time and reason for downtime) are very useful information to be analysed in order to maximize machine utilization and increase mill's productivity.

The above mentioned good practices and switching off machines when not in use help to consolidate production.

## $CO_2$ Emissions Factors

### Fuels

Fuel combustion may be defined as the oxidation of materials in order to provide energy (either heat or mechanical work). Combustion processes are optimized to derive the maximum amount of energy per unit of fuel consumed, that is, to ensure oxidation of the maximum amount of carbon available in the fuel, hence delivering the maximum amount of carbon dioxide ($CO_2$). $CO_2$ emission factors are therefore relatively insensitive to the combustion process itself and hence are primarily dependent only on the carbon content of the fuel.

| Fuel | $CO_2$ Emissions Factor ($KGCO_2/KWH_{TH}$) |
|---|---|
| **Natural gas** | 0.184 |
| **Fuel oil** | 0.267 |
| **Coal** | 0.333 |
| **Biomass** | 0* |

*$CO_2$ emitted by biomass is very low as the emission is balanced by $CO_2$ absorbed in the growth of additional biomass feedstock. This is why biomass is considered a carbon-neutral fuel (only applicable to 'sustainable biomass')

### District Heating

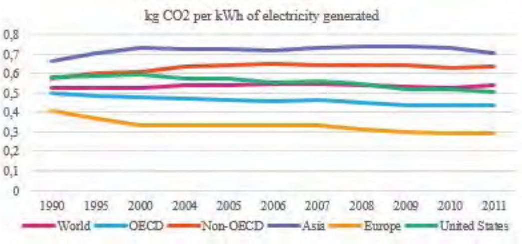
The $CO_2$ emissions factor of a district heating system is highly dependent on the source of energy used to produce the heat and the extension of its distribution system. Therefore there will be plants with very high emissions factors (i.e coal boiler) and others with lower emissions factors (i.e. biomass or natural gas CHP).

### Grid electricity

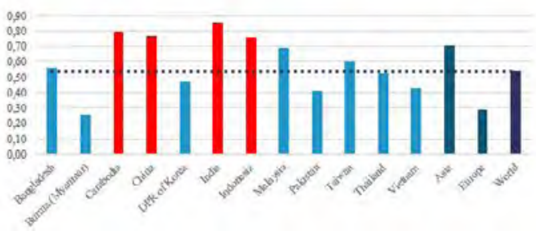
The $CO_2$ emissions factors for grid electricity measure $CO_2$ emissions per unit of electricity generated in the grid system. (kg $CO_2$/kWh). The carbon intensity of a grid system is determined by the fuel mix used in the energy generation and varies greatly depending on the fuel source. It is based on the combined emissions factors of the fuels used in generation of electricity and weighted by the amount of energy generated by each technology.

The trend in OECD, Europe and United States is to reduce $CO_2$ emissions per kWh of electricity generated, due to the incorporation of renewable energy technologies into the supply mix as well as increasing the use of fuels with lower emissions factors, such as natural gas. However, in non-OECD countries, where the majority of textile factories operate, carbon intensities of their electricity grids have gradually increased in the last years.

In Asia, the emissions factor is far higher than the world average, mainly because of their reliance on coal for electricity generation.




Having a closer look at Asia though, there are big differences amongst countries. According to the study Perspectives on retail and consumer goods (McKinsey & Co 2014) the expected top sourcing markets in apparel sourcing over the next 5 years will be Bangladesh and Vietnam, followed by India, Myanmar, Cambodia, China, Indonesia and Pakistan. The average $CO_2$ Emission Factors for grid electricity in those countries in kg $CO_2$/kWh, compared to other countries in the Asia region and to Asia, Europe and World averages can be seen in the below.

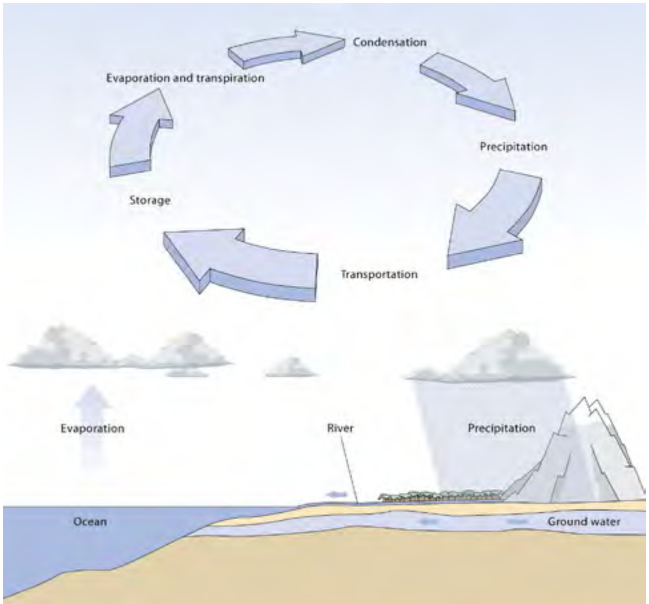



The $CO_2$ emissions factor in Bangladesh is lower than the average in Asia and similar to the world average, although it is significantly higher, nearly double, than the emissions factor for Europe. $CO_2$ emissions in four of the top sourcing markets (Cambodia, China, India and Indonesia), are extremely high, above the Asian and world averages. Moreover, electricity generated in India has almost triple the $CO_2$ emissions than electricity generated in Europe, due to coal as India's largest energy source. On the other hand, Pakistan and especially Myanmar emerge as more sustainable alternatives. Myanmar (Burma) heavily relies on hydropower for most of its electricity generation (71% in 2011), so electricity related emissions are very low.

## Water sources

Water is a precious, limited resource and it is constantly moving.

Water evaporates from the soil and open water surfaces as a result of solar and wind energy. In addition, plants draw water up from the soil and release it to the atmosphere with the transpiration. When the precipitation on land exceeds evapotranspiration, the water run-off. Run-off water from land finally ends up in the ocean.




Although water forms a cycle, so that freshwater on land is continuously replenished, its availability is not unlimited. Per year, people need a certain volume of water for domestic, agricultural and industrial purposes such as textile mills, which cannot exceed the annual replenishment rate of each water system (for example the ground water).

Water is essential to the ecosystems and people's well being. The human activities affect water quantity and quality generating an impact which is called, Water Footprint. This is an indicator that expresses human appropriation of freshwater in volume terms. It is a multidimensional indicator, showing water consumption volumes by source and polluted volumes by type of pollution. The Water Footprint is divided in the following types of water:

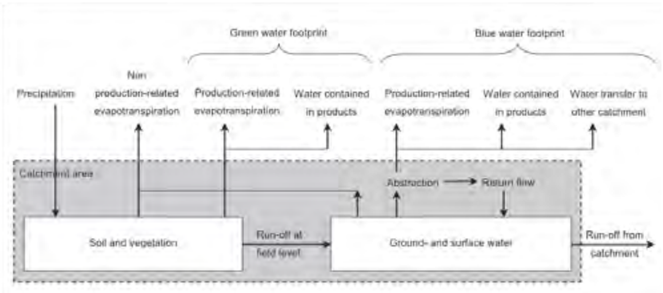
- The **blue water** footprint refers to consumption of blue water resources which are the surface and groundwater along the supply chain of a product

# Energy and water consumption

- The **green water** footprint refers to consumption of green water resources which is rainwater insofar as it does not become run-off (evaporative flow from the land surface, mostly for growing crops or production forest)

- The **grey water** footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards

Therefore, the water footprint of a textile mill will need to consider not only the water that is supplied from the utilities or taken from the groundwater but also the impact of the waste water pollution in the receiving freshwater streams and bodies.




**The green and blue water footprint in relation to the water balance of a catchment area**

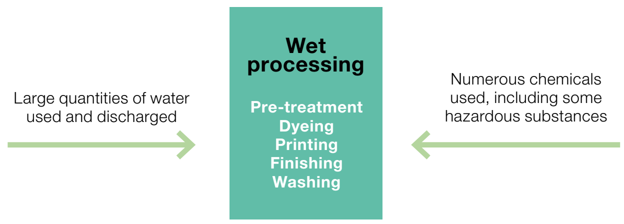
## Water use efficiency in mills

### Water wet processes

(based on the European Commission reference document of Best Available Techniques for the Textiles Industry)

Inditex integrates sustainability criteria for the use of water in all of its business areas through its Global Water Management Strategy, which includes initiatives to ensure correct water management in each and every one of the links of its value chain.

Textile processing is known to be a water-intensive sector. The majority of water used occurs during 'wet processing', such as dyeing, printing, finishing and washing.




Optimising water consumption in textile operations starts with controlling water consumption levels. The next step is reducing water consumption, through a number of often-complementary actions. These include improving working practices, reducing liquor ratio in batch processing, increasing washing efficiency, combining processes (e.g. scouring and desizing) and reusing/recycling water. Most of these measures allow significant savings not only in water consumption, but also in energy consumption because energy is used to a great extent to heat up the process baths.

Well-documented production procedures and training are important.

- **Identifying all the water sources**

  It is the first issue to check regarding water consumption. The auditor has to identify all the water sources and their corresponding use. As well as this information, the mill will provide the official authorization (if applicable) for each water supply.

  This information, together with consumption data, help to draw the water balance of the mill.

GtW Indicator

**Poor performance C**
Check that the mill has an official authorization for each water supply use

A water balance chart of the mill not only shows all the water sources but also the different processes, helping to better understand the mill and to see where the big risks are.

- **Controlling water consumption**

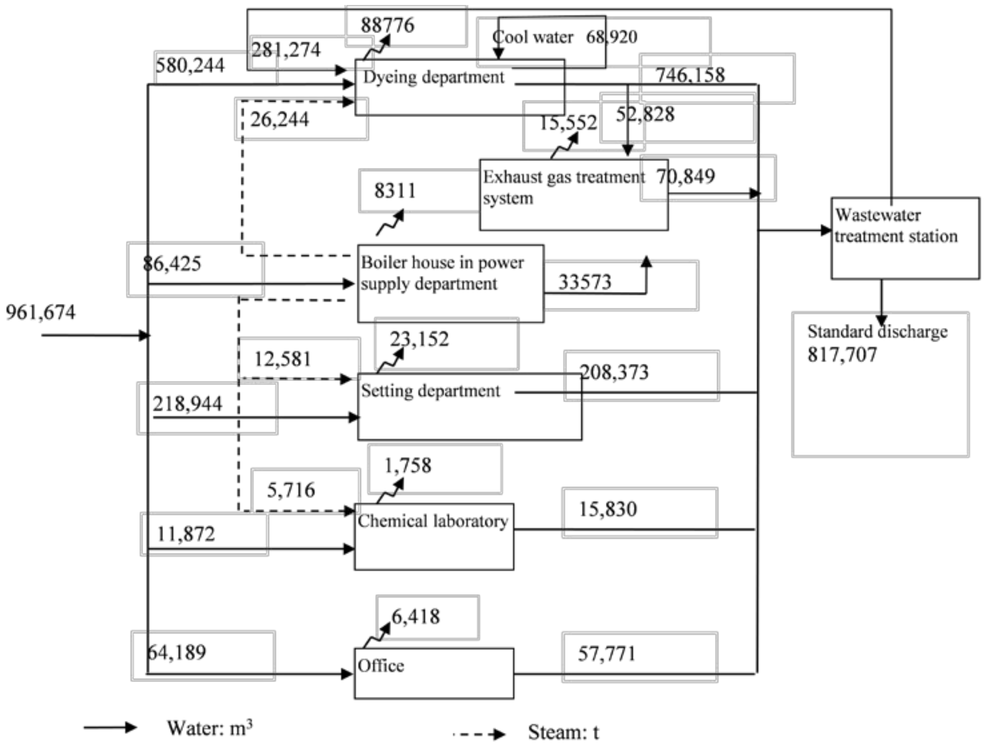
  A second step is to collect information on the installation and the volumes consumed in the various processes. In practice, mills rarely measure and keep control of water use. Water use should be monitored and recorded at machine/process level and water meters should be regularly maintained and calibrated.

GtW Indicator

**Poor performance C**
Check if the mill has flow-meters in use to monitor at least water consumption or total discharge

GtW Indicator

**Best in class A**
Check if the mill has monitoring track records of its water and energy consumption




Water balance chart

Significant water reduction has been observed in industry experience after the installation of cheap flow control devices on washers. A systematic procedure can be applied aimed at defining the optimum flow needed to achieve the desired level of product quality.

Automatic stop valves that link the main drive mechanism of the range to the water flow can save considerable quantities of energy and water by shutting off water flow as soon as a stoppage occurs. With manual control, the water flow may not be switched off until the machine has stopped for more than 30 minutes.

Data at site level is a good benchmark in determining whether water consumption is excessive and is a good baseline against which to measure improvements.

- **Reducing water consumption**

  o by improved working practices

Inappropriate working practices and the absence of automated control systems can lead to significant wastage of water, e.g.: During filling and rinsing, for example, where machines are equipped only with manual water control valves there is potential for overfilling displacement spillage during immersion of the fibre in the machine may account for up to 20% of total operating volume over the course of a dyeing cycle (this may also lead to losses of dyes and hazardous chemicals if these are introduced before the displacement takes place). Well-documented production procedures and training are important. Dyeing machines should at least be fitted with modern process control equipment, capable of accurately controlling both the fill volume and the liquor temperature.

GtW Indicator

**Good performance B**
Check if at least 80% of the production is coming from dyeing or finishing machines with automated control

  o by reducing liquor ratio

In continuous dyeing, the dye is applied in the form of a concentrated liquor. This parameter (liquor ratio) is the ratio of the weight of the dyebath or other processing bath to the weight of the goods being dyed or processed for immersion dyeing in art dyeing processes.

All major machine manufacturers now have units for dyeing at low liquor ratio. An investment in such units pays because it cuts operating costs (energy, water, chemicals, dyes, etc.) and raises productivity by reducing processing times.

# Energy and water consumption

GtW Indicator

**Good performance B**
Check if the liquor ratio is shown in each individual process recipe and the annual average is consumption is < 140l/kg fabric (for dyeing processes of woven fabric of cotton, linen, synthesis fibres and their blends)

In exhaust dyeing there is a wide variety of machines with a broad range of efficiency in water consumption (air jet dyeing, jet, jigger, winch, etc.). Although the liquor ratio depends on the raw material that is going to be dyed, modern commercial dyeing equipment often works with low values as 1:7 or 1:5. However winch dyeing machines work with high liquor ratios (1:20 or even 1:40), which entail low efficiency values and high levels of water consumption.

GtW Indicator

**Poor performance C**
Check if at least 80% of the production (only for exhaust dyeing mills) is not coming from winch dyeing machines with liquor ratio > 1:7

- o by improving washing efficiency

GtW Indicator

**Good performance B**
Check if the mill uses batch rinsing instead flow washes" Applicable to washing processes in wet process mills. The washing processes at continous dyeing mills are excluded

In both batch and continuous processing, water consumption for washing is significantly higher than for the treatment itself. Modern continuous washing machines have greatly improved their washing efficiency.

Many factors influence washing efficiency (e.g. temperature, residence time, liquor/substrate exchange, etc.). The techniques applied in modern washing machines depend largely on the type of fabric to be washed, e.g light or very heavy fabrics, etc.

Two basic principles/strategies are applied in modern washing machines: countercurrent washing and reduction of carry-over.

GtW Indicator

**Good performance B**
Check that at least 80% of the production is coming from washing machines with level meters and temperature controllers in use in each front loading washers and no belly washers

- · The countercurrent principle means that the least contaminated water from the final wash is reused for the next-to-last wash and so on until the water reaches the first wash stage, after which it is discharged.
- · Reduction of carry over is another fundamental factor. Water (containing contaminants) that is not removed is 'carried over' into the next step, contributing to washing inefficiency. Proper extraction between steps is essential.

- o by combining processes

Combining and scheduling processes reduces the number of chemical dumps. This is often feasible for pretreatment operations (e.g. scouring/desizing, scouring/desizing/bleaching).

- **Re-using water**

In order to evaluate the possibility of water recycling, it is important to consider the storage facilities for re-usable waste water and the non-continuous character of the waste stream and the higher liquor ratios.

Machines are now available with built-in facilities for waste stream segregation and capture. For example, the wash water from a previous load can be recovered and fully used in the bleach bath for the current load, which can then be used to scour the next load. In this way, each bath is used three times.

Also, efficient machines allow to reuse cooling water after textile processes. This water has not been in contact with the chemical products (dyes and auxiliaries) so that it can be continuously reuse.

GtW Indicator

**Poor performance C**
Check if the mill reuses cooling water in all the installation

*Source: Arup*

**Top energy and water efficiency measures in textile mills. (Low medium cost)**

| | Measure brief Description and comments | Investment range (US$) | Pay back (months, years) |
|---|---|---|---|
| **Improve boiler efficiency** | Improving combustion, heat transfer and reducing losses by<br>- Better gas burner control, prescreening of coal or including automatic oxygen trim.<br>- Insulating casing or back of the boiler.<br>- recovering additional heat by an economizer in the boiler stack exhausts | $ 4,000-40,000 (1) | 5 To 15 months |
| **Steam piping: Insulate, repair leaks and traps** | - Program to find, label and fix steam leaks in pipes.<br>- Inspection and Replacing or repairing steam traps<br>- Insulate all the steam piping distribution | Insignificant<br>$3,000-15,000 (2) | Instant<br>3- 7 months |
| **Reuse and reduce steam condensate** | - Recover condensate from process equipment (as drying cylinders) returning to boiler (or reuse in process for DH or distant boilers).<br>- Install condensate return<br>- Reduce steam use by Control of dryers by humidity analyser in stenters | $ 12,000 – $33,000 (3) | 4 -8 months |
| **Insulate process equipment and tanks** | - Insulate process equipment as dye vats operating at high temperatures or steam condensate tank | $ 10,000 – 45,000 | 6-10 months |
| **Water leak detection and control** | - Inexpensive measures as periodical reviews and repair of leak in pipes and fittings.<br>- Installation of trigger nozzles in hoses and shutoff valves | Insignificant to $3,000 | Instant to 2 months |
| **Recover heat from hot water** | - Recover heat from hot waste water that cannot be directly reuse in order to preheat incoming water.<br>(Additional benefit to reduce temperature of water going to ETP) | $12,000 to $79,000 (4) | 5 to 10 months |
| **Reuse cooling and process water** | - Use of non-contact cooling water (high quality and with useful heat) for washing or rinsing<br>- Use of last rinses as feed for first ones | $3,000 - $20,000 (4) | 3-6 months |
| **Heat recovery from electrical generator** | - Retrofitting existing on site electrical generator (In mills producing their own electricity) recovering the heat from exhaust and/or refrigeration system | $15,0000- $80,000 | 6-10 months |
| **Recover heat from hot air** | Recover hot air from air compressors to be used in the process or into boilers.<br>Heat recovery from Stenters exhaust air | 16,000- $55,000 | 7-18 months (5) |
| **Optimize air compressor system** | - Repair leaks in pipes and connection points<br>- Install trigger nozzles in hoses<br>- Reduce adjust operating pressure setpoints | Insignificant | instant |

Notes:

1. Lower range of investment for simple insulation of boilers
2. Lower range of investment for steam trap replacement, higher range for full insulation of uninsulated piping network. Fixing main steam leaks should have insignificant investment cost and instant payback
3. Higher range of investment for new condensate return installation
4. Upper range of investment for a full retrofit of discontinuous processes requiring buffer tanks, piping &fittings, pumps and associated control. Lower range for localized recovery or direct use of water from existing heat exchangers
5. A mill reported payback of 4 years for the installation of hot air recovery in a stenters

*Source: Prepared by Arup based on 'NRDC's 10 Best Practices for Textile Mills to Save Money and Reduce Pollution' by Natural Resources Defense Council, 'Promoting Cleaner Production in the Textile Washing/Dyeing/Finishing Sector in Bangladesh' by Reed Consulting Bangladesh Ltd for Inditex and IFC, and 'Energy Performance Benchmarking and Best Practices' by Canadian Textiles Institute and Natural Resources Canada.*

# Combustion air pollution

## General description

Combustion pollutants are gases or particles that come from the burning of fuels, particularly fossil fuels.

When pure hydrocarbons burn efficiently in an excess of air/oxygen (complete combustion) the only products generated are carbon dioxide and water. If there is not enough oxygen present to completely burn the fuel to carbon dioxide and water (incomplete combustion) other products may be form causing pollution and combustion inefficiency. The most common partially burned products are likely to be carbon (C) particulates and carbon monoxide (CO).

Fossil fuels contain other compounds like sulphur, lead or nitrogen. When the fuel is burned, the sulphur compounds also oxidise to form sulphur dioxide. High temperature combustion also produces other pollutants including nitrogen oxides and unburned hydrocarbons $C_xH_y$. Lead (Pb) compounds added to petrol produce lead compound emissions, although lead is being phased out from fuels in many countries.

The main effects on the environment and people of combustion pollutants are the following:

- Carbon dioxide ($CO_2$): its emissions alters the earth's natural carbon cycle and increases the greenhouse effect
- Carbon monoxide (CO): very toxic for humans and involved in the chemistry of photochemical smog, a mixture of hundreds of different and hazardous chemicals known as secondary pollutants
- Sulphur dioxide ($SO_2$): an acidic gas which dissolves in rainwater, it then reacts with water and oxygen to form a solution of sulphuric acid involved in the acid rain. It is also a harmful gas to health and lung irritant
- Nitrogen monoxide (NO): a compound that in combination with oxygen oxidizes to nitrogen dioxide ($NO_2$), lung and eye irritant, and nitric acid. Nitrogen dioxide along with nitrogen monoxide (generally named as $NO_x$), is involved in the chemistry of photochemical smog. Nitric acid is dissolved in rainwater, contributing to the acid rain phenomena
- Particulate Matter (PM): it can cause a variety of health problems including respiratory and reproductive problems and mutations
- Unburned hydrocarbons ($C_xH_y$): they can be carcinogenic and are also involved in photochemical smog chemistry
- Lead compound emissions: they are nerve toxins

### Pollutants according to the fuel

Natural gas is the least dirty of the fossil fuels due to its efficient combustion, which produces less carbon monoxide and particulate matter for the energy released. Composed primarily of methane, the main products of the combustion of natural gas are carbon dioxide and water vapour.

Coal and oil are composed of more complex molecules, with both a higher carbon ratio and higher nitrogen and sulphur contents. This means that when combusted, coal and oil release higher levels of harmful emissions. Coal and fuel oil also release ash particles into the environment, substances that do not burn but instead are carried into the atmosphere and contribute to pollution. The combustion of natural gas, on the other hand, releases very small amounts of sulphur dioxide and nitrogen oxides, virtually no ash or particulate matter, and lower levels of carbon dioxide, carbon monoxide, and other reactive hydrocarbons.

| Pollutant | Natural gas | Oil | Coal |
|---|---|---|---|
| **Carbon Dioxide** | 117,000 | 164,000 | 208,000 |
| **Carbon Monoxide** | 40 | 33 | 208 |
| **Nitrogen Oxides** | 92 | 448 | 457 |
| **Sulfur Dioxide** | 1 | 1,122 | 2,591 |
| **Particulates** | 7 | 84 | 2,744 |
| **Mercury** | 0.000 | 0.007 | 0.016 |

Fossil Fuel Emission Levels (Pounds per Billion Btu of Energy Input)
Source: EIA – Natural Gas Issues and Trends 1998

GtW Indicator

**Good performance B**
Check if exhaust air from combustion is monitored and tested

## Control emission technologies

A detailed review of the technologies used to control emissions of the pollutants indicated above is beyond the scope of these guide. The questionnaire is requiring information regarding some of the pollutants indicated above and some prove of the records of the third party combustion air verification tests.

In terms of the textile industry, the local air pollution main impact is the one associated to the use of coal for the production of steam and in less cases electricity. These technologies include:

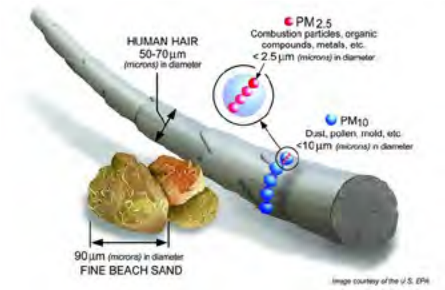
- **$SO_2$ control:** Flue Gas Desulphurisation (FGD). Wet scrubbers are the most common technology followed by spray dry scrubbers and sorbent injection systems. Commercial wet scrubbing systems are available in many variations, including proprietary designs including a combination of lime/limestone/sludge or gypsum such as Dual Alkali (combining Sodium solution and lime) and other (including seawater, ammonia, caustic soda, sodium carbonate, potassium and magnesium hydroxide). Wet scrubbers can achieve removal efficiencies as high as 99%. Wet scrubbers producing gypsum should be preferred especially with the increased cost and impact of land filling and the introduction of stricter regulations regarding by-product disposal.

- **$NO_x$ emissions** abatement and control by flue gas treatment is primarily used in large electric power plants. For small and medium sized combustion facilities, $NO_x$ flue gas treatment technologies are not common (even in developed countries). For the textile industry combustion facilities, measures to comply with $NO_x$ emission targets focus on fuel selection and/or pretreatment, with especial attention on the right combustion mixture and temperature to be achieved by the design of burner and boilers, as well as operation and maintenance practices.
- **Particulate emissions** (PM10 and PM2.5) control technologies are explained in more detailed in the section below).

## Particulate filtering technologies

Particulate matter, also known as particle pollution or PM, is a complex mixture of extremely small particles and liquid droplets. These particles can be made up of hundreds of different components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. They can be directly emitted from sources such as industries, or they can form when emitted gases react in the atmosphere.

The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose. Once inhaled, these particles can affect the heart and lungs and cause serious health effects.

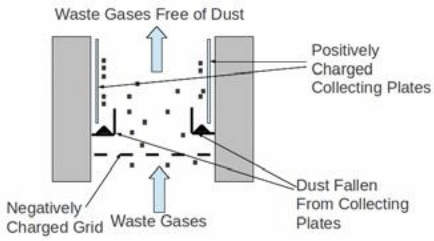



EPA groups particle pollution into two categories: inhalable coarse particles (also known as PM10) and fine particles (also known as PM2.5). During coal combustion, the mineral matter is converted to ash. Part of the ash is discharged from the bottom of the furnace as bottom ash. The particles suspended in the flue gas are known as fly ash. Fly ash constitutes the particulate matter emitted during combustion process, which can be treated by a particulate control device. Main technologies used to control particulate emissions from small scale combustion processes are:

| Particulate filter types | | |
|---|---|---|
| | Removal efficiency (%) | Particle size range (µm) |
| **Fabric filters (baghouses)** | 99-99.9999% | 0.01- >100 |
| **Chimney top electrostatic precipitators (ESP)** | 99-99.99% | 0.01->100 |
| **Wet particulate scrubbers** | 90-99.9% | 0.5 - >100 |
| **Mechanical/inertial collectors (cyclones/ multicyclones)** | 75-99% | 1.0-100 |

### Chimney top electrostatic precipitators (ESP)

The electrostatic precipitator is a device fitted to factory chimneys to collect PM that would otherwise escape into the atmosphere as pollution. It basically consists of oppositely charged plates, over which waste gases containing pollutants and dust pass.




The gases pass through a negatively charged metal grid, becoming negatively charged. As the gases are blown over positively charged plates attached to the chimney wall, particulates are attracted to the plates. When they make contact with the plates, they become neutralized and fall into dust collecting fittings. The collecting plates are anyway shaken periodically to remove dust. The gas that enters the atmosphere is then cleaner of dust.

# Combustion air pollution

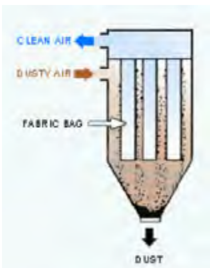


Various examples of chimney top ESP can be seen below

## Fabric filters (baghouses)

Fabric filters, commonly known as Baghouses, are one of the most efficient and cost effective dust collection systems.

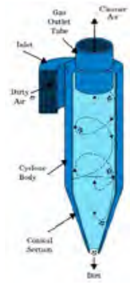
A fabric filter unit consists of a compartment containing rows of fabric bags. Flue gasses pass along the surface of the bag and then through the fabric. Particles are retained on the upstream face of the bags and the cleaned gas stream is vented to the atmosphere. Dust accumulated on the bags is periodically removed.




## Mechanical/inertial collectors (cyclones/ multicyclones)

Cyclonic separation is a method of removing particulates from an air stream, without the use of filters, through vortex separation. Rotational effects and gravity are used to separate particle from the air.

A cyclone is a cylindrical vessel, usually with a conical bottom. The flue gas enters the vessel tangentially and sets up a rotary motion whirling in a circular or conical path. The particles are 'thrown' against the walls by the centrifugal force of the flue gas motion where they impinge and eventually settle into hoppers.

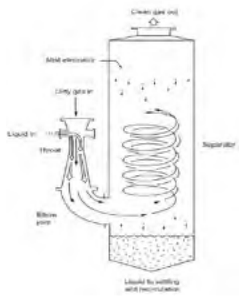



*Source: http://www.iea-coal.org.uk/site/ieacoal/databases/ccts/mechanical-inertial-collectors-cyclones-multicyclones*

## Wet particulate scrubbers

Wet scrubbers are devices that rely on direct and irreversible contact of a liquid (droplets, foam, or bubbles) with the particulate matter. The liquid with the collected PM is then easily collected.

There are many types of wet scrubbers, which are generally classified by the method that is used to induce contact between the liquid and the PM. The most widely used wet scrubber is the venturi scrubber, as the one below.




GtW Indicator

**Poor performance C**
If the mill burns coal/sludge, check that it does so using a filter or controlling the emissions

# Boiler

## General description and types

A boiler is a closed container designed to transfer the heat, generally produced by combustion, to a distribution fluid, which generally is water. This generated hot water (usually below 90ºC / 194ºF) can then be circulated though pumps to other equipment to provide ambient heating, for human comfort, or the heat required for some manufacturing processes (i.e. drying).

Boilers can be classified according to numerous characteristics, being one of them the source of energy used. Boilers may be designed to burn gases (i.e natural gas), fuel oil (i.e. gasoil), coal or other types of combustibles as wood or residual biomass (waste from forestry or agriculture).

## Components

Their main components of a boiler are the burner, the furnace, the heat exchanger and the flue.

**Burner:** The burner is the part of the boiler that provides the mix of fossil fuel with air for the combustion to happen. Burners can have constant or variable output. Variable output can be staged, in generally two or three capacity steps or provide continuous modulating capacity. A two stages burner could provide, for example, (50-100%) heating capacity. A modulating burner could provide any capacity between its minimum and maximum heating capacities.

**Furnace:** The burner supplies the mix of fossil fuel and air into the furnace, where combustion happens. They are usually constructed with cast iron or steel and coated with ceramic tiles or a refracting material to increase durability and enhance efficiency.

**Heat exchanger:** The hot gas mix produced by the combustion is passed through an array of tubular tubes surrounded by water, known as heat exchanger, Here the heat is exchanged from the gas mix into the water.

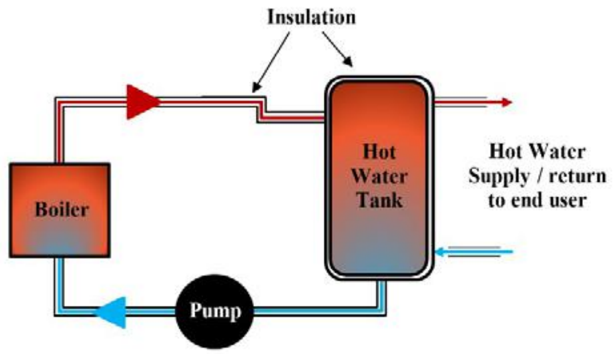
**Flue:** Once the hot gas mix has exchanged most of its heat with the water, is then exhausted to the atmosphere through the flue.

Other system accessories are:

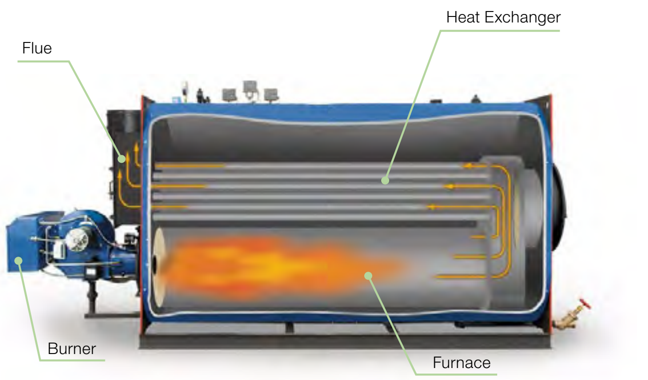
**Pumps:** To push the heated water from the boiler into the end use equipment.

**Hot water tank:** The heated water is generally pumped into a hot water storage tank from which it is extracted to supply the hot water for air conditioning or process heating.

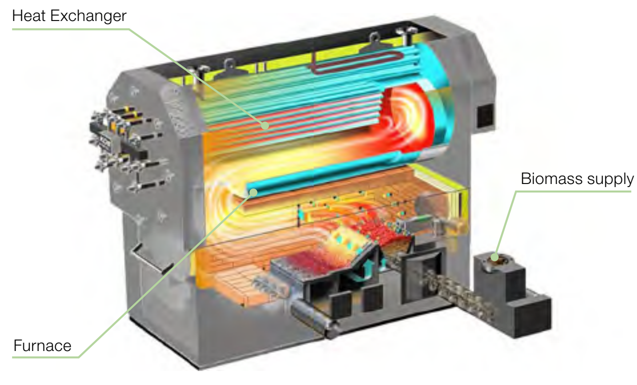
**Insulation:** Boilers, flues and hot water pipes are generally insulated to avoid to loss of heat to the surrounding spaces.



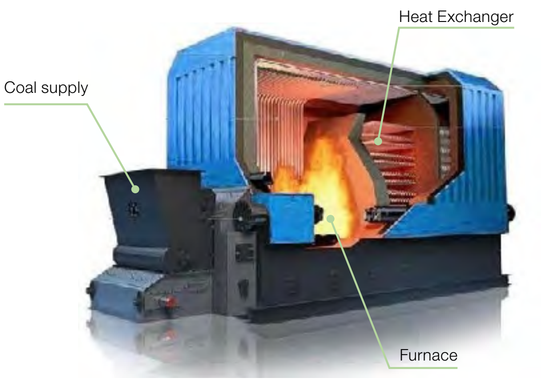

## Descriptive images




**Gas or fuel boiler**
*Source: hurstboiler*




**Biomass Boiler**
*Source: Köb boilers*




**Coal-fired boiler**
*Source: Olymspan boilers*

## Efficiency key facts

### Insulation ★★

Due to either poor construction or poor maintenance practices, boilers, flue and pipe insulation may be damaged or even not existent, thus greatly reducing the amount of heat that can be used for ambient heating or process heating.

> **Check that the insulation is still in place and is preserved in good state**

**Well insulated pipework**

**Worn out insulation**

**Damaged insulation**

**Uninsulated hot water tank**

GtW Indicator

**Good performance B**
Check if all the tanks and steam pipes are insulated

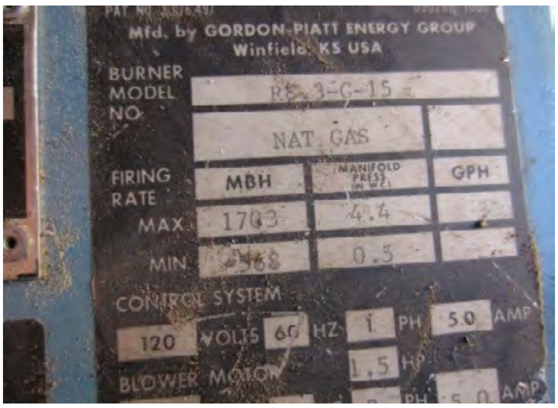
### Burner type

As described above, there are several different types of burners – constant capacity burners, staged burners and modulating burners. Modulating burners have the greatest flexibility, able to adapt their heating capacity to the heating load required at any time and are thus the most efficient. Staged burners can adapt their capacity to some degree but do not have the flexibility that modulating burners have. Finally, constant capacity burners cannot modulate at all and are thus least efficient in applications that have changing loads.

Example: If the heat load is 72%, a modulating burner will modulate to 72% providing the required amount of heat, a two-stages burner (50-100%) could operate at 50% (below requirement) or at 100 % (well above requirement), a three-stages burner (50-75-100%) could modulate at 50% capacity (below requirement), 100% capacity (well over requirement) or 75% capacity (very close to the required heat demand). A single stage burner can only operate at 0% or 100%.

When the capacity supplied by the boiler is above the heat load required (staged boiler or constant burner), the temperature will raise above that needed switching the boiler off to avoid overheating. Boilers switching on and off will have a reduced life compared to those modulating.

> **Ask what type of burner is installed in the boiler. Take a photograph of the data in the manufacturer plaque. Is the boiler revised annually? Is combustion or boiler efficiency checked annually?**




**Burner plaque**

### Heat Exchanger

As described above, the heat exchangers transfer the heat between the hot combustion gases and the water. Their efficiency can be compromised by depositions in the heat

# Boiler

exchanging tubes. These depositions can be produced by the combustion products on the air side as well as by water scale on the water side. It is therefore recommended to clean the heat exchanger tubes as per manufacturer recommendations.

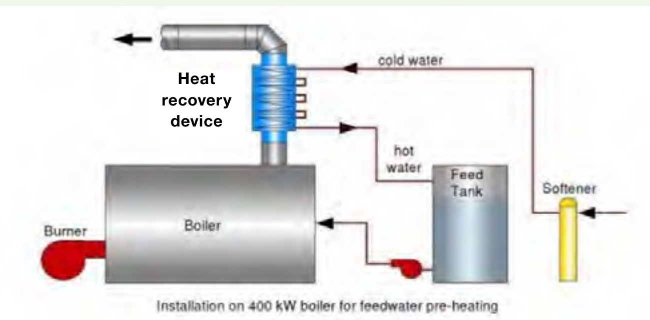
> **Ask if the heat exchanger has been cleaned, how often is cleaned and whether there is a register keeping this information.**

**Tubes before & after cleaning**
*Source: universal chemicals.co.in*

## Heat recovery in flue (economizer) ★★

Downstream of the heat exchanger, the combustion gases are exhausted to the atmosphere though the flue. Since there are inefficiencies in the heat exchanging process, the gases exhausted are generally still quite hot, and therefore still contain substantial energy. By installing a heat recovering device, the heat that would have been discharged and wasted to the atmosphere is instead harvest and used (generally to pre-heat the air or water used in the same or other processes).

> **Is there heat recovery devices in the boilers? Can they be used to preheat process water?**




**Heat recovery in flue**
*Source: Thermgard.com.au*

## Combustion monitoring ★★

Boiler combustion gases monitoring is a very effective way to ensure boilers are working correctly. Testing of flue gases, regular checking of $CO/CO_2$ concentrations, and the percentage of excess air is a necessary input to tune up boilers.

> **Are the combustion gases regularly monitored? Is there a register of the monitoring results?**

*Source: Testo*

GtW Indicator
**Good performance B**
Check if exhaust air from combustion is monitored and tested

## Coal prescreening

It standardizes the feed size into the coal boiler and removes some non-coal material, allowing a more efficient combustion.

> **Where is the coal sourced from? Has it been pre-screened?**

## Control parameters

When assessing the performance of a boiler system, the following parameters are able to be measured and monitored:

**Hot Water Temperature:** The temperature of a hot water system is dependent on the process requirements. The temperature of the water reaching the final equipment should not be higher than what is required, as this would increase heat losses and reduce boiler efficiency.

While in building applications water temperatures are usually needed in the range of 45-80ºC, in industrial applications higher temperatures are often required. Hot-water systems can be classified by its operating temperature into three groups:

- Low temperature (LTW): Systems that operate within a temperature of 120ºC and pressures below 2 bar.
- Medium temperature (MTW): Systems that operate within a temperature of 180ºC and pressures below 10.5 bar.
- High temperature (HTW): Systems that operate at temperatures above 180ºC and pressures below 21 bar.

**Fuel Consumption:** Fuel consumption needs to be measured in order to calculate boiler efficiency. According to the fuel type, the consumption will be measured in $Nm^3$ (Normalized cubic meters) for gases, litres or $m^3$ for liquids and kg or tons for solids.

Together with the consumption, it is recommended that information on the density ($kg/m^3$) and calorific power ($kJ/Nm^3$, kJ/l, $kJ/m^3$ or kJ/kg) for the delivered fuel is is obtained from the provider. Although there is tabulated standard values for these two parameters, it is often prudent to request this information from the providers as there may be significant variations between providers.

**Combustion efficiency:** Combustion efficiency is a measurement of how well the fuel being burned is being utilized in the combustion process. If there is not enough air, the fuel will not have enough oxygen to fully complete combustion of all fuels and will result in some unburned fuel will being exhausted. The combustion efficiency will increase with increased excess air, until the heat loss due to the excess air being at room or outdoor temperatures is larger than the heat provided by the more efficient combustion. Carbon dioxide ($CO_2$) is a product of combustion and its measurement within the combustion gases in the flue is an important indication of the combustion efficiency.

**Combustion analyser**
*Source: Tsi*

Equipment measuring combustion efficiency additionally corrects this measurement by subtracting the heat carried away by the flue gases which indicates the energy that did not transfer from the fuel to the water in the heat exchanger. The lower the stack temperature, the more effective the heat exchanger design is. Combustion efficiency in boilers will generally range between 60 to 90%

**Water Chemistry:** Water treatment is critical to system performance given that even minor water quality problems can cause major costs. The main parameters to be corrected are the following: water pH should be controlled to be in a range of pH 8-10, and water hardness should be treated to avoid scaling and microbiological matter.

**Flue gas temperature:** If there is no access to combustion analysers, the temperature in the flue gasses can be measured to assess the effectiveness of the heat exchanger and any opportunity for heat recovery.

Flue gas temperatures can range from 90ºC in gas condensing boilers to 300ºC in coal boilers. Be aware that low flue temperatures can cause water vapour to condense. The condensate mixed with other combustion subproducts (e.g. $SO_x$ and $NO_x$) can corrode flue materials.

**Boiler efficiency:** This parameter will indicate the efficiency of the boiler as a whole. It is calculated as the ratio of energy transferred into the water circuit to the energy contained in the fuel consumed.

Typical values for boiler efficiency are:

| | |
|---|---|
| Gas fired boiler | 90% to 98% |
| Oil fired boiler | > 90% |
| Biomass boiler | 80% to 90% |
| Steam boiler | 75% to 87% |
| Carbon/Coal boiler | 75% to 85% |

GtW Indicator

**Best in class A**
Check if the boiler efficiency is higher than 95%

If the mill has several boilers, the auditor will have to check that at least 80% of the production is coming from a boiler with efficiency higher than 95%.

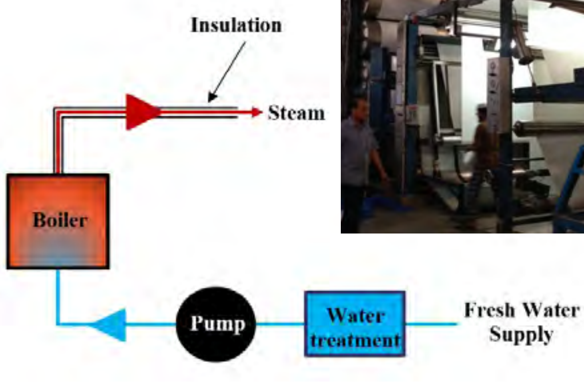
# Steam boilers and pipework

## General description and types

Steam can carry as much as five times more energy than hot water, which is often the reason it can be more cost-effective to use rather than hot water and are more frequently used in the textile processes. Steam boilers are very similar to the already explained conventional boilers, with the difference that they work at different pressures and temperatures in order to produce steam. To produce the steam, the water must be heated well beyond boiling temperature. The boiling temperature depends of water pressure, for example, water in atmospheric conditions (approx. 1 bar) boils at 100 ˚C, and water at 10 bar, working pressure for some steam boilers, boils at 184 ˚C.

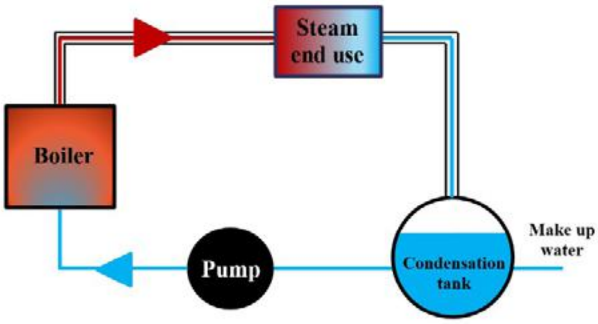
The generated steam is then accumulated in what is called the dome of the boiler until it reaches a pre-set pressure, which is then released through a steam valve into the distribution system. There are two types of steam systems:

**Open systems:** In this type of systems, the steam generated is injected into a product or in other way discharged or sprayed out, requiring new treated water to produce more steam.




Steam open circuit system

**Closed systems:** In this type of systems, the steam generated is transported to the end use consumer where it is used. The used cooled steam condenses into water, and it is returned into a feeding tank and supplied again into the burner to start the cycle again.



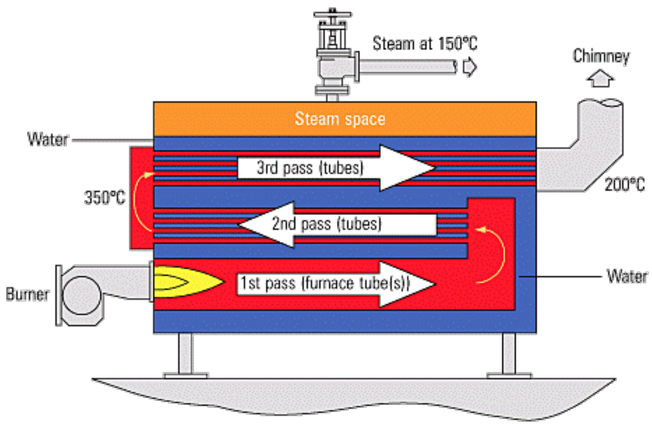

Steam closed circuit system

GtW Indicator

**Poor performance C**
Check if the boiler feed tank is receiving the condensates

## Components

A steam boiler is very similar to a conventional boiler with the difference that at the top of the boiler there is steam instead of water. Steam is released into the distribution system through a steam valve pre-set to a fixed pressure setpoint.




Steam boiler
*Source: Spirax Sarco*

Other system components are:

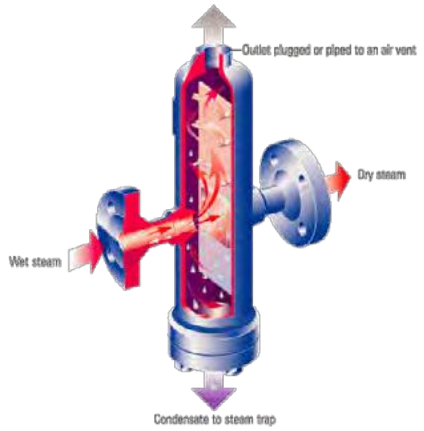
**Water softener and chemical treatment:** Different mains water supplies from different locations will have different characteristics such as hardness (mineral content), PH (acidity or alkalinity) and dissolved gases, each of which will influence in the efficiency and durability of the system.

- Water hardness can affect the heat transfer through surfaces as well as clog control valves and steam traps leading to system failure.

- The PH and dissolved gasses can enhance system corrosion and other adverse effects that will increase the requirement for maintenance.

By installing a water softener and chemical treatment system, the quality of the water can be maintained to preserve system efficiency and durability.

**Separators:** The steam produced in a boiler is inherently wet, which means that carry drops of water, which can cause maintenance problems, including lower efficiencies, erosion, corrosion and other maintenance issues. Separators are designed to efficiently remove the water, also known as moisture from the steam flow.



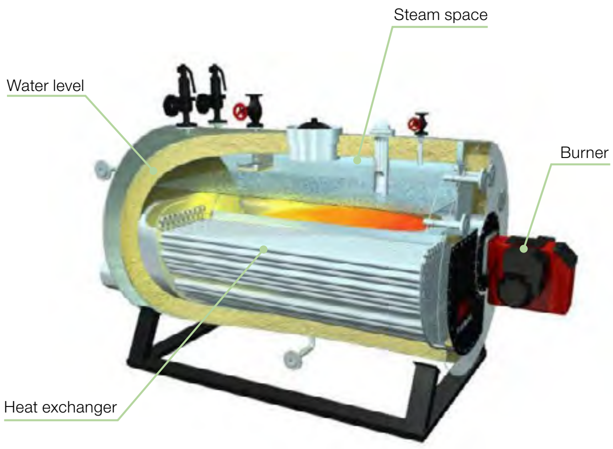

**Separator**
*Source: Spirax Sarco*

**Air venting:** When steam plants are shut down, the distribution pipes are filled with air. It is important to have in place air vents to remove this air, and other gases, when the plants go back online, as they adversely affect the heat transfer and therefore system efficiency and quality of the steam.

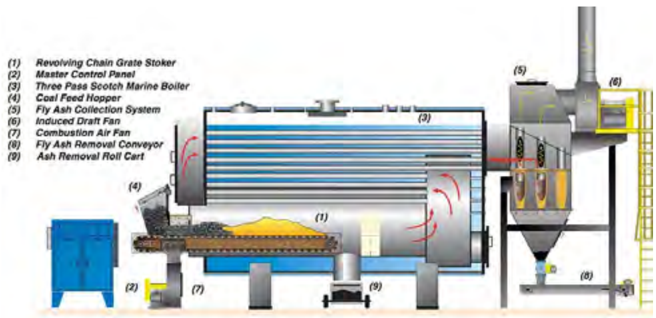
**Steam traps:** Steam traps are installed in the steam system to discharge condensate while not permitting the escape of useable steam. This a very important item in a steam system and should be maintained adequately.

**Strainer:** A strainer is a filter for distribution fluid. It protects valves, pumps and other accessories from water solid impurities.

## Descriptive images




**Gas or Gasoil steam boiler**
*Source: Ttboilers*




**Coal steam boiler**
*Source: Hurst boilers*

**Coal steam boiler**

# Steam boilers and pipework

## Efficiency key facts

All the efficiency key facts described for the conventional boilers are also applicable for steam systems. Additional measures applicable to this type of system are as follows:

### Steam traps

Steam traps are fundamental in any steam system. As described above, they separate condensed water from the steam. It is therefore important to inspect these at least once a year to ensure they are not blocked.

The condensed water separated in the steam traps still has a lot of energy that can be used to preheat the process water used in other systems. Ideally the condensate should be discharged into the boiler feed water tank to recover most of its energy, but it could also be discharged in any sort of tank from where energy could be extracted for other processes.

Additionally to the energy saved, the condensate water, with high purity, can be reused in the boiler feed tank or in any other process requiring clean water, reducing the overall water consumption.

> **Ask how often steam traps are inspected. Are the steam traps leaking? Are they discharging water or steam into a drainage system or the floor? Is the hot condensate sent back to the boiler feed water tank or it energy recovered for other processes?**


Steam traps discharging on the floor

Heat recovery tank

Steam trap

### Steam distribution system

Steam distribution systems work at pressures around 4 to 10 bar. Corrosion and other effects derived from the presence of condensate in the systems can cause cracks and fissures through which the steam escapes reducing system efficiency and creating corrosion and other maintenance issues.

> **Is the steam distribution system leakage-tested annually? Are cracks dripping water or steam fixed timely?**


Steam leakage from a batch drying machine

### Strainer maintenance

Strainers are usually placed before valves, pumps and other elements susceptible to blockage or damage by scale or other impurities. Drainers are usually provided with a basket or filter where the solid particles are collected. It is important to clean these baskets or filters every so often to avoid blockage. Note that this also applies to conventional hot water systems.

> **Are there strainers in the system? How often are they checked and cleaned?**

Strainer

Dirty basket

### Steam Flow meters

Steam flow meters can register the amount of steam consumed by each system. By using steam meters, the measured amount can be compared against manufacturer data to check if the right amount of steam is being used by the system. Lower flow rates could affect the quality of the product; high steam consumption could also affect quality and energy consumption.

> **Are there any flow meters? What are they used for?**

Steam flow meters

### Steam leaks ★★

They are present in almost all factories. The steam leaks are mainly due to damaged fittings, damaged pipe, valves, glands and faulty steam traps.

> **How frequently are steam leaks repaired?**

GtW Indicator

**Good performance B**
Check if steam and water leakages are frequently monitored and tested

### Insulation ★★

Due to either poor construction or poor maintenance practices, boilers, flue and pipe insulation may be damaged or even not existent, thus greatly reducing the amount of heat that can be used for ambient heating or process heating.

> **Check that the insulation is still in place and is preserved in good state**

Well insulated pipework

Worn out insulation

Uninsulated pipe

Insulation of process dying equipment

GtW Indicator

**Poor performance C**
Check that more than 80% of the steam pipelines are insulated

GtW Indicator

**Good performance B**
Check if all the tanks and steam pipes are insulated

## Control parameters

When assessing the performance of a steam boiler system, the following parameters should be measured and monitored:

**Steam Temperature:** The temperature of a steam system is dependent on the process requirements. The temperature of the steam reaching the final equipment should not be higher than is required, as this would increase heat losses and reduce boiler efficiency. Steam temperature usually ranges from 100ºC for wet saturated steam to 230ºC for superheated steam, also known as dry Steam

**Steam Pressure:** The pressure of a steam system is dependent on the process requirements. The pressure of the steam reaching the final equipment should not be higher than it is required, as this would increase steam losses through cracks and reduce boiler efficiency.

Steam systems can be classified by its operating pressure into three groups:

- Low pressure: Vacuum to 0.1 bar
- Medium pressure: 1bar to 6 bar
- High pressure: 6 bar and above

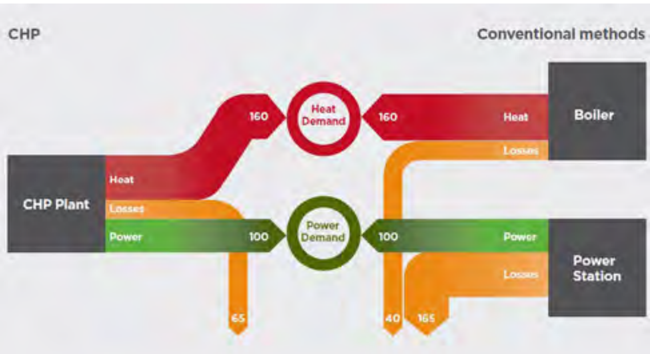
See rest of control parameters under section ‘Boiler’.

# Electrical Generators and CHP

## General description and types

An electrical generator is a term that can mean several things. For the context of textile factories, however, it generally refers to a machine that converts a fuel into electricity for generating on-site electrical power. The most common generators are typically a large diesel engine generator, also called a genset. Generators can be very important in industries and countries where the electrical grid supply is not reliable, and thus on-site generators can be used to prevent disruption of industrial operations. Electrical generators are assessed (as far as the scope of this guide and questionnaire), when they are used as main form of supply of electricity to the factory.

A Combined Heat and Power (CHP) plant is very similar to an electrical generator, with the difference that the heat emitted by the engine is recovered and utilized instead of being disposed to the atmosphere. In industries where process heating is required, as the textile mills, the heat generated by the electrical generator (CHP plant) could substitute the heat that would otherwise need to be generated by a boiler. In the image below it can be seen how for the same output, the energy losses of a CHP plant are much lower.




**Sankey diagram**
*Source: chpa.co.uk*

For CHP plants to be economically feasible it is important to size them so that the majority all the heat and power generated is either consumed onsite or otherwise exported/sold off site. General practice states that for a cogeneration system to be feasible it should run at least 12 hours a day with full electricity and heat demand, which could be a good rule of thumb to recommend it or not. Be aware that CHP plants are usually not sized to provide 100% of the heating/electrical load. It is recommended to install boilers and additional generators (likely diesel gensets) if needing to provide for the peak demands.

## Components

The main components of an electrical generator are:

**Engine:** The engine is the source of mechanical energy to the generator. The size of the engine is directly proportional to the maximum power output the generator can supply. The engines can use different types of fuel such as diesel, gasoline, propane or natural gas, although the type of generator that we expect to find in industries will generally be run on diesel.

**Generator:** Is the part of the generator that produces the electrical output from the mechanical input supplied by the engine. It contains an assembly of static and moving parts (stator and rotor) encased in a housing which through electromagnetic induction creates the electrical current. The components work together to cause relative movement between the magnetic and electric fields, which in turn generates electricity. Note that this is also often referred to as the generator, which can lead to confusion since the entire machine is also called a generator.

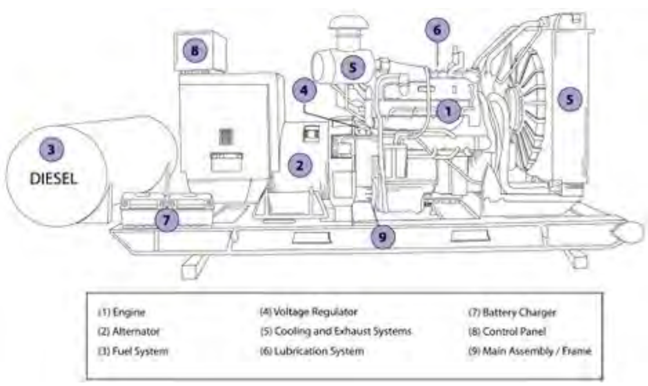
**Fuel tank:** The fuel tank has to be sized according to the expected use, whether it is for shorts or long periods of time.

**Voltage regulator:** this component regulates the output voltage of the generator to adapt it to that required.

**Cooling system:** Continuous usage of the generator causes its components to get heated up. It is essential to have a cooling and ventilation system to withdraw the heat produced in the process. The typical cooling system is a radiator and a fan mounted in the generator as shown below. In large generators it may be needed to reject the heat into a dry air coolers or a cooling towers.

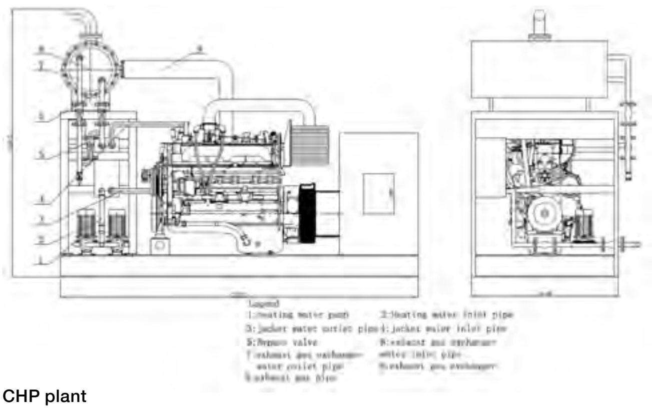
In the case of CHP plants, they will generally have two heat exchangers to recover the heat from the exhaust gases and the engine jacket coolant. The recovered heat will need to be used as process heat or otherwise dissipated in dry air coolers or cooling towers, reducing the efficiency of the CHP process.

**Exhaust system:** Exhaust fumes emitted by a generator contain highly toxic chemicals that need to be properly managed. Exhaust pipes are usually attached to the engine using flexible connectors to minimize vibrations and prevent damage to the generator's exhaust system.




**Electrical generator**
*Source: Cleantechnica*

**Electrical generator**



**CHP plant**
*Source: Camda*

**Electrical generator**
*Source: Huaquan Power Machinery*

## Descriptive images

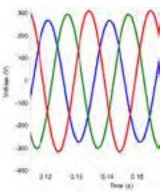
**Electrical generator**
*Source: Nvidia*

## Efficiency key facts

### Balance loads

For three phase generators, it is always recommended to have the connected load as balanced as possible (each phase with similar connected kW), since unbalanced loads can cause heating of the alternator, which may result in unbalanced output voltages. The maximum unbalanced load between phases should not exceed 10% of the capacity of the generator.

> **Are loads managed?**



# Electrical Generators and CHP

## Parallel operation

In many cases, the electrical load will not be constant throughout the day. If there is substantial variation in load, then consideration should be given for parallel operation of several electrical generators, switching on and off generators as the load increases or decreases, respectively. With parallel operation, generators can be run at or near their optimum operating points or, optimizing efficiency and resulting in the least possible fuel consumption. Caution must be taken to ensure generators are not constantly being switched on and off, as this would reduce their working life.

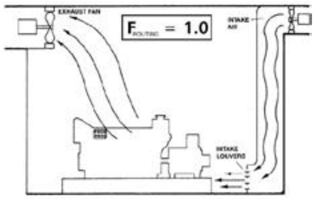
> **How many generators are installed onsite? How is it managed its functioning?**

*Source: Logistics Engineering College*

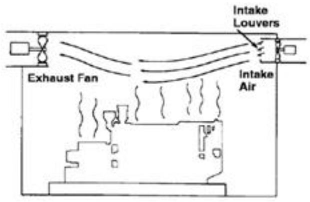
## Ventilation air

A properly designed ventilation system should be able to maintain engine room air temperatures within 8-12ºC above ambient air temperature when engine is running. Room temperatures above 40º C will derate the generator performance. Fresh air inlets should be located as far from the sources of heat as practical and as low as possible. Ventilation air should be exhausted from the engine room at the highest point possible, preferably directly over the engine.

> **Are the generators located in an enclosed space? What is the room temperature when generators have been running for a few hours? Are the intake and exhaust adequately located?**




Adequate ventilation




Incorrect ventilation

## Combustion air

It directly impacts on the engine and package unit performance. Generators should run on cold dust-free air. All quality generators have intake air filters with replaceable filter elements. Air intake system can generally be wet or dry. In wet filters air is sucked through a housing that holds a bath of oil such that the dirt in the air is removed by the oil in the filter. In a dry filter system, paper, cloth, or a meal screen material is used to catch and trap dirt before it enters the engine. In addition to cleaning the air, combustion air should be as cool as possible since cooler air is denser which increases the combustion efficiency and increases the generator output.

**Filter**
*Source: knfilters*

## Fuel filter and water separator

These accessories are highly recommended in any generator to protect the engine from dirt and sediment, which can restrict the fuel flow to the injectors reducing the engine output. Additionally to the power reduction, dirty fuel filters can clog injectors and in general deteriorate engines reducing their lifespan. It is also recommended to install an air filter in the tank breathers to reduce the amount of dirt entering the fuel tank.

Water in the fuel can cause corrosion and reduces the lubricity of fuel. It can negatively affect the combustion process and consequently damage system components. Water generally enters in the fuel system through the storage tank.

> **Has the fuel supply system filter and water separators? How often this accessories are maintained?**

If the electrical generator is already installed onsite, a heat exchanger could be retrofitted to pre-heat the water going into the steam generator, pre-heat air for drying or other process applications.

> **Are there any electrical generators on-site? Does it need replacement? Could the heat recovered from the electrical generator be used for process heating?**

GtW Indicator

**Best in class A**
Check if the mill carries out cogeneration by heat recovery of electrical generation exhaust and cooling

## Calibrate fuel injection pumps

Time, poor fuel quality, water and other impurities, and normal wear and tear cause the fuel injection pump and injectors to perform outside specifications, reducing the power generated, increasing fuel consumption and emitting more contaminants. Injectors and injection pumps should be calibrated as often as recommended by the generator manufacturer.

> **Have the injector or injector pumps ever been calibrated? When was the last time?**

## Generator efficiency

Generator efficiency can be calculated as the ratio between the amount of electricity generated, measured in kWh, and the energy contained in the fuel consumed (calculated as the fuel volume consumed x fuel density x fuel calorific power). Monitoring generator efficiency is fundamental to evaluate when generator needs corrective maintenance.

> **Is the generator efficiency measured? Is it registered generator fuel consumption? Are these values registered and monitored?**

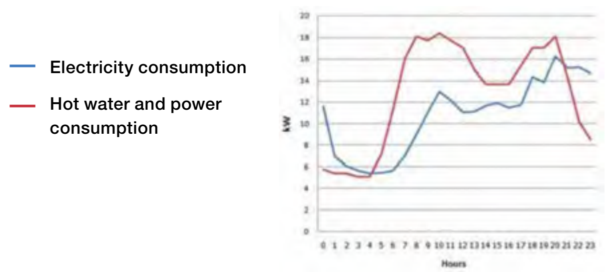
## Electrical generator VS CHP plant ★★

Any CHP plant is based on an electrical generator in which the engine cooling components have been sized and adapted to recover the heat to produce hot water or steam at the designed temperature. Whereas an electrical generator have efficiencies in the range of 30-35 %, a CHP plant have efficiencies in the range of 80-90 % if all the electricity and heat generated is used, producing average energy cost savings of 30-40%.

## Heat and power load

When installing a new CHP plant it is very important to know what are your electrical and heat demand profiles (average daily demand) to appropriately size the CHP plant. CHP plants are generally sized according to heat demand, being the electricity generated the by-product when the main source of reliable electricity is the grid.

This could not be so relevant in those factories in which the electrical generator is designed to supply the electrical load, due to the electrical grid not being reliable. In any case, heat recovery for other process loads will always increase system efficiency, although some energy may have to be rejected into the atmosphere if process heating demand is lower than the energy recovered. Many existing mills in countries such as Bangladesh are producing their own electricity not recovering the heat and simultaneously burning fuels to provide heat for the process. The scope for efficiency in those mills derive from the waste heat reuse for the textile process is enormous.



# Electrical Generators and CHP

## Control parameters

When assessing the performance of an electric generator, the following parameters can be measured and monitored:

**Electrical power:** The performance of an electrical generator can be reduced by many causes. Measuring the power output of the generator working at 100% load could be a way to detect if the generator is working correctly, however to do this functional test, a resistor bank it is required which may not be easily accessible.

**Other electrical parameters:** Electrical equipment is designed to work at a certain voltage and electrical frequency conditions. (see *http://www.worldstandards.eu/electricity/plug-voltage-by-country/*)

It is important to ensure that the electricity produced by the generator complies with the local requirements. As explained in the motors section, electrical motors can operate within certain deviations in voltage which should not be exceeded.

**Fuel Consumption:** Fuel consumption needs to be measured to calculate generator efficiency. According to the fuel type, the consumption will be measured in $Nm^3$ (Normalized cubic meters) for gases or litres or $m^3$ for liquids.

Together with the consumption, it is recommended to obtain from the provider information on the density ($kg/m^3$) and calorific power ($kJ/Nm^3$, kJ/l, $kJ/m^3$) for the delivered fuel. Although there is tabulated standard values for these two parameters, it is better to request this information from the providers as there may be significant variations between providers.

**Generator efficiency:** This parameter will indicate the efficiency of the generator as a whole. It is calculated as the ratio of the electrical energy generated, measured with an electrical energy meter, to the energy contained in the fuel consumed by the generator engine. The instantaneous efficiency will fluctuate with the loading of the generator. It is therefore recommended to calculate the average efficiency of the generator in a period of time that represents a full factory cycle (e.g. 1 day, one week, etc.)

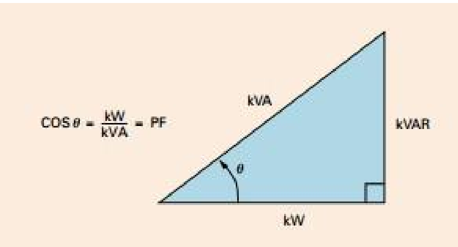
The efficiency of a generator usually ranges between 20-40%. If the generator is also used to produce hot water (CHP plant), the maximum efficiency will range from 70 to 85%. It is very important in the design of a CHP plant to find a consumer for all the heat rejected by the CHP plant. If heat production exceeds the heat demand, cooling towers, radiators or other heat rejection devices will be needed reducing the overall system efficiency.

**Flue gas temperature:** Due to inefficiencies in the combustion process, approximately 30% of the fuel energy is exhausted through the flue in the combustion gasses. By measuring flue gas temperature, it could be estimated the amount of heat that could be recovered. Flue gas exhaust, also known as exhaust stack, temperatures are generally within the 300-500ºC range.

# Electrical Power Factor (PF) correction

## General description and types

Power factor is a term that expresses the relationship between real power (the power actually consumed in kW) and the apparent power (the power that must be supplied by the electric company to have this true power available in kVA). This ratio is a number between 0 and 1, and is expressed as a percentage (e.g. 0.98 = 98% pf).




**The 'Power Triangle' illustrates this relationship between KW, KVA, KVAR, and Power Factor**


**True power** is measured in kilowatts (kW), and represents the ability of the circuit to perform useful work.

**Reactive power** is measured in kilovolt-amperers reactive (kVAR), and represents the power required for reactive loads, such as maintaining electromagnetic fields for electric motors.

**Apparent power** is measured in kilovolt-amperes (kVA), this power is required to operate the device.

A high power factor is generally desirable in a transmission system to reduce transmission losses and improve voltage regulation at the load. It is desirable to adjust the power factor of a system to near 1.0 or 100%.

Some of the benefits of improving the power factor is that the energy bill will generally be smaller. Low power factors increase losses in the distribution system, requiring an increase of the capacity of electric generation, which generally result in a penalty fee to customers with power factors lower than 0.95.

Low power factor reduces the electrical system's distribution capacity by increasing current flow, causing voltage drop, overheating of cables and motors and premature failures of motors and other inductive equipment.

**Power Factor Correction Equipment**
An automatic power factor correction unit consists of a number of capacitors that are switched on and off by means of contactors. These contactors are controlled by a regulator that measures the power factor in the electrical system. Depending on the load and power factor of the network, the power factor controller will change the necessary blocks of capacitors in steps to make sure the power factor stays above a selected value.

## Components

1. **Reactive Power Control Relay:** is the automatic control of capacitor. The relay maintains the system power factor at a set value under fluctuating load conditions.

2. **Network Connection Points.**

3. **Slow-Blow Fuses:** help provide overcurrent protection on systems that experience large and frequent current peaks as part of their normal operation.

4. **Inrush Limiting Contactors:** is a component used to limit the maximum instantaneous input current drawn by an electrical device when first turned on.

5. **Capacitors** (single-phase or three-phase units, delta-connection): is a two-terminal, electrical component, used to store energy electrostatically in an electric field.

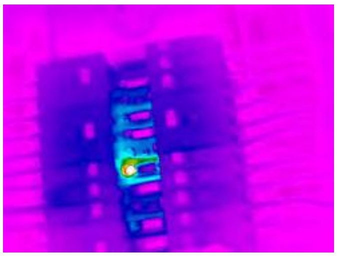
6. **Transformer** (for controls and ventilation fans): is an electrical device that transfers energy between two or more circuits, are designed to reduce supply voltages to control circuit.

## Descriptive images

Examples of PF measures and correction equipment in some factories audited:




**Hot spots:** With the help of thermal imaging, it is possible to asses if there is any problem in the electrical devices or connections within the power correction device.



Thermal image

As a general rule, corrective maintenance should be undertaken when an electrical component reaches a temperature of 40ºC above room temperature.

## Efficiency key facts

### Power factor

It is recommended to install a power factor correction device to reduce reactive energy consumption. This can be installed either at the connection point to grid or next to the reactive energy consuming equipment (e.g. electric motors, fluorescents, transformers, etc.). Corrective power factor equipment generally includes a display indicating the instantaneous power factor of the facility.

> **Is there any power factor correction equipment? If none exists, is the electricity utility applying penalties for reactive power consumption? If power factor correction equipment does already exist, what is the instantaneous power factor?**

## Control parameters

When assessing the performance of a power factor correction device, the following parameter should be measured and monitored:

**Power factor:** In electrical systems with power factor correction devices, it is expected to find a power factor between 0.9 and 1.0. The closer this figure is to 1.0 the less reactive energy is being consumed from the grid.

# Air compressors and distribution

## General description and types

An air compressor is a machine that extracts air from the atmosphere and compresses it into a pressurized tank. The most common use of compressed air is for the operation of pneumatic tools. Air compressors are classified by volume of compressed air ($m^3$/s or cfm) they can produce and the pressure at which they can deliver that air. Air compressors are generally powered by electric motors connected to the grid or by fuel engines (diesel, gasoline, gas).

**Reciprocating, screw and scroll compressors**
*Source: Atlas Copco*

## Components

**Compressor:** There are three main types of compressors. These types are:

- Reciprocating air compressors: Generally used for high pressures and lower volumes. It is a cheaper technology but usually more noisy and they deliver the air at higher temperature and with higher oil content.
- Screw air compressor: Used for continuous applications as they can deliver higher volumes at lower pressures. Low noise level, Good energy-efficiency, relatively low air supply temperature but higher cost and more maintenance required. They can be oil injected or oil free.
- Scroll air compressor: they generally provide lower volume capacity at higher temperature compared to the types above. They are expensive but are the quietest of the three and run without oil.

Air compressors can be single or dual stage when they have two stages of compression. Compressors can be oil-injected or oil-free, first ones are cheaper and quieter but the compressed air will carry a small amount of oil.

**Air filters:** Compressor air filters can be found in two places: at the air intake of your air compressor and in the compressed-air piping, between the compressor and the consumers (machines, air tools, etc).

Air intake filters protect the compressor from any dust and dirt which it might draw in. These are very important as dust will wear to the compressor element, valves and other parts.

Compressed air filters protect the end use equipment from dust, dirt, oil and water. Dust will wear down the equipment, especially when the dirt and dust is combined with oil, which is often the case with cheaper compressors.


*Source: Atlas Copco*

**Intercooler and aftercooler:** Air temperature is raised when the air is compressed. When the heated air passes through the intercooler or aftercooler (air to water or air to air) it is cooled which condenses some of the moisture content, drying the air and protecting the system from rust. The term intercooler is generally used when the cooling system is located between stages of compression. Aftercoolers are used after the last stage of compression.

**Air dryer:** Air dryers are generally placed after the aftercooler and remove additional moist from air. There are many different types of dryers according to the application. The most usual are mechanical dryers, working by centrifugal force, refrigerated dryers, similar to aftercoolers but reducing further air temperature and desiccant air dryers, using desiccant materials.

**Oil:** Oil in air compressors have multiple functions:

- Removes heat from the compressor.
- Seals to prevent air leakage, which would lower the efficiency.
- Lubricates all moving parts.

**Pressure switch:** The pressure switch regulates when the compressor switches on and off. It has settings for upper pressure, when the compressor will cut-out, and a cut-in lower pressure setpoint.

**Unloader valve:** The air compressor unloader is the valve that blows off the pressure inside the discharge pipe when the compressor stops.

**Variable Speed Drive:** Variable speed drives regulate the compressor speed to control the amount of compressed air being produced, and avoid the compressor to switch on and off, which is known as loading and unloading.

Other system components:

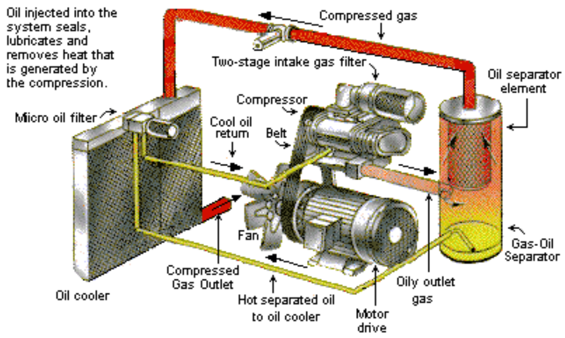
**Air storage tank:** Compressed air is delivered in an air tank that acts as a buffer tank absorbing the fluctuations of the compressed air consumed by the end use equipment. Air tanks have to be appropriately sized according to the consumption profile. Air tanks can be horizontal or vertical according to the spatial requirements.

Drain traps: drain traps collect any condensed water that may have been formed or carried into the pipe distribution system.

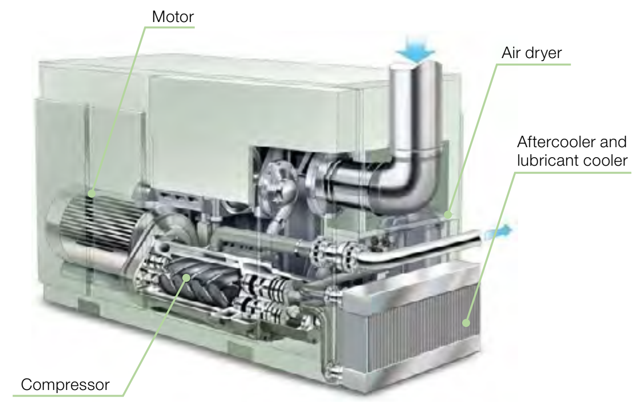
Special machinery may need additional air dryers or pressure controllers before the point of connection.

**Drain trap**
*Source: Kaeser*

## Descriptive images




**Oil lubricated air compressor**




**Rotary screw compressor**

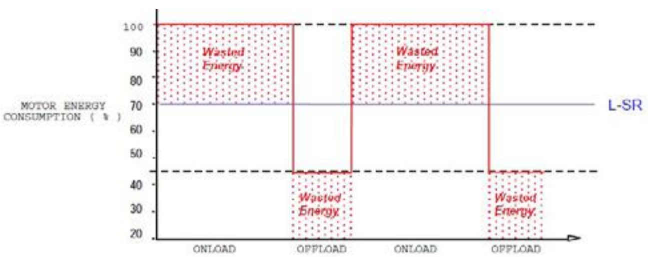

**Air compressor, tank and filters in audited mills**

# Air compressors and distribution

## Efficiency key facts

### VFD

The use of variable speed drives in compressors reduce the unload losses, that is the energy consumed by the compressor when there is no compressed air demand. In the image below it can be seen how air compressors still consume 20-40% of the maximum power when they are unloaded or offload.




**Conventional load/unload graph**
*Source: genaircomp*

VFD compressors allow for a tighter pressure band and a lower average working pressure, resulting in reduced energy consumption.

> **Have the air compressors VFDs? Is it possible to install them?**

### Cleaning air filter

Compressor air filters need to be cleaned and/or replaced regularly. Replacing the air intake filter is part of the standard service routine. Dirty air filters will restrict the flow of air to the compressor, incrementing the pressure drop and reducing the output of the compressor which in turn increases the energy bill.

In very dusty or dirty environments, it is recommended to install compressors in their own room with fresh air, or install ducting to supply the compressor with fresh air.

> **How often are air filters cleaned or replaced?**


**Dirty and clean air filter**

### Reduce pressure settings

Working pressure is commonly set to the maximum pressure to compensate for pressure drop between the compressor and the target equipment. However, it is often possible to reduce this pressure without negative effects on manufacturing. Optimizing pressure settings, almost always a zero-cost practice, saves energy and reduces the volume of air loss through leaks. To do this it is essential to know what the required pressure of the end use equipment is and install pressure gauges to be able to compare them.

> **Is there information on the require air pressure of the end use equipment? Is there manometers in the distribution system to check the pressure?**

### Repair leakages in compressed air lines

Large distribution systems are susceptible to leakage. Most such leaks are at threaded connection points, rubber hose connections, valves, regulators, seals, and in old pneumatic equipment. Compressed air leaks can account for 20 to 75 percent of air demand in a plant that has no regular maintenance policy. It is therefore essential to monitor air leakage at least once a year and repair air leaks.

> **How often are distribution system air leakages checked and repaired? Is there any system in place to monitor air leakage?**

### Switch off compressors

Adequate controls are always essential to reduce energy demand. Compressed air demand may have substantial fluctuations throughout the day. When there is one single air compressor or a set of them, it is recommended to have controls so the least number of required compressors are running. Ensure compressors are not running for long periods of time with no demand.

> **In the case there are multiple compressors, how are they managed? Manually or automatically by any controller? Are compressors left running without any air demand?**

### Recover waste heat

As much as 80 to 90% of the electrical energy used by an air compressor is converted to heat. A properly designed heat recovery unit can recover 50 to 90% of this heat for heating air or water.

> **Is the heat emitted by the air compressor reused in any way? Some newer models may already come prepared for heat recovery.**

### Cooler intake air

The energy required to compress cool air is much less than that required to compress warmer air. Move air intake to shaded areas and away from equipment emitting heat. It is estimated that a 10ºC reduction in air temperature will reduce the operating costs in 4%.

> **Is the air withdrawn from hot areas? Does it seem possible to take the air from cooler areas?**

### V-belts

Loose belts slip more frequently which reduces compressor efficiency.

> **Is the tightness of the V-belts checked regularly?**

### Air tank

Air tanks can buffer short-term demand changes and reduce on/off cycling of the compressor, reducing costs and increasing the lifespan of compressors. The tank has to be correctly sized according to the power of the compressor.

> **Is there an air tank? What is its size?**

### Pressure drops

The compressor must produce air at a pressure high enough to overcome pressure losses in the supply system and still meet the minimum operating pressure of the end use equipment. Pressure loss in a properly designed system will be less than 10% of the compressor's discharge pressure found on a gage on the outlet of the compressor. If pressure loss is greater than 10%, evaluate your distribution system and identify areas causing excessive pressure drops.

> **Are pressure drops monitored? What are they?**

## Control parameters

When assessing the performance of an air compressor, the following parameters should be measured and monitored:

**Air pressure:** Air pressure is the most critical parameter of an air compression system. The system should include pressure gauges distributed throughout the installation to allow for checking of the air pressure at the different parts of the system. The air pressure of a system depends on the pressure requirements of the devices connected to the system, but it can generally be expected to find pressures in the range of 6 bar to 15 bar.

**Air volume:** The performance of the air compression system will derate throughout its lifetime, due to a variety of reasons, including poor maintenance practices and normal wear and tear. As part of the maintenance practices it is recommended to check the volume of compressed air produced by the systems at 100% load and then compare this to manufacturer's recommendations.

**Electrical consumption:** The electrical consumption of an air compressor may be affected by multiple variables. When assessing the performance of an air compressor it is important to measure the energy consumed by it to compare it to manufacturer data.

**Air quality:** Air quality, or 'class' of any given air system is determined according to the purity of the air. Oil content, residual dust content and water content are considered impurities that reduce air quality. In the table below it can be found the maximum concentrations allowed for different air classes according to the international standard ISO 8573.

# Air compressors and distribution

| Class | Max. Dust | | Max. Water | | Max. Oil concentration (mg/m³) |
|---|---|---|---|---|---|
| | Partical size (µm) | Concentration mg/m³) | Residue (g/m³) | Pressure dew point (°C) | |
| **1** | 0.1 | 0.1 | 0.003 | -70 | 0.01 |
| **2** | 1 | 1 | 0.117 | -40 | 0.1 |
| **3** | 5 | 5 | 0.88 | -20 | 1 |
| **4** | 15 | 8 | 5.953 | +3 | 5 |
| **5** | 40 | 10 | 7.732 | +7 | 25 |
| **6** | - | - | 9.356 | +10 | - |

**Compressed Air Purity classification**
*Source: ISO 8573-1*

Please also find a table below showing the recommended air quality for different compress air uses.

| Typical Class | Dust | Water | Oil |
|---|---|---|---|
| **Air agitation** | 5 | 3 | 3 |
| **Air bearing** | 2 | 3 | 2 |
| **Air gauging** | 3 | 3 | 2 |
| **Air motors** | 4-1 | 5 | 4 |
| **Cleaning of machine parts** | 4 | 4 | 4 |
| **Construction** | 5 | 5 | 4 |
| **Food and beverages** | 3 | 1 | 2 |
| **Hand-operated air tools** | 5-4 | 5-4 | 4 |
| **Machine tools** | 3 | 5 | 4 |
| **Micro-elements manufacture** | 1 | 1 | 1 |
| **Packaging and textile machines** | 3 | 3 | 4 |
| **Pneumatic cylinders** | 3 | 5 | 3 |
| **Pneumatic tools** | 4 | 4 | 4 |
| **Process control instruments** | 2 | 3 | 2 |
| **Paint spraying** | 3 | 3 | 3 |
| **Sand blasting** | 3 | 3 | - |
| **Welding machines** | 4 | 5 | 4 |
| **General workshop air** | 4 | 5 | 4 |

**Compressed air purity required for each application**
*Source: ISO 8573-1*

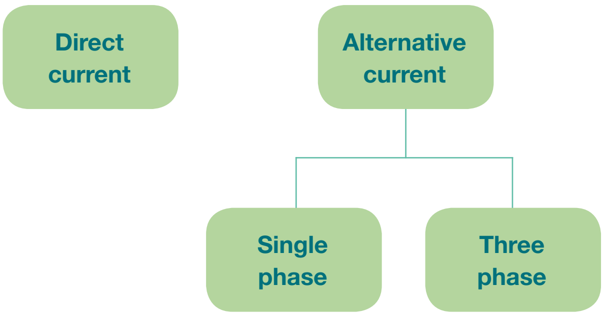
# Electrical motors

## General description and types

An electric motor is an electric machine that converts electrical energy into mechanical energy; in this way they are the opposite of an alternator/generator. Electric motors are one of the largest end user of electricity in factories. They are used to drive pumps, fans, compressors, conveyors and many other processing equipment such as Stenters or Spinning machines.

Motors are generally selected according to their power, often measured in units of kW or horsepower (hp), as an indicative of the torque they can provide. Torque is the force acting on an object that causes it to rotate about an axis. Other parameters that define an electric motor are its rotating speed, service factor or the type of electricity consumed.

The widest classification of electric motors, without going into too much detail, is to divide them into direct current (DC) and alternative current (AC). Within AC motors they are split further into single phase (generally for smaller motors) and three phase (for larger motors). A diagram showing these groups is shown below.




Three phase motors are generally more efficient than single phase motors. One of the major problems with single phase motors is that they tend to require large starting currents relative to the motors' size, which increases the size of installation required.

## Components

The main components of an AC electric motor are:

**Frame:** The frame or enclosure holds all the motor components together at the same time that protects it from moisture and contaminants. Frames can be open or enclosed, according to their permeability to outside air. Frames are generally ribbed to help dissipate heat.

**Stator:** The stator is the stationary part of the motor's electromagnetic circuit. It creates the electromagnetic field that induces the rotor to turn.

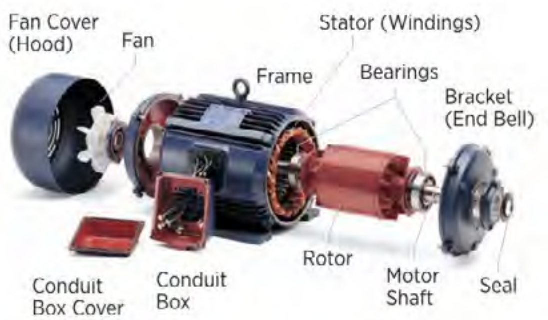
**Rotor:** The rotor is the rotating part of the motor's electromagnetic circuit. The magnetic field from the stator induces an opposing magnetic field onto the rotor causing the rotor to 'push' away from the stator field.

**Bearings:** The bearings mounted on the shaft, support the rotor and allow it to turn. The bearings have to be selected according to the weight of the stator, rotating speed, operating temperature, dirty and rust environmental conditions within other characteristics.

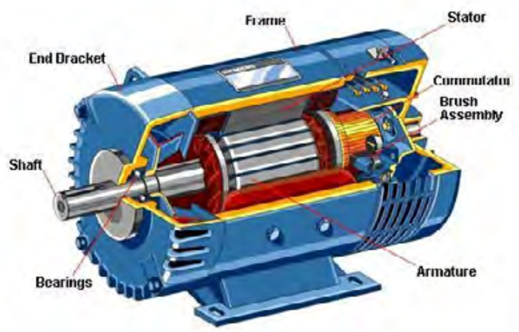
**Conduit box:** Point of connection of electrical power to the motor's stator.

**Fan:** Some motors have a fan attached to the motor shaft for cooling. Others rely on convection and radiation.

## Descriptive images




**Induction motor**
*Source: Leeson Electric Corporation*




**Brushed Direct current motor**
*Source: electrical-knowhow.com*

**DC motor**
*Source: Rotron and greenheck*

**AC motor**
*Source: Marelli and Baldor*

## Efficiency key facts

### Energy Efficient motors

Old electric motors are generally less efficient than new motors, with efficiencies above 92%. For motors working continuously during many hours a day, its replacement can payback in short periods of time. All motors should be assessed to evaluate how effectively and efficiently they are meeting the needs of the system. This evaluation has several benefits, which include helping to prioritize performance improvement opportunities and providing a useful baseline for determining whether system efficiency is declining and remedial actions need to be taken. Screening a plant's motors by motor size and annual operating hours can make it easier to identify the best opportunities for improvements.

When replacing a standard motor with a premium efficiency one, it is important to pay careful attention to replacement motor performance parameters such as full-load speed and torque. The replacement motor's performance should be as close as possible to that of the original motor (if the load remains equal)

> **How old are the motors? Has their efficiency ever been measured?**

### Installation of VFDs

Some motors drive equipment (i.e. fans, pumps, washing/drying and other equipment) that do not need to be always working at 100% speed. In these cases, most motors can be fitted with a Variable Frequency Drives (VFD) that will alter the frequency of the incoming electricity changing the motor speed. It is required that a professional evaluates the motor to ensure it can be fitted with a VFD control. To install a VFD, other sensors or controllers need to be installed so there is one or a few measured parameters that will dictate if motor speed can be reduced or needs to be incremented (i.e. for a fan that provides ventilation and cooling to a plant room, a thermostat could be used to increase/decrease fan speed according to room temperature.

> **Has it been evaluated if motors can be provided with Variable Frequency Drives? If some motors are fitted with VFSs, is it indicated in the VFD screen their load? What is it?**

*Source: Nuenergy*

### Power factor

As explained in its section, the power factor is the relation between the active and apparent (which includes both the active and reactive) power consumed by the equipment. Low power factors can be consequence of oversized motors. Lightly loaded motors tend to operate with low power factors. Low power factors increase losses in distribution systems as well as create additional stress on transformers.

Since utilities often charge fees for reactive power to recover the costs associated with losses on their distribution lines, it is recommended to install condensers or capacitor sets to correct it and reduce the amount of reactive power consumed.

> **What is the power factor of the installation? Is it corrected with a condenser set?**

# Electrical motors

### Overvoltage and undervoltage

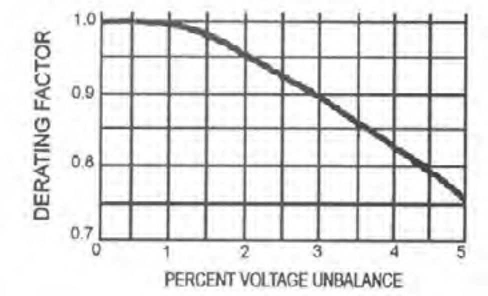
Motors are designed to operate with +/– 10% of their rated voltage. However, even within this range, changes in the voltage supplied can affect a motor's performance, efficiency, and power factor. Ideally, deviations in the voltage supplied to a motor system should be less than +/– 2%.

> **What is the voltage reaching the motors? Is it withing the ± 2% or ± 10% range?**

### Unbalances

A nonsymmetrical, or unbalanced system is so called because of differences between any of the three phases. A voltage unbalance results in a current unbalance, which can significantly reduce the efficiency of a motor. An unbalance will also reduce the life of the motor because of the excess heat generated in the stator and rotor assembly.

> **Is it possible to detect any unbalance in the motor current with an electrical analyser?**




### Motor management program

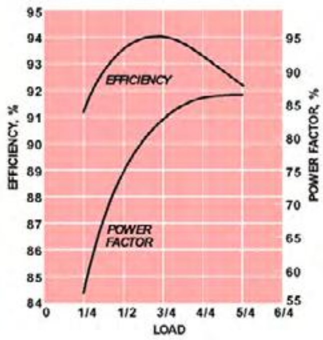
Although most industrial facilities rely heavily on motor systems to maintain or support production, these systems are often overlooked as manageable assets. A management program must institute repair/replace and purchasing policies, establishing a motor inventory, tracking motor life, creating a spares inventory, and establishing a schedule for required maintenance. The benefits of implementing a motor management pro¬gram include greater motor reliability, improved overall system performance, and lower energy costs.

> **Is there any motor management program?**

### Oversized motors

Motors are oversized when they power end uses that require less horsepower than the motor is capable of producing. For example, when a 10 hp motor is used for an application that calls for a 5 hp motor, the motor is 100% oversized, or operates at 50% full-load. At smaller load factors motor efficiency is lower, leading to increased operating costs. Motors operated at low load factors have lower power factors.

> **Are the motors correctly sized to their use? Are electric motors working at higher loads than 50% for most of the time?**




### Starter controls

A soft starter is a device used to temporally reduce the electrical current surge of the motor during startup. This reduces the mechanical stress on the motor and shaft, as well as the electrodynamic stresses on the power cables and electrical distribution network, extending the lifespan of the system. It is also beneficial to sequence the start of the equipment to avoid adding the current surge of all the different equipment, making a big peak of current. Delay 1 minute the start of each system.

> **Is there any starter control? Is all the equipment being enabled through a single switch?**

## Control parameters

When assessing the performance of an electrical motor, the following parameters should be measured and monitored:

**Electrical consumption:** The electrical consumption of the electrical motor may be affected by multiple variables. When assessing the performance of a motor it is important to measure the current draw by the motor and compare it with the manufacturer data. Together with this measurement, it is recommended to measure the voltage in the connection point to the electrical distribution system to ensure voltage is within the motor's allowed voltage deviation.

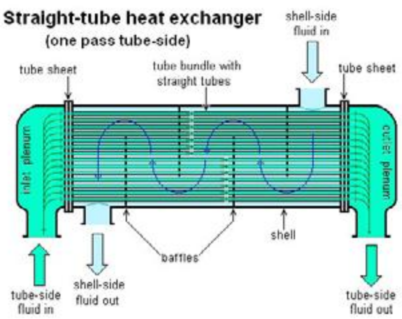
# Heat exchangers and heat recovery

## General description and types

A heat exchanger is a device that allows heat from a fluid (a liquid or a gas) to be transferred to a second fluid (another liquid or gas) without the two fluids having to mix together or come into direct contact.

There are four types of heat exchangers based on the type of fluids used (applicable to this guide):

- Water to water heat exchanger
- Water to air heat exchanger (e.g. Air handler)
- Air to water heat exchanger (e.g. boiler)
- Air to air heat exchanger




This technology also enables heat recovery, that is, the collection and re-use of heat arising from a process that would otherwise be lost or 'wasted'. Heat recovery can help to reduce the overall energy consumption of the process itself, or provide useful heat for other purposes.

Heat recovery and heat exchangers need a source of wasted heat and a lower temperature 'heat sink' to transfer the recovered heat to. Ideally, the source of wasted heat and the sink should be nearby. For example, recovery of heat from boilers' exhaust air to preheat boiler's incoming water is a good example of the heat source and sink located in close proximity.

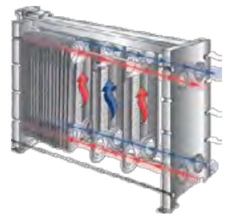
Recovered heat is a valuable and flexible resource. Examples of potential sources of waste heat can be the following: boiler exhaust gases, steam boiler blow down, flash steam from steam condensate, process cooling systems heat rejection, air compressors, hot exhaust air from dryers, furnaces, and generators, hot water from dyeing machines.

The most common uses of recovered heat are: pre-heating of combustion air for boilers, ovens, furnaces, etc.; pre-heating of fresh air used to ventilate the building or space heating; hot water generation, including pre-heating of boiler feed water; drying.

## Components

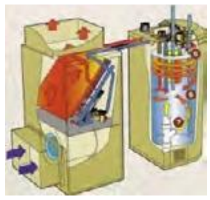
There are several possible layouts for a heat exchanger. The basic components are the frame holding together the tubes or plates, and the heat exchanging tubes or plates with the different fluids in each side.

## Descriptive images

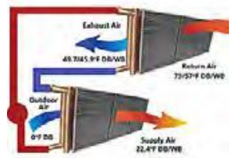
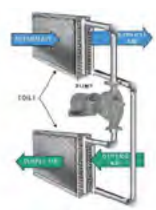



Water to water heat exchanger

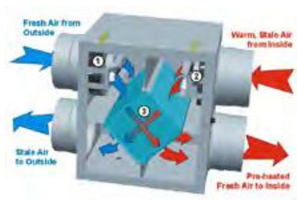




Water to air heat exchanger

Air to water heat exchanger


Air to air heat exchanger

## Efficiency key facts

### Heat recovery from process water ★★

Manufacturing processes use large quantities of hot water that can be directly reused for other processes, reducing the demand of fresh water and heat demand. If water quality doesn't allow to reuse it, the heat contained in it can still be captured and used to preheat incoming water. This heat recovery also adds the additional benefit of reducing the temperature of the wastewater prior to treatment.

GtW Indicator

**Best in class A**
Check if there are heat exchangers to recover heat from wastewater

### Maintenance

Exchange surfaces have to be as clean as possible to guarantee the system maximum efficiency. Avoid oxide and lime formation.

Maintenance should include a periodical clean out with a lime, scale and rust removal product. This can also apply to air heat exchangers where the dust and other impurities can reduce the amount of heat recovered.

> **Are there heat exchangers? How often are they cleaned and maintained?**

### Leaks

Rust or just normal wear and tear may damage the heat exchanging surfaces or the seals, which could result in damaged plates or tubes mixing both fluids, or the heat exchanger dripping water or air outside the frame.

> **Are there any leaking heat exchangers?**

## Control parameters

When assessing the performance of a heat exchanger, the following parameters can be measured and monitored:

**Pressure drop:** The pressure drop through a heat exchanger may be increased throughout its use due to the scaling or rusting. As part of the maintenance it is recommended to measure the pressure drop and compare it to the manufacturer's data to assess if scale or rust is building up.

**Efficiency:** Heat exchanger performance can deteriorate with time, from changes in operations and other interferences such as fouling, scaling, etc. It is therefore necessary to assess periodically the heat exchanger performance in order to maintain a high efficiency level. By measuring temperature and flowrate of both air/water streams, the heat exchanger efficiency can be calculated. The expected calculated efficiency should be in the range of:

| | |
|---|---|
| Water-Water | 80-99% |
| Water to air | 40-90% |
| Air to air | 40-70% |

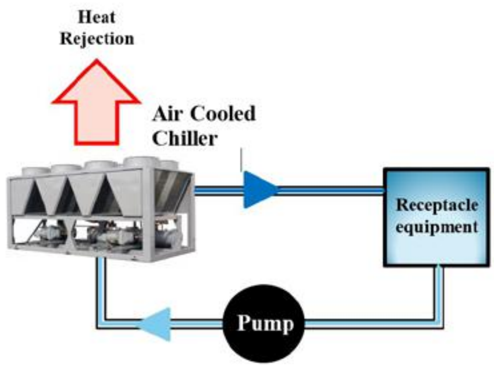
Water to water heat exchanger in a gen set of audited mill

# Chillers

## General description and types

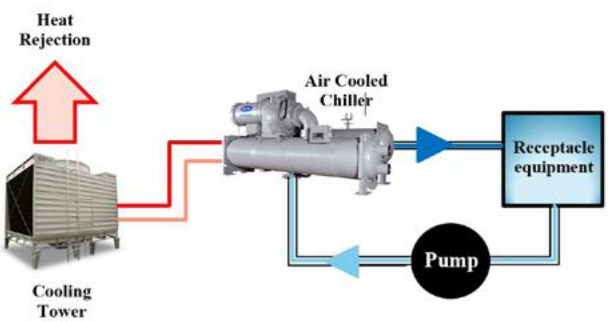
A chiller is a machine designed to produce chilled water. The chilled water generated is then pumped throughout a distribution system to the receptacle equipment where it exchanges heat/coolth through a heat exchanger. The heated water is then pumped back into the chiller where it is cooled again. There are two main types of chillers according to the way heat is rejected into the atmosphere, air-cooled chillers and water-cooled chillers.

**Air-cooled chillers** are those that reject the heat directly into the atmosphere. They are generally less efficient than water cooled chillers, consuming more energy, but they require less equipment and therefore there is also less equipment to maintain.




Air cooled chiller
*Source: shahnawazengg*

**Water-cooled chillers** are those that reject the heat into another water loop, called condenser water loop. Through this loop heat is carried into cooling towers or dry air coolers where it is rejected into the atmosphere. Water-cooled chillers connected to cooling towers are more efficient due to the capacity of the water to absorb a great amount of heat in the evaporation process.




Water cooled chiller system schematic
*Source: Carrier and SPX*

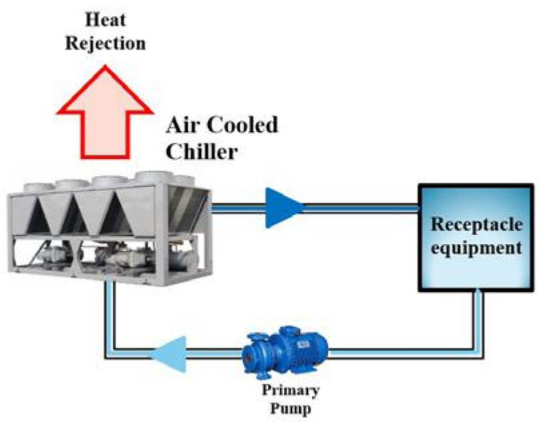
There is a third type of chiller known as **absorption chiller**, which through a chemical process, is able to generate cold water with a thermal energy source, rather than electrical energy source like the majority of the other chiller technologies. Due to their very low efficiency, however, it is required to have an abundant low-cost source of heat for them to be economically and environmentally feasible. These can be good solutions for some CHP systems where a surplus of heat can be available to be used for running absorption chillers to produce coolth.

Regardless of whether chillers are air-cooled or water-cooled, they can utilize different type of compressors which are used to elevate the pressure of the refrigerant from the evaporator on the low pressure side to the condenser on the high pressure side. Compressors are typically one of three types: centrifugal (for bigger machines), scroll and screw. In general terms, centrifugal compressors are more efficient than scroll or screw compressors.

### Chilled water distribution systems

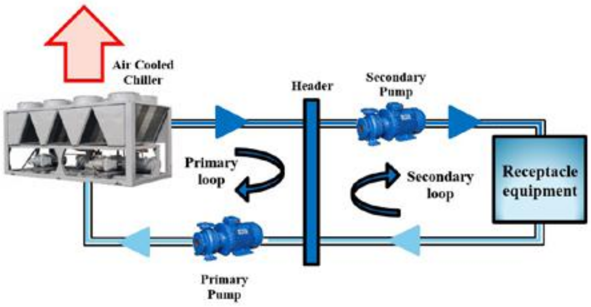
Chilled water distribution systems can generally have a single loop (primary only) or a two loop (primary/secondary) arrangement. The considerations on circuit configuration and variable flow strategies described below are also applicable to the hot water distribution also found in the textile mills audited.

**Primary** only when the chilled water is pumped directly into the receptacle equipment.




Primary only cooling loop arrangement
*Source: Arup*

**Primary/Secondary** when there are two linked water loops. Generally the primary loop only contains generation equipment and the secondary loop contains receptacle equipment. Both loops are linked by a big sized pipe called a header.

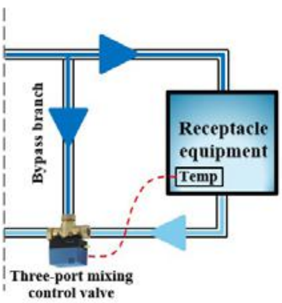



**Primary/secondary cooling loop arrangement**
*Source: Arup*

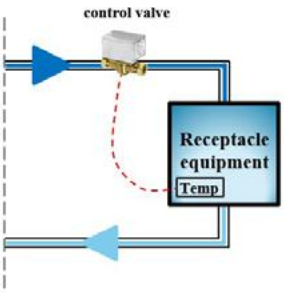
Chillers perform best when there is a constant flow of water going through them, which is why primary pumps usually operate at constant flow, independently of the amount of water required by the receptacle equipment. Secondary loops can work at both constant or variable flow, depending of the type of pumps and control valves installed.

A variable speed pump is generally the same pump as a constant speed pump but fitted with a Variable Frequency Drive (VFD), that though electronics is able to reduce pump speed and thus the pumped volume of water.

As shown in the diagram below, when the receptacle equipment requires less amount of cooling, a three-port valve (Constant flow systems) will divert some of the chilled water from the receptacle equipment through the bypass branch, whereas a two-port valve (Variable flow systems) would simply close to reduce the amount of water propelled by the pump. As a reference, if the amount of water pushed by a pump is halved, the energy consumed by it is reduced to less than 20%. For example, if we assume a pump with a motor power demand of 5 kW has its flow reduced by half, it will experience an 80% reduction in power, which would be equivalent to switching off 80-100 fluorescent lights.



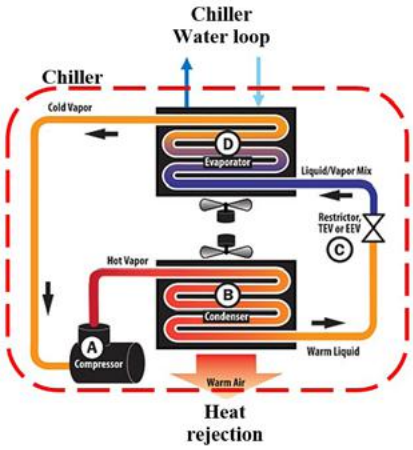

**Constant flow system**




**Variable flow system**

## Components

The main components of a chiller are: the evaporator, the compressor, the condenser and the expansion valve. Following there is an explanation of how a chiller works.




*Source: achrnews.com*

Starting by the evaporator (D), the water coming from the receptacle equipment rejects its heat into the refrigerant liquid/vapour mix within the chiller's evaporator. The water in the chilled water loop gets cooled ready to go back into the receptacle equipment, whereas the liquid/vapour mix inside the chiller gets heated into cold vapour. The cold vapour goes then into a compressor (A) that compress the cold vapour into hot vapour, the hot vapour is then passed through the condenser of the chiller (B) where it exchanges the heat with the outside air (air-cooled chiller) or a condenser water loop (water-cooled chiller). In the condenser the hot vapour gets cooled into warm liquid and the heat extracted from the receptacle equipment is finally rejected into out of the chilling system. The warm liquid is then directed into an expansion valve (C) where it losses some of the pressure created by the compressor. As the refrigerant losses pressure gets cooled into the liquid/vapour mix ready to start the cycle again.

# Chillers

## Descriptive images

**Air cooled chiller**
*Source: Carrier*

**Water cooled chiller**
*Source: Tecogen*

## Efficiency key facts

### Variable flow vs constant flow

As described above, variable flow systems are more efficient that constant flow systems. A constant flow system can be turned into a variable flow system by changing and adding some new equipment (i.e. a Variable Frequency Drive, Pressure Sensors, two port valves).

> **Ask if the chilled water system has a single loop, or a primary/secondary loop configuration. In the case there is a secondary loop ask if it has constant volume or variable flow. This can also be observed by looking at the pipe arrangement in the equipment connection**

### Recommissioning or Retro-Comissioning (RCx)

When a new system is connected, the installers usually perform what is call a commissioning (Cx), which is the process by which an equipment, facility, or plant is tested to verify if it functions according to its design objectives or specifications. During factory operations, systems may become out of balance or may be altered. As a result, the system may not operate in an efficient manner due to these changes. Re-Commissioning, also called Retro-commissioning (RCx) is the application of the Commissioning Process to adjust all parameters to its most efficient setpoint (i.e. flow, temperature, pressure).

> **Ask how often the system is retro-commissioned or adjusted. If modifications have been performed to the initially designed system. Has the system been re-commissioned? Have these modification been updated in the design drawings? Do they have design drawings or schematics of the system?**

### Insulation

As with hot water or steam systems, the distribution loops for chilled water have a temperature that may be quite different to that of the surrounding environment. If a non-insulated chilled water pipe carrying water at 7 ˚C is exposed to higher surrounding temperatures, it will absorb heat getting warmer, and this will increase the chiller load reducing the efficiency of the system.

> **Check if the chilled water pipes are insulated and if insulation is in good state**

### Chilled water temperature

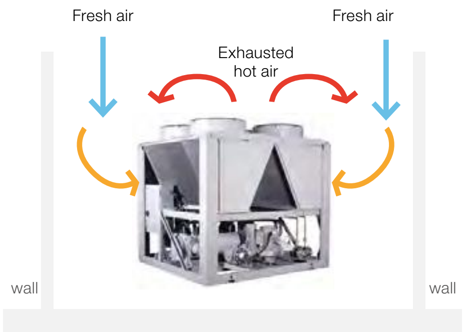
The efficiency of a chiller depends on many factors. One of them is the chilled water supply temperature (CHWT). Higher supply temperatures usually will be traduced in higher efficiencies.

> **Compare the temperature required by the receptacle equipment, according to manufacturer data, to the chilled water temperature delivered by the chiller. If the later was lower than that required by the receptacle equipment it could be adjusted to increase efficiency**

### Air recirculation in air cooled chillers

Air cooled chillers must be installed in open spaces to avoid air recirculation. Recirculation happens when the exhausted air is recirculated back into the chiller reducing its efficiency.

> **Check if recirculation of air may be happening**




### Water reuse

In some cases cooled water is used in open circuit systems for singeing or preshrinking. Once this water has been heated by the process, it can still be used in other processes as desizing, scouring, washing or rinsing, reducing the water consumption, and the amount of water treated in the wastewater treatment plant.

## Control parameters

When assessing the performance of a chiller, the following parameters should be measured and monitored:

**Chilled water temperature:** The efficiency of a chiller is largely dependent on the desired chill water temperature; the lower the CHW temperature, the harder the chiller needs to work and thus generally the lower the efficiency. It is therefore recommended to ensure that the chilled water temperature is adjusted to only what is required by the process loads. Chilled water temperatures generally range from 6 to 15ºC.

**Condenser air or water temperature:** Similar to chilled water temperature, the higher the condenser air or water (air-cooled chiller/water-cooled chiller) is, the harder the chiller will have to work to produce the chilled water, and the higher the lower the chiller efficiency will be. In an air-cooled chiller the condenser air temperature will be the outdoor dry bulb air temperature. In a water cooled chiller the condenser water temperature will be that coming from the cooling tower which will generally range from 15ºC to 40ºC; the CW temp is generally at or near the ambient air web bulb temperature.

**Pressure drop:** Scale, biological growth, rust and water impurities can also reduce the efficiency of the chiller. In water-cooled chillers measuring the water pressure drop through the evaporator and condenser, can indicate if any of these occurrences may be happening. Pressure drop values range between 10-200 kPa.

**Electrical consumption:** The electrical consumption of the chiller may be affected by multiple variables. When assessing the performance of the chiller it is important to measure its energy consumption to compare it with the manufacturer's data.

**Efficiency, or Coefficient of Performance:** The efficiency of a chiller is calculated as the ratio between the energy contained in the chilled water produced over the electrical consumption. The efficiency is highly dependent on the chiller/condenser water inlet and outlet temperatures and part load ratio. Energy Efficiency Ratios usually ranges from 2 to 6.

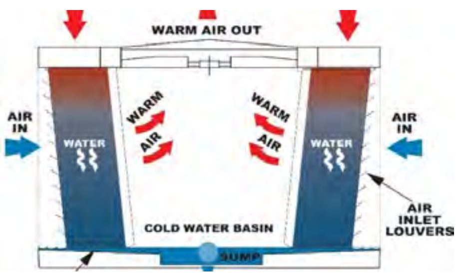
# Cooling towers

## General description and types

A cooling tower is a heat rejection device, which extracts heat from the condenser water loop and rejects it into the atmosphere. In the textile mills audited cooling towers are also used for the rejection of the excess heat coming from the electrical generators. They could also be used to cool down the process waters, for example in the waste water of the dyeing processes before the waste water treatment plant.

There are two main types of cooling towers:

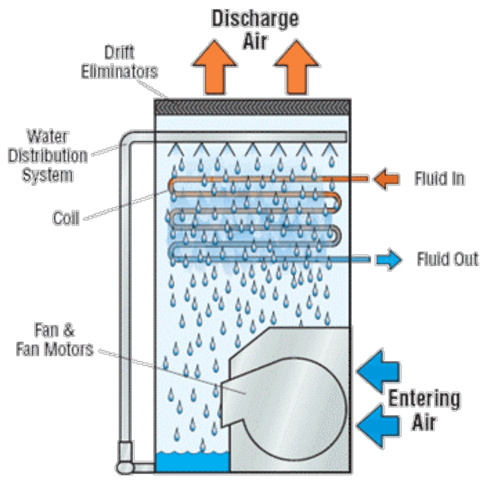
**Open circuit cooling tower**, where the condenser water from the system rejects the heat directly into the air. As the heated condenser water enters in the cooling tower, it is distributed over the fill. The fill is an array of wooden slats or woven wire screens arranged is such a way that breaks up the water into small water droplets increasing the water surface exposure to the outside air (heat transfer surface). Air is induced or forced through the fill, causing a small portion of the water to evaporate. This evaporation removes heat from the remaining water, which is collected in the cold water basin and returned to the chiller to absorb more heat.




**Open cooling tower**
*Source: baltimore*

*Source: SPX*

**Closed circuit cooling towers,** operate in a manner similar to open cooling towers, except that the heat load to be rejected is transferred from the condenser water loop to the ambient air through a heat exchanger. The heat exchanger serves to isolate the water in the condenser water loop from the outside air, keeping it clean and contaminate free in a closed loop. This creates two separate water circuits: an external circuit, in which spray water circulates over the coil and mixes with the outside air, and an internal circuit, in which the condenser water circulates inside the coil. During operation, heat is transferred from the internal circuit, through the coil to the spray water, and then to the atmosphere as a portion of the water evaporates.

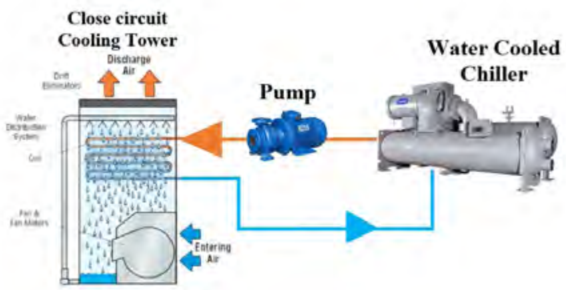



*Source: Evapco*

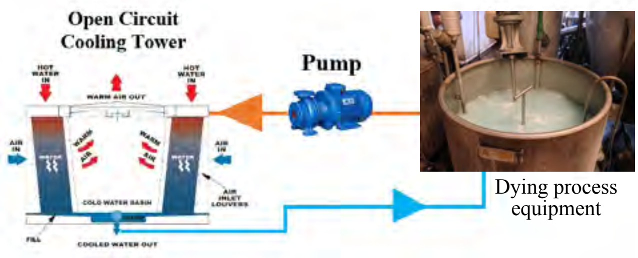
In both cooling tower types, as the water evaporates, the mineral content (calcium carbonate, magnesium, sodium, salts, etc.) of the remaining water increases in concentration of minerals (Total dissolved Solids TDS). If left undiluted, these minerals will cause scaling, biological growth and corrosion, possibly damaging the system. To avoid this situation some water is drained from the cooling equipment to remove the mineral build-up. This activity is called 'blow-down' water or 'bleed' water. The blow-down water TDS can range from 500 to 1300 ppm, depending on local practices and manufacturer recommendations. The blow-down water is usually dumped into the wastewater drain, yet in some cases, this water can be reused for irrigation and other selected uses.

### Condenser water distribution

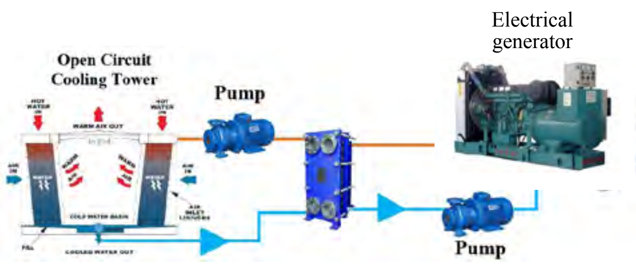
The condenser water loop can be configured in many ways according to the cooling tower type and other variables. The configurations that are typically found are:




**1-. Closed circuit cooling tower primary only arrangement**




2-. Open circuit cooling tower primary only arrangement




3-. Open circuit cooling tower primary/secondary arrangement

Each of the system arrangements shown above have its own benefits and disadvantages.

**Closed circuit cooling tower primary only system arrangement:** The main benefit of closed circuit cooling towers is that the water of the condenser loop is in a closed circuit, keeping it clean and free from dust, pollutants and air bubbles that could be introduced in the system. Having control on the water PH and minerals content will reduce the risk of scale building up in the chiller heat exchanger which would reduce its efficiency and could create maintenance issues. The water used for the cooling of the cooling tower heat exchanger needs to be legionella treated to avoid the possibility of spreading legionella. The amount of water that needs to be treated will be considerably less than for arrangement 2. This system in turn is less efficient that open circuit cooling towers. Closed circuit cooling towers are considerably heavier that those open circuit, which could increase the structural requirements if they were to be installed in the roof.

**Open circuit cooling tower primary only system arrangement:** Open loop cooling towers will increase the system efficiency but in turn will require to be more careful with the maintenance and operation of the system. The amount of water that needs softening and legionella treatment would be increased which would result in higher operational costs. Failing in the water treatment could result in loss of performance of the chillers and expensive maintenance.

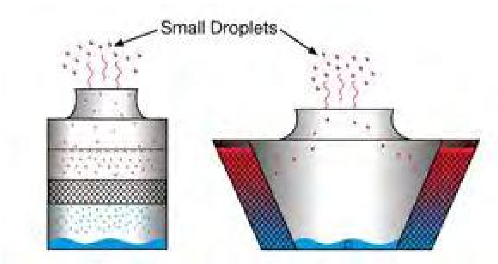
**Open circuit cooling tower primary/secondary system arrangement:** This arrangement would be the mid solution between arrangement 1 and arrangement 2. Some of the increased efficiency of the cooling tower would be lost in the heat exchanger but as in arrangement 1 the amount of water that need treating would be reduced compared to arrangement 2.

## Components

The main components of a cooling tower are:

**Fan and motor:** Fans can induce or force the draft through the cooling tower. Inducing fans are located at the top of the cooling tower, pulling air up through the tower (as the image below). Force draft fans are located at the bottom side and they force the air to go through the cooling tower (See image of close circuit cooling tower above).

**Drift eliminators:** Drift is the undesirable loss of liquid water to the environment via small droplets that are carried by the leaving air stream. There, water droplets carry with them chemicals and minerals, thus impacting the surrounding environment.




*Source: towercomponentsinc*

Drift eliminators prevent the water droplets and mist from escaping the cooling tower. Eliminators do this by causing the droplets to change direction and lose velocity at impact on the blade walls and fall back into the tower.

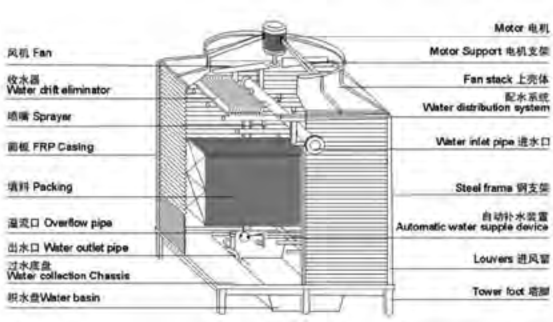
**Water distribution:** Cooling towers employ either gravity distribution or pressurized spray systems to distribute the water over the fill. In the gravity distribution systems a series of holes in the hot water basins spread the water evenly over the fill. Spray distribution systems, feature a series of pipes fitted with spray nozzles mounted inside the tower above the fill.

**Fill:** One of the single most important components of a cooling tower is the fill. Its ability to promote both the maximum contact surface and the maximum contact time between air and water

# Cooling towers

determines the efficiency of the cooling tower. The two basic fill classifications are splash type fill (breaks up the water) and film type fill (spreads the water into a thin layer).

**Water basin:** Once the water has been cooled in the film is recollected in the water basin to be sent back into the chiller, in the open cooling towers, or pumped to the top of the cooling tower in the closed cooling towers.




Cooling tower section

## Descriptive images


Open circuit cooling towers
*Source: B.A.C*


Closed circuit cooling towers
*Source: B.A.C*

As it can be seen in the images above, open and close circuit cooling towers are very similar in shape. A way to identify them would be to look at the pipe arrangement. While an open cooling tower would generally have three pipe connections (condenser water IN, condenser water OUT and water make-up) a closed circuit cooling tower generally will have 5 pipe connections (condenser water IN, condenser water OUT, a pipe getting water from the basin into the spraying nozzles at the top and the water make-up connection).

## Efficiency key facts

### Cooling tower arrangement

Although the most efficient arrangement would generally be the open circuit cooling tower directly connected to the condenser loop, if the make-up water is not correctly chemically treated and/or there is a lot of dust and pollution in the air, it may be recommended to pursue any of the other two arrangements where the main condenser water loop and chiller will be protected from corrosion and impurities.

> **Ask what kind of cooling towers are installed in the factory. In the case the person doesn't know, note the information in the plaque and try to figure out according to the pipes coming in and out of the cooling tower**

### Fan speed

Fans in cooling towers can be constant speed, 2 speed or variable speed. Variable speed fans adjust through Variable Speed Drives the speed according to the temperature of the water leaving the cooling tower. The better control there is on fan speed, the greater capacity to reduce fan consumption.

> **Ask how the cooling tower fan is controlled**

### Conductivity meter

As the amount of Total Dissolved Solids (TDS) rises, due to the evaporation of the water, the efficiency of the cooling tower raises, and so does the risk of scale, biological growth and corrosion. In some older systems the blow-down is programmed regularly, independently of water quality. Water conductivity is a good measure of water TDS content, also measured as cycles of concentration (ratio of the concentration of dissolved solids in the blowdown water compared to the make-up water). By installing a conductivity meter, the blow-down can be programmed to when the conductivity of the water reaches the setpoint value. Check manufacturers documentation for the recommended maximum conductivity as this will reduce the amount of water consumed.

> **Ask how often and according to which parameters blow-down is performed. Ask how often and according to which parameters blow-down is performed**

*Source: walchem*

### Clean nozzles

The scale content in the water can clog the spray nozzles, reducing the dispersion of water in the fill, and therefore reducing the efficiency of the cooling tower.

> **Ask how often the nozzles are cleaned**

*Source: weiku*

### Water meters

Cooling towers are a major water consumer. Most of the water is generally evaporated, but in many cases faulty drift eliminators, dripping water basins or components may increase unnecessary the amount of water consumed. By installing water meters it can be registered and monitored the amount of water that a cooling tower consumes. Be aware that the water consumption will have a one year cycle according to the cooling loads and external dry and wet-bulb temperatures.

> **Is the water consumed by the cooling towers measured? Is it also registered and monitored?**

*Source: techniquip*

## Control parameters

When assessing the performance of a cooling tower, the following parameters should be measured and monitored:

**Condenser water temperature:** The efficiency of a cooling tower is dependent on the condenser or process water temperature, the lower the temperate is, the more difficult it will be for the cooling tower to reduce further its temperature. Typical condenser water temperatures range from 15ºC to 40ºC.

**Electrical consumption:** The electrical consumption of the cooling is that of the fan. When assessing the performance of the cooling tower it is important to measure its energy consumption to compare it with the manufacturer's data.

**Water consumption:** Excessive water consumption can be due to high frequency blowdown, drift, splash, leaks or overflow. Water consumption should be monitored to ensure water consumption in not above manufacturer's recommendations.

**TDS concentrations:** It is a good practice to measure concentration of TDS to ensure the water bleeding is being carried out correctly. TDC concentrations should not exceed 1500 mg/l.

**Efficiency:** The efficiency of a cooling tower is calculated as the ratio between the energy contained in the condenser water produced and the electrical consumption. The calculated value should be compared with the manufacturer's data.

# Lighting and small power

## Lighting

- **Artificial light**

Artificial light can be created in three different ways:

- Incandescent: light is created by passing and electrical current through a wire so that it glows white hot.

  - Incandescent
  - Halogen

- Discharge: the generation of light occurs within a gas filled envelope that is driven by an electric circuit.

  - Fluorescent
  - CFL
  - HID

- Solid state: light is generated at the junction of a semiconductor.

  - LED

**Incandescent:** An incandescent light bulb consists of a glass bulb where light is produced with a filament wire heated to a high temperature by an electric current through it, until it glows. Approximately 95% of the power consumed by an incandescent light bulb is emitted as heat, rather than as visible light. As a result, incandescents are very inefficient light sources.

**Halogen:** A halogen lamp, is an incandescent lamp with similar efficacy. It contains the addition of halogen such as iodine or bromine to the glass bulb. The combination of the halogen gas and the tungsten filament produces a chemical reaction known as a halogen cycle which increases the lifetime of the filament and prevents darkening of the bulb.

**Fluorescent:** Fluorescent lights are phosphor-coated glass tubes filled with an inert gas and a small amount of mercury. All fluorescent lights need a controlling ballast to operate.

The ballast alters the electric current flowing through the fluorescent tube, activating the gas inside and causing it to glow.

**CFL (Compact Fluorescent Lamp):** A variation on the fluorescent tube, compact fluorescents work the same way, only the tube has been made smaller and folded over in a way to make them fit into spaces designed for incandescent bulbs, with a screw base that fits a normal light bulb socket.

**HID (High intensity Discharge):** High-intensity discharge lamps make more visible light per unit of electric power consumed than fluorescent and incandescent lamps since a greater proportion of their radiation is visible light in contrast to infrared. Thus, they have a higher efficiency. HID lamps require a ballast.

Various types of chemistry are used in tubes of HID lamps:

- Low pressure sodium
- High pressure sodium
- High pressure mercury
- Metal halide and ceramic metal halide

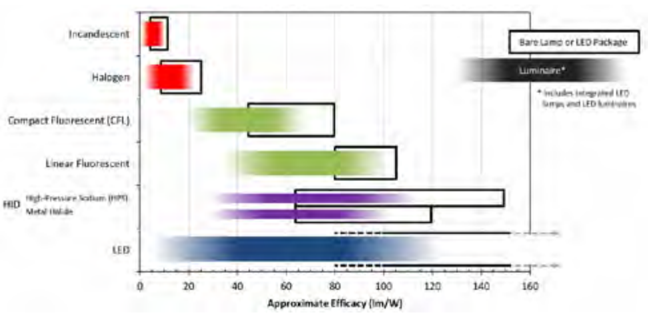
**LED:** LEDs, or light–emitting diodes, are semiconductor devices that produce visible light when an electrical current is passed through them. The LED do not emit great amounts of heat since there is no filament to burn out, so they produce light very efficiently.

## Light source efficiency, or efficacy

Efficient lighting source is achieved in two different ways:

- Efficient lamp selection (and inefficient lamps phase-out).

Incandescent lamps, both conventional incandescent and halogen, are extremely energy inefficient: approximately only 5% of power consumed is converted into visible light, with the remainder converted to waste heat. In this sense they are much more effective heaters than they are light sources. Due to their incredibly poor efficacy (lumens/W), they should be phased out of any facility still using them as soon as possible and substituted by higher efficiency such as CFL or LED technology. Additionally, LEDs do not contain mercury, which has some health and environmental implications.



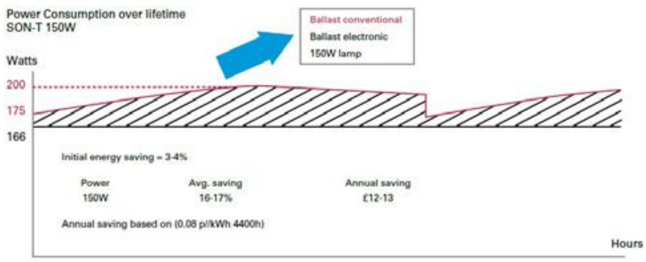

*Approximate range of efficacy for various common light sources, as of January 2013. US Department of Energy. Energy Efficiency & Renewable Energy.*

- Efficient fixtures:

  o Replace Magnetic Ballasts (also known as core and coil ballasts) with Electronic Ballasts (also called high-frequency or solid-state ballasts), which save energy in four ways:

  - Light output is increased, so fewer fixtures (or lower wattage lamps) are required to deliver the same light levels.
  - They require less energy to operate and have lower energy losses.
  - Lamp life is longer. The light output from lamps depreciates slower with electronic ballasts.
  - They are available with a dimming option and can be used with advanced controls such as daylight or occupancy sensors.

Additionally to energy savings, high frequency operation of discharge lamps eliminates visible flicker and hum and buzz completely within the human aural range.




Data courtesy of Philips Lighting

o Select high LOR (Light Output Ratio) fixtures.

LOR compares the total light emitted by the luminaire with that of the bare lamp. Each type of luminaire will have different performance characteristics; they will have a lower or higher LOR depending on their optical design (reflectors, lenses, diffusers, louvers) and on the materials used.

Typical luminaires with high light output ratio are spotlights and downlights. On the other hand, the luminaires which use specular louvers to prevent glare can provide higher illuminance on the working plane despite lower LOR.

- **Natural light**

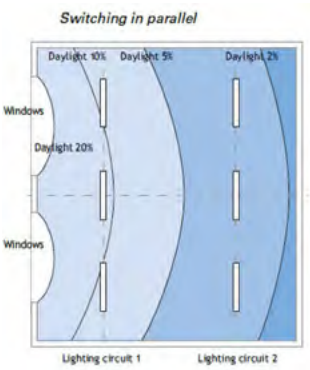
Daylight is the only freely available light source. Well controlled daylight can provide a space with a high quality light, with great colour rendering and zero cost or $CO_2$ emissions.

Daylight can be brought into spaces through roof lights, atria and light guidance systems as well as windows. Using daylight successfully involves a good shading strategy to avoid glare and unwanted heat gain from direct sunlight.

# Lighting and small power

Lightly coloured walls and ceilings aid the distribution of daylight in spaces.

The disadvantage of natural light is that it is a variant non-uniform source of light, so it has to be complemented with artificial light, when the expected task for that space requires a minimum luminance level.




Energy is not saved by simply having daylight enter a space; energy is saved, rather, by dimming down or switching off electric lights that are not needed due to the presence of daylight.

An efficient lighting layout would be set in circuits parallel to the windows lines, so that lighting can be switched off when daylight provides an appropriate lighting level.

To improve efficiency a maintenance plan can be implemented. By regularly cleaning windows and skylights you can reduce the need for artificial light.

## Lighting controls

Lighting controls are the key to managing the use of light and avoid unnecessary costs and energy use. Artificial light can be switched off or dimmed, both when there is sufficient daylight and when there is no-one there to benefit from its use. The light level may also be varied according to the needs of a task or activity.

Automated functions should be combined with user controls to optimize performance. Types of light controls:

- Time clock: to manage lighting overall operating hours


- Movement sensors: they can be used in two different modes: presence and absence detection.

  o Occupancy (presence) sensors: they automatically switch the light on as soon as movement is sensed and switch the light off when the space is empty.

  o Vacancy (absence) sensors: light is switched on manually and the sensor then switches the light off when the space is empty.

- Light sensors: they measure natural light levels and use that information to determine whether artificial lighting should be on, off or dimmed.

- Dimmers: they give occupants more choice over the levels of lighting than turning them on and off. Lighting can be dimmed to adjust to the task required level and energy saving is achieved. (Most HID lamps are not suited for dimmer controls)

- Luminaire integrated controls: some manufacturers include daylight sensors or dimming controls in their luminaires.

## Small Power

Small power electrical loads are often overlooked, but there are also efficiency opportunities to be considered in this energy consuming equipment.

The greatest small power consumers in industrial and office buildings are computers and display devices. Although not covered by this guide many textile factories the sewing machines represents the main electrical load.

The power consumption of computer or screen displays vary significantly based on the display technology used, manufacturer and build quality, the size of the screen, what the display is showing (static versus moving images), brightness of the screen and if power saving settings are activated.

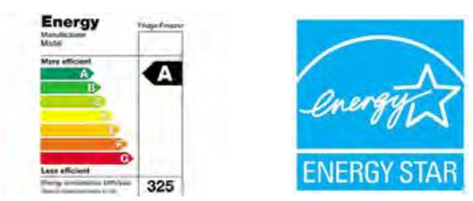
The two main technologies for display devices is CRT or LCD. CRT monitors, short for cathode-ray tubes, were the only choice consumers had for monitor technology for many years. Cathode ray tube (CRT) technology has been in use for more than 100 years, and is found in most televisions and computer monitors. LCD/Flat panel monitors, short for liquid crystal display, can be found in digital watches and computer monitors.


LCD monitors use on average 50 to 70% less energy in on-mode than conventional CRT (Cathode Ray Tube) monitors. The LCD monitor may be not only the best environmental option but also economical in terms of cost-of-ownership for office-workers, together with other advantages —saving space, displaying a calmer image and possibly saving on air-conditioning.

## Appliances

Energy rating labels for appliances and office equipment are generally given to products based on their energy consumption. The idea behind is to allow comparison between two similarly sized products. It is recommendable to look for the product with the best energy rating for the size of product required.

The most extended energy rating labels for appliances are the EU Energy efficiency label (below, left) and the US Environmental Protection Agency Energy Star label (below, right)




Besides looking for a good energy rating, it is important to choose the right size, making sure the equipment suits the needs. Oversized equipment wastes energy and money. Although energy-efficient appliances cost more initially, they'll save money in the long run.

## Efficiency key facts

A **time clock** can manage the overall operating hours, especially for exterior lighting.

> **Are light automatically or manually controlled? If automatically controlled, do the time control adjust to the working hours? Is the scheduled revised through the year to adjust to the seasons?**

**Daylight sensors** in areas expected to be well daylit, so that artificial lighting output is adjusted to match the luminance level set by the building operator.

> **Is there enough access to natural daylight? Are natural daylight sensors installed?**

**Occupancy sensors** in all restrooms, stairways and other back of house areas.

**Vacancy sensors** in technical rooms and service areas.

> **Is the lighting level adjusted to that required for the type of work? Too much? Not enough?**

**Dimmers** in multiple purpose spaces to enable lighting to be adjusted to the ongoing task.

> **Is the lighting level adjusted to that required for the type of work? Too much? Not enough?**

**Appliances** should be chosen to suit needs and reduce energy consumption.

> **Are there small appliances? Do they have any energy rating?**

Green to Wear · Supporting guide

# Water discharge treatment

# Water discharge treatment

Green to Wear
Supporting guide

# Treatment plant process

## Definition of key basic parameters

**BOD:** Biochemical Oxygen Demand. A measure of the oxygen consumed by bacteria to biochemically oxidise organic substances present in water to carbon dioxide and water. The higher the organic load, the larger the amount of oxygen consumed. As a result, with high organic concentrations in the effluent, the amount of oxygen in water may be reduced below acceptable levels for aquatic life. BOD tests are carried out at 20°C in dilute solution and the amount of oxygen consumed is determined after 5, 7 or, less commonly, 30 days. The corresponding parameters are called $BOD_5$, $BOD_7$ and $BOD_{30}$. The analytical values are usually expressed in mg $O_2$/l (effluent) or mg $O_2$/g (substance).

**COD:** Chemical Oxygen Demand. A measure of the amount of oxygen required to chemically oxidise organic and inorganic substances in water. COD tests are carried out at ca. 150°C in the presence of a strong oxidant (usually potassium dichromate). To evaluate the oxygen consumption, the amount of chromium VI reduced to chromium III is determined and the obtained value is converted into oxygen equivalent. The analytical values are usually expressed in mg $O_2$/l (effluent) or mg $O_2$/g (substance).

**Conductivity:** measure of the ability of the wastewater to conduct electricity and it depends on the dissolved solids (mycrosiemens per centimetre (µS/cm). It is important to measure also the temperature.

**CRT:** sludge age, number of solids in the system divided by the number of wasted per day.

**Dissolved oxygen:** measure of the amount of gaseous oxygen ($O_2$) dissolved in water. This is a key parameter to control the biological reactors. In general, the acceptable range should be 1 to 2 mg/L (± 0.5 mg/L).

**ETP:** Effluent Treatment Plant.

**F/M:** food to microorganism ratio. The food to microorganism (F/M) ratio is one of the significant design and operational parameters of activated sludge systems. It describes the degree of starvation of the microorganism. A balance between substrate consumption and biomass generation helps in achieving system equilibrium.

**HRT:** Hydraulic retention time, is a measure of the average length of time that a soluble compound remains in a constructed bioreactor.

**MLSS:** mixed liquor suspended solids. MVLSS is generally defined as the microbiological suspension in the aeration tank of an activated-sludge biological wastewater treatment plant.

The biomass solids in a biological waste water reactor are usually indicated as total suspended solids (TSS) and volatile suspended solids (VSS). The mixture of solids resulting from combining recycled sludge with influent wastewater in the bioreactor is termed mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS).

**pH:** measure of the acidity or alkalinity of the water. The range of compliance will depend on the specific standards where the ETP is located, but in general it should be between 6 to 8.5.

**SAC 254, Spectral Absorption Coefficient:** measure of the dissolved organic carbon ($m^{-1}$) as these substances are capable of absorbing the UV light.

**TSS:** Total Suspended Solids, include all particles suspended in water which will not pass through a filter.

**Turbidity:** measure of water clarity how much the material suspended in water decreases the passage of light through the water. It is used to measure the suspended solids as it is directly related.

## Treatment plant process

Textile sector not only is a big water consumer, but also discharges significant amounts of wastewater which have a complex chemical composition:

- High volume and pollutant load
- Low colloidal and suspended materials content; most of the pollution is in dissolved form
- Average organic load, which is about twice that of urban wastewater
- Generally do not contain toxic products, although they usually have trace compounds that can generate human health risks and environmental risks in case they are bioaccumulative
- Deficient in nutrients, especially nitrogen
- Free from pathogenic microorganisms, if not mixed with fecal sewage

Nevertheless, specific characteristics will depend on the processes carried out at the mill. Inditex pays special attention to those mills which develop wet processes (dyeing, printing, finishing and washing) since their effluents have chemical reactives, colour, etc.

| Pollutants | Units | Range |
|---|---|---|
| **Oils and fats** | mg/L | 14 - 53 |
| **Alkalinity** | (mg/L $CaCO_3$) | 17 - 22 |
| **Colour** | ADMIa | 325 - 600 |
| **Colour** | mg Pt-Co/L | 300 - 3000 |
| **Conductivity (µS/cm)** | mS/cm | 3000 - 9600 |
| **Total chromium** | mg/L | 0.04 - 0.27 |
| **$BOD_5$** | mg/L | 200 - 1100 |
| **$BOD_5$ /COD** | - | 0.31 - 0.54 |
| **COD** | mg/L | 800 - 3000 |
| **Phenols** | mg/L | 0.04 - 0.24 |
| **pH** | uds | 8 - 12 |
| **TSS - Total Suspended Solids** | mg/L | 50 - 300 |
| **TS - Total Solids** | mg/L | 6000 - 7000 |
| **Sulphides** | mg/L | 0.09 - 3 |
| **Temperature** | °C | 37 - 39 |
| **Toxicity / inhibitory materials** | Equitox/$m^3$ | 3 - 15 |

**Reference variance ranges of raw wastewater in the textile industry**
*Source: UDC - 'WaterInTEX: Un índice para la evaluación de la gestión del agua en la industria textil'. P1.- Procesos, consumo de agua y generación de aguas residuales en la industria textil del algodón'. Octubre de 2012. GEAMA-UdC para Inditex.*

| Process | $BOD_5$ | pH | Water consumption | Total solid | T° |
|---|---|---|---|---|---|
| **Desizing** | High | Alkaline | Low | High | - |
| **Scouring** | High | Strongly alkaline | High | High | High |
| **Bleaching** | Low | Strongly alkaline | Maximum | High | - |
| **Mercerizing** | Low | Strongly alkaline | Medium | Low | - |
| **Dyeing** | High | Strongly alkaline | High | High | - |
| **Printing** | High | Neutral to strongly alkaline | High | High | - |
| **Finishing** | High | Close to neutral | Minimum | Medium | - |

**General effluent characteristics from different mills of textile industry**
*Source: 'Environmental Legal Guideline for Printing and Dyeing Enterprises' issued by the Ministry of Environmental Protection of People's Republic of China in November 2013*

The monitoring of the effects and possible impacts that a pressure, such as that generated by the textile industry, has on a body of water can be performed either by control at discharging point (emission control) or by controlling the quality of the environment (environmental quality control of the body of water). The GTW standard focuses on the first of the strategies, ie, the discharge control in order to decrease the pressure on the environment.

Inditex reduces pollution generated in the supply chain from a combined approach, which includes:

- **Control of origin:** wet processes in the supply chain are likely to introduce pollutant compounds into the environment. The treatment of hazardous substances is sometimes difficult, because these compounds are persistent, or expensive because they require advanced wastewater treatments. This is why a proper management of the chemical inventory and the identification and phase out of reactives that contain hazardous substances must become priorities throughout the whole supply chain.

- **Discharge Limit Values:** It is defined as the amount or concentration of a pollutant which may not be exceeded by the discharge. These limits allow to control wastewater discharges. These limits are often conditioned by the quality of the water body and its capacity to neutralize the discharge, which in turn determines the required level of wastewater treatment.

In this sense, Inditex, as the generally applicable legislation in each country, distinguishes two types of discharge:

**Direct discharge:** the mill effluent is discharged into the natural environment. In many cases wet processing mills are located in delocalized areas or cities with a urban sanitation that is not fully developed. As a result, the treatment of the industrial wastewater is a responsibility of the mill. The facility has to always avoid direct discharge to the environment without a previous treatment.

GtW Indicator

**Very poor performance D**
Check that there is no direct process wastewater discharge to the environment (including improper bypass channel for the mill effluent)

GtW Indicator

**Poor performance C**
Check that mill wastewater is treated with at least biological treatment before discharge to natural media

**Indirect Discharge:** the mill effluent is discharged to a downstream public sanitation system. The mill's compliance level with its limits will determine the capacity of the external ETP to treat its inlet and therefore its compliance with its own emission limit values.

# Treatment plant process

Municipal ETPs have usually been designed to treat domestic wastewater, so that textile mills have to perform a pretreatment of their wastewater to decrease the pollution load prior to their indirect discharge.

GtW Indicator
**Poor performance C**
Check that the indirect discharge is at least pre-treated before being sent to a municipal effluent treatment plan

In both cases (direct and indirect discharges), mills have to meet the discharge limit values established by the competent authority.

GtW Indicator
**Poor performance C**
Check that direct discharge or discharge to a municipal ETP meets the parameters applicable by law

## Test of Global Effluent Requirements (COD, BOD, pH, TSS)

A better understanding of wastewater composition, parameters and corresponding treatment processes with process monitoring, control and operational strategies is needed. All this knowledge is vital to achieve consistent and optimal performance at the Effluent Treatment Plant.

Therefore, through this standard Inditex pays special attention to parameters such as COD, BOD, pH, and TSS that allow to properly manage the ETP. Inditex assesses not only the extent to which the mill analyses its outlet but also its own ETP's inlet in order to ensure a proper operation.

The type (internal or external) and frequency of the analysis to characterize the ETP inlet and outlet or the indirect discharge show the involvement and responsibility of the mill to ensure the compliance with the discharging limits.

As well as this analysis, suitable staff has to be trained on process monitoring, instrument calibration, process operation in order to get a continuous improvement at the effluent treatment plant.

GtW Indicator
**Poor performance C**
Check if the mill has an internal or external analysis of the effluent (direct or indirect discharge). At least an annual analysis of COD

GtW Indicator
**Good performance B**
Check if the mill has an external analysis (by 3rd party or government) of the own ETP effluent for at least four parameters: COD, BOD, pH, TSS. If the annual discharge is above 700,000 m$^3$/yr the frequency required is monthly, if below, quarterly

GtW Indicator
**Best in class A**
Check if the mill has an internal or external (by 3rd party or government) weekly analysis of the ETP inlet and outlet for at least four parameters: COD, BOD, pH, TSS

## Test of priority chemical groups

For those parameters which are not considered by applicable legislation but are included in Inditex's Manufacturing Restricted Substances List, this standard establishes maximum concentrations (ppm) before treatment (treatments at own ETP in case of direct discharge or pre-treatment in case of indirect discharges). In this way intentional use of undesirable chemical substances by suppliers can be detected.

GtW Indicator
**Poor performance C**
Check that the concentration of MRSL substances in effluent before treatment is lower than 0.1 ppm (Heavy metals and any value >0.1 ppm due to the incoming water are not considered)

GtW Indicator
**Good performance B**
Check that the concentration of MRSL substances in effluent before treatment is lower than 0.01 ppm (Heavy metals and any value >0.01 ppm due to the incoming water are not considered)

Compliance with the discharge limit values (either sewer or natural environment) requires the installation and operation of a set of wastewater treatments.

The textile wastewater has specific characteristics that involve adapting the conventional ETPs configuration and treatments (in design, sizing and operation) to this particular sector.

Despite the existence of different cultures and technology markets, Green to Wear standard has identified the most common wastewater treatments for textile mills with either direct or indirect discharge.

## Efficiency of the ETP

The ETP has to have both proper wastewater treatment measures as well as an adequate size to be able to treat the 100% of the mill's process wastewater.

GtW Indicator

**Very poor performance D**
Check that the own Effluent Treatment Plan properly treats the 100% of the process wastewater (excluding losses as evaporated process wastewater)

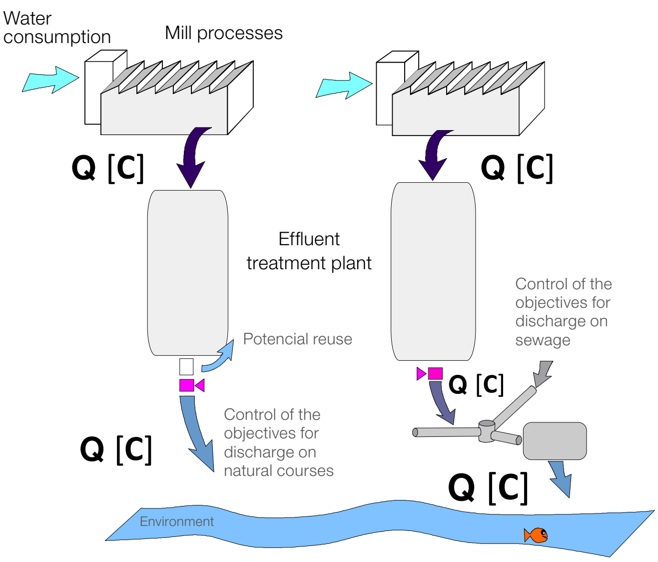
Once it is confirmed that the mill treats the 100% of its process wastewater and every wastewater treatment has been identified, the auditor will have to pay attention to the Global Effluent Parameters' results.

The analysis of these parameters before and after treatment might reflect an improper operation of the ETP or inefficient water consumption at the facility.

Sometimes (non paid water source, no control over water consumption, etc.) the presence of low COD values before treatment indicate that the pollution load has been previously diluted, which is an unsustainable practice.

GtW Indicator

**Poor performance C**
Check that the mill has an efficient use of water (if COD before treatment > 300 mg/l for dyeing mills or COD before treatment > 100 mg/l for dyeing & washing mills)




On the other hand, in some textile mills, part of the process water, once it is treated, is recirculated to the system. Reuse of process wastewater (different from the cooling system) not only allows to reduce the water consumption but also the flow rate.

GtW Indicator

**Best in class A**
Check that the mill reuses at least 30% of the process water after treatment

As a summary, see below the elements of a basic wastewater process that are explained through the document:

- **Pre-treatments** (physical and some chemical treatment): previous process to facilitate the treatment in other phases. It consists of the removal of particles and other impurities of the effluent in order to prevent damage and blocking of the equipment.
  - Screening / sieving
  - Equalization/homogenization
  - Neutralization
- **Primary treatment** (physicochemical treatment): first treatment processes to remove grease, suspended and floating solids in the wastewater facilitating the effectiveness on the downstream biological process operation. Chemicals are often used during this phase to accelerate the sedimentation process.
  - Chemical coagulation / flocculation
  - Primary clarifier
  - Dissolved air flotation
- **Secondary treatment** (biological treatment): these are the second treatments in a wastewater treatment plant. The objective is to remove the biodegradable dissolved and organic matter (suspended solids) that escapes primary treatment. This is achieved by bacterial culture that consume the organic matter as food, and converting it to carbon dioxide, water, and energy for their own growth and reproduction.
  - Activated sludge process
  - Fluidized bed
  - Upflow anaerobic sludge blanket

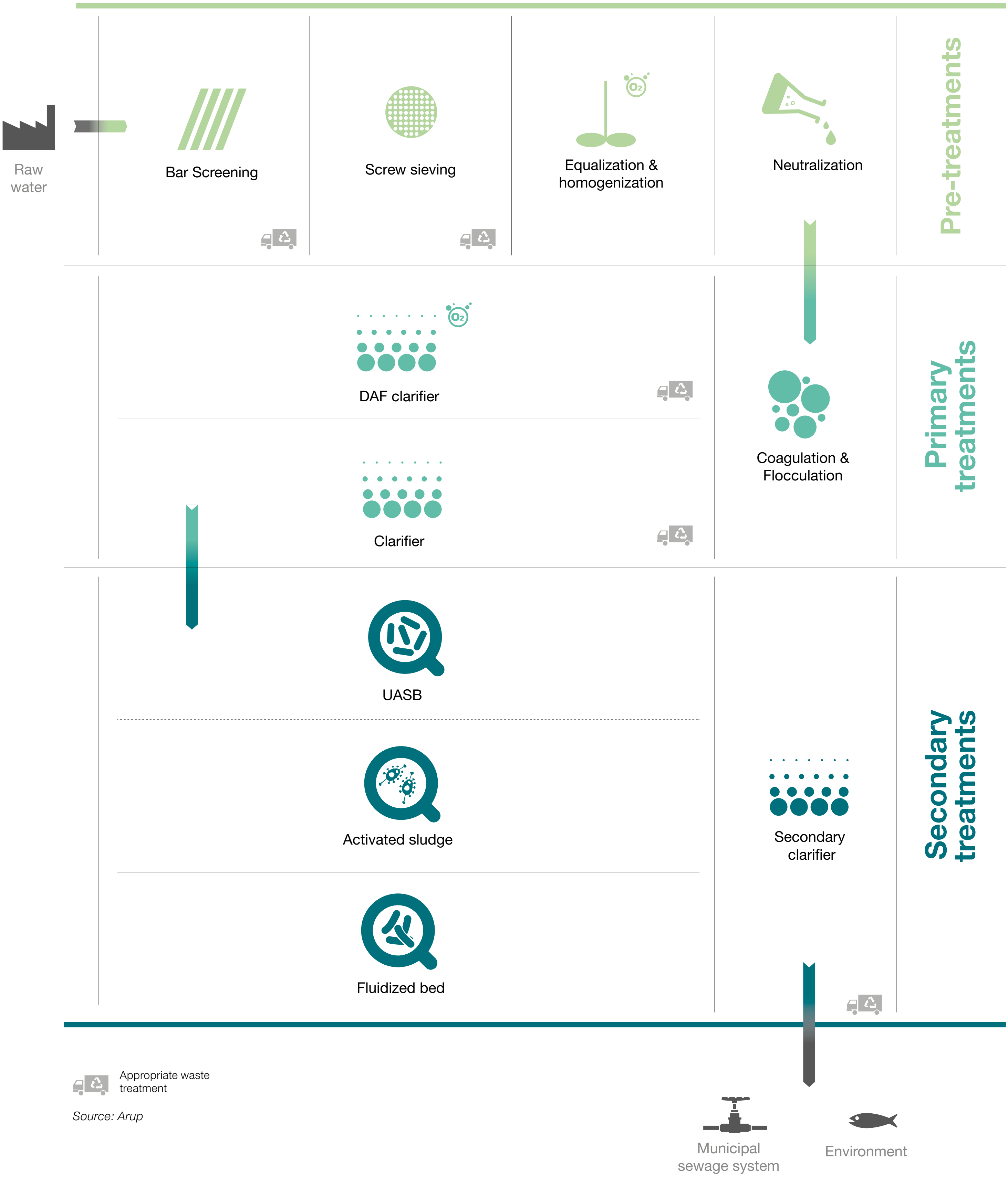
In addition, there are other wastewater treatment processes called **tertiary treatments** which have the objective to improve the quality of the treated effluent allowing its possibility to reuse it in other processes. These treatments are designed to remove the rest of the BOD and other pollutants not treated in the other processes. These pollutants are mainly the nitrogen and phosphorous as part of the results of the biological treatment.

# Treatment plant process

The main tertiary treatments are:

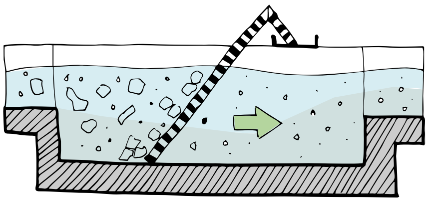
- High rate filtration (single layer and multilayer)
- Adsorption with activated carbon
- Fenton reaction
- Ozone reaction tanks
- Ultrafiltration, nanofiltration, microfiltration
- Reverse osmosis
- UV radiation
- Ion exchange
- Chlorine reaction tank

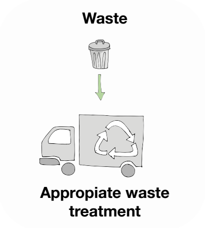
These treatments are not part of this supporting guide which focuses on the primary and secondary treatment.


Raw water
Bar Screening
Screw sieving
Equalization & homogenization
Neutralization
Pre-treatments
DAF clarifier
Clarifier
Coagulation & Flocculation
Primary treatments
UASB
Activated sludge
Fluidized bed
Secondary clarifier
Secondary treatments
Appropriate waste treatment
Municipal sewage system
Environment

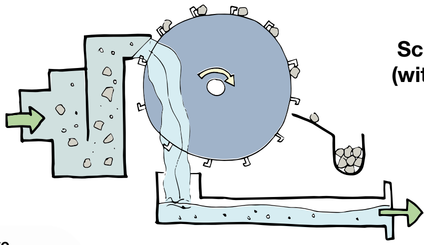
*Source: Arup*

**Raw water**

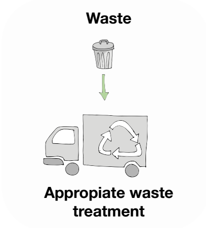




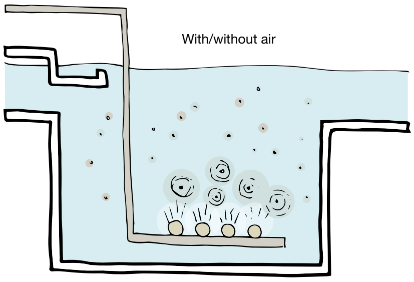

Bar Screening



**Screened effluent (with variable flow)**



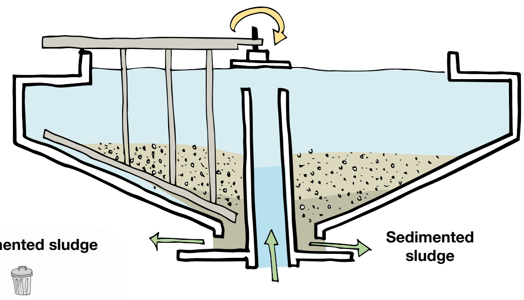

Screw sieving

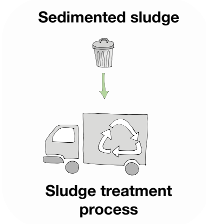



Biological treatment

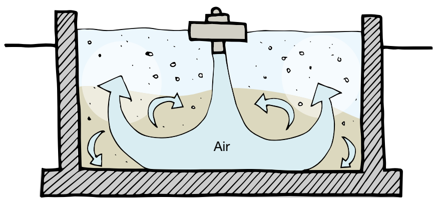
> **Complete a flowchart with the different processes of the ETP like the following example**

# Effluent Treatment Plant Process



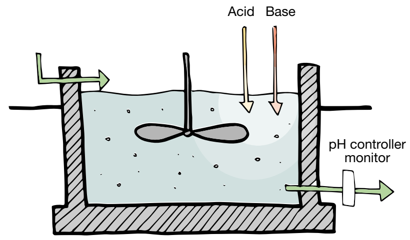




Secondary clarifier



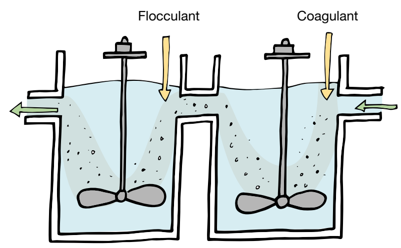

Equalization & homogenization

Stable effluent and constant flow

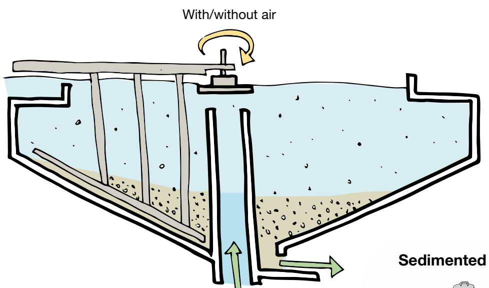



Neutralization

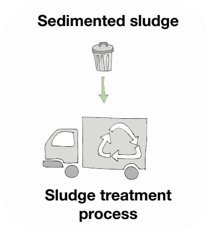
Neutralized effluent



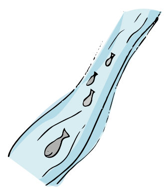

Coagulation & Flocculation



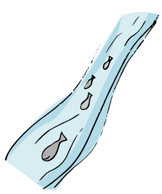

Clarifier




Municipal sewage system



Treated effluent



Treated effluent

Source: Arup

# Screening

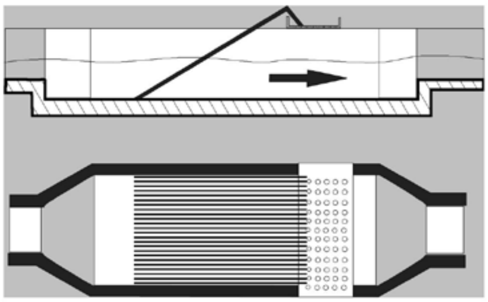
## General description and types

Physical pre-treatment is conducted to remove the large and medium size residues (including solids, sand, oil and grease, etc.) that are likely to cause pipe clogging, equipment abrasion, fouling, deposit coarse sand settling, etc. Bar screening and sieving are commonly used to achieve this objective.

### Bar screening

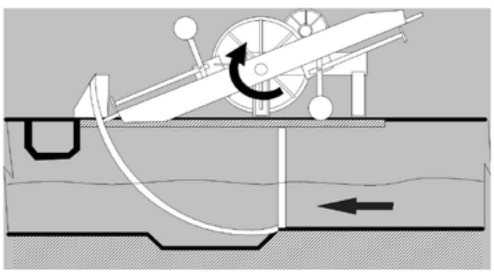
Bar screens are placed in transversal or opposite direction to the water flow, so that water passes through them and solids bigger than bar separation are retained.

In general, bars can be made with a curved or straight (flat) shape. When straight, bars positioning with respect to the horizontal may be vertical or inclined.



Hand cleaned inclined bar screen

Mechanically cleaning bars minimize clogging problems and reduce the maintenance time. The cleaning mechanism is usually a mobile rake which periodically sweeps the bars, extracting the retained waste. In curved bars, the cleaning rake has circular mechanic motion.



Curved bars screen with reciprocating rake mechanical cleaning

The extracted residues must be evacuated to a storage area that, depending on the size of the facility, will require transport by conveyor belts or spiral screws. Whatever is the size of the facility, the presence of a compacting element is advisable. In small installations removed residues can be accumulated and drained off on a perforated board.

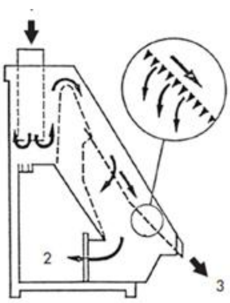
Straight system

Curve system

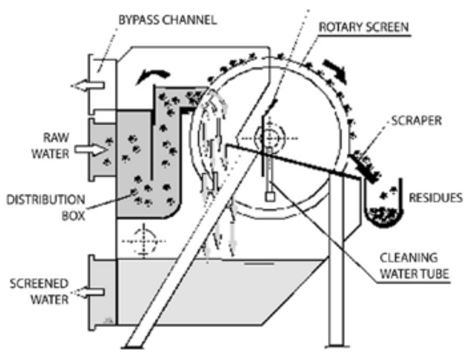
### Fine screening (sieving)

Fine screening consists of a filtration through a thin mesh. Sieves are generally self-cleaning electromechanical equipment. Mesh size ranges from 3 to 6 mm in fine screening. Rotary, screw and steps sieves are essentially distinguished.

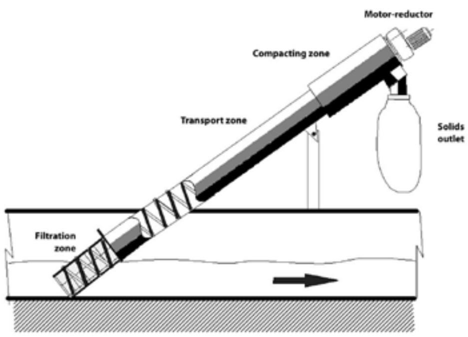
### Static sieves



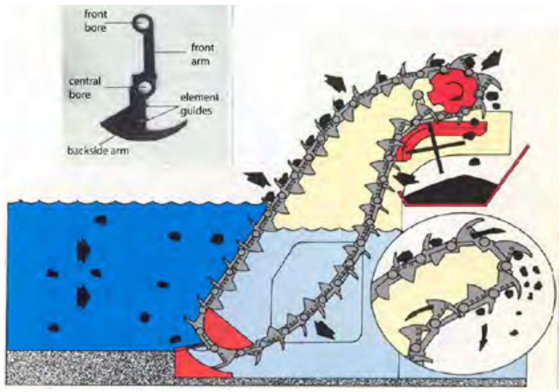
The **rotary sieves** or drum screens are in widespread use (large and small wastewater treatment facilities) due to their easy maintenance and mechanical robustness. It consists of a horizontal axis cylindrical grid or mesh, made of stainless steel, rotating slowly by a motor drive. Removed residues are extracted from the mesh by a fix scraper and disposed into a container.




On the **screw sieve**, the screening is performed through a semi-cylindrical perforated plate. Solids separated from the filtration zone are automatically dumped from the channel by a coreless spiral screw. A spiral brush attached to the lower end of the screw ensures that the filter mesh is continuously cleaned. On the top of the screw, solid compaction is performed and the drained water flows into the channel. The compacted waste can be downloaded directly into containers or bags.




**Step** screens are of vertical continuous sieving type. This kind of sieves incorporates scrapers on the filtration belt. The arrangement of the scrapers on stainless steel shafts forms a filtering screen that is assembled on a frame-support which is installed directly on the channel. Wastewater solids are captured by the filtering screen, withdrawn by the scrappers and discharged at the top of the unit to the back side of the sieve. The circuit of the mesh belt is disposed in order to be self-cleaned as the scrappers pass between the arms of the next row of elements.




Self-cleaned step fine screen scheme

# Screening

## Sizing criteria

The selection of the electromechanical equipment (bar screens or sieves) depends on the following:

- Mesh size, average size of the solids to retain
- Pretreatment maximum flow
- Fouling degree requirements
- The concentration of suspended solids, and where appropriate, head loss capacity

### Bar screens

When the arrival of a treatment plant has a head pumping station, a prior screening unit will be needed, based on bar screens with a bar spacing of 20 or 40 mm. This bar spacing, regardless of the presence of a pumping head tank, should consider the following criteria:

> **If the ETP owns a head sump, the bar screens spacing will be 40 mm**

> **If the ETP does not have head sump, bar spacing will be 20 mm**

- Bars must have a minimum thickness like:

> **Bar spacing of 40 mm: thickness between 12 and 25 mm**

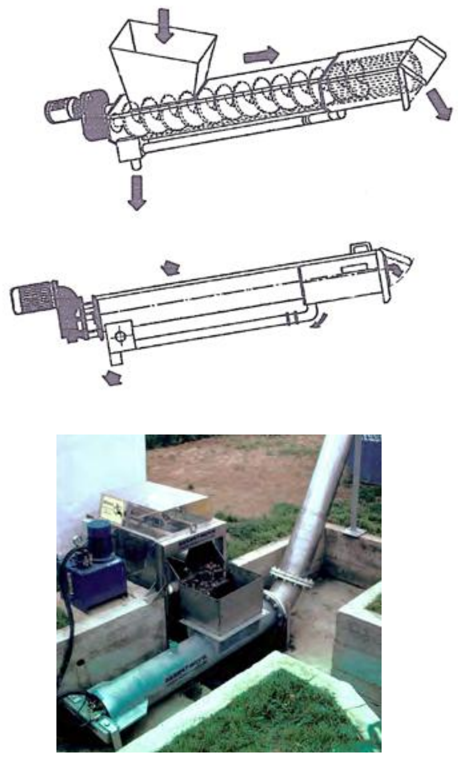
> **Bar spacing of 20 mm: thickness between 6 and 12 mm**

### Sieves

All sieving equipment should be preceded by a previous bar screening. All screens are provided with gates to be isolated, if needed, in every possible hydraulic conditions.

### Waste storage

The waste is transported (conveyor belts or pneumatic ejectors) to a container usually preceded by a waste compactor.



Operating scheme of a screening unit waste compactor

To prevent debris from falling out of the container, the big heights (more than 1 meter) between the output of compacted waste and the mouth of the container shall be shielded. In pipe transportation of compacted waste, the presence of elbows must be avoided as they use to generate pipes clogging.

## Control parameters

Hand-cleaned bar screens:

- Hand cleaning takes place by raking, depositing removed waste at perforated troughs provided for that purpose, to get waste drainage prior to its collection in a container and the subsequent convey to the landfill

> **Cleaning frequency should be at least twice a day, but experience in operation will set the proper operation rate**

Mechanically cleaned bar screens:

- Checking the waste removal degree of bar screens
- Inspection of bars fouling. If it is foul, clean it before it gets blocked

- Cleaning bars, and where appropriate, conveyor belts or screws
- Check lubrication level
- Monitoring the container filling level
- Electromechanical operation inspection

Sieves:

- Checking the waste removal degree of sieves
- Cleaning sieves, and where appropriate, conveyor belts or screws
- Notice for waste transport if necessary
- Check lubrication level
- Checking the degree of clogging of the waste press.
- Monitoring the container filling level
- Inspection of screen clogging and, if clogged, clean it before it gets blocked
- Electromechanical operation inspection

# Equalization - Homogenization

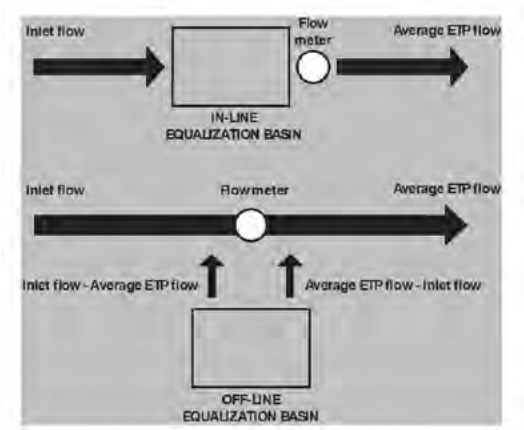
## General description and types

The purpose of setting up equalization tanks is to avoid malfunction of process steps caused by significant variation of inlet flowrates or pollutant load. The equalization tank can achieve two objectives: flow control (equalization) and/or homogenization of contaminated flows.

The two basic modes of operation of the ponds or tanks flow control are:

- **Online/In-line:** The tank of regulation is in line with the feed to the treatment plant and consequently, all wastewater passes through the tank or the regulation basin

- **Parallel or off-line:** Only the water exceeding the average flow rate is derived to the equalization tank, and is forwarded to the treatment when the arrival rate is below average




Basic operation schemes for equalization tanks

If wastewater has suspended solids regulation tanks implement agitation in order to prevent settling.

## Sizing criteria

The two basic mixing systems are:

- Mechanical agitation. The mixing power should be about 15 to 25 W/m$^3$ of water (3 to 4 W/m$^3$ in some references). In the case of a regulation tank always working with variable levels, keep in mind that the agitators cannot stay in the air

- Air agitation by injection through diffusers. The amount of air should be between 0.4 and 0.6 m$^3$ air/m$^3$·hour. The type of diffusers to use are medium or coarse bubble

Sketch of the effect of surface agitation system

Agitation system ejector example

Bottom agitation system

Vertical axis floating agitation/ aeration system

Oblique axis floating agitation/ aeration system

Details of bottom impeller agitation equipment

In practice, the volume of the equalizing tank, or the regulation tank, must be bigger than that of theoretical calculations, in order to take into account the following factors:

- Continuous operation of stirring and mixing equipment in the homogenization and regulation tanks, if needed, will not allow complete emptying

- Return flows to treatment plant entry and filtered supernatants require an additional storage volume
- Please note an additional volume to meet contingencies that may arise from unexpected changes daily flow or composition
- The retention time in these units is estimated in the range from 12 to 24 hours for a defined volume based on the daily flow

> **Maintaining aerobic conditions requires having an air supply of 9 to 15 L/m³. Storage retention (min)**

> **Although it cannot be any fixed value, the additional volume can vary between 10% and 20% of the calculated value**

### Specifications in the treatment of wastewater of textile industry

Different tables with ranges of pollutant concentrations present in textile industry wastewater are presented in the next page. These pollutant levels can be homogenized in the tanks.

# Equalization - Homogenization

| Parameters concentrations of water pollutants generated in the textile sector in terms of treatment and finishing of yarn, wool, cotton or knitt | | | | |
|---|---|---|---|---|
| Parameter | Yarn | Cotton fabric | Wool fabric | Knitted cotton |
| **pH** | 8 -12 | 8 – 13 | 5,5 – 8 | 5,5 – 9 |
| **COD (mg/L)** | 600 – 1000 | 1000 – 3000 | 1000 – 1800 | 800 – 1300 |
| **$BOD_5$ (mg/L)** | 200 – 350 | 300 – 1100 | 250 – 600 | 200 – 450 |
| **SS (mg/L)** | 50 - 150 | 50 – 200 | 50 – 200 | 50 – 150 |
| **Colour (Pt-Co)** | 100 - 1000 | 300 - 3000 | 200 – 1500 | 1000 - 1000 |
| **Water consumption (L/kg)** | **60 – 125** | **100 - 400** | **100 – 300** | **100 – 200** |

| Categories and characteristics of textile process effluents | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | Categories | | | | | | |
| | Raw wool scouring | Yarn and fabric manufacturing | Wool finishing | Woven fabric finishing | Knitted fabric finishing | Carpet finishing | Stock and yarn dyeing and finishing |
| **BOD/COD** | 0.2 | 0.29 | 0.35 | 0.54 | 0.35 | 0.3 | 0.31 |
| **$BOD_5$ (mg/L)** | 6000 | 300 | 350 | 650 | 350 | 300 | 250 |
| **TSS (mg/L)** | 8000 | 130 | 200 | 300 | 300 | 120 | 75 |
| **COD (mg/L)** | 30000 | 1040 | 1000 | 1200 | 1000 | 1000 | 800 |
| **Oil and grease (mg/L)** | 5500 | - | - | 14 | 53 | - | - |
| **Total chrome (mg/L)** | 0.05 | 4 | | 0.04 | 0.05 | 0.42 | 0.27 |
| **Phenol (mg/L)** | 1.5 | 0.5 | 0.014 | 0.04 | 0.24 | 0.13 | 0.12 |
| **Sulphide (mg/L)** | 0.2 | 0.1 | - | 3 | 0.2 | 0.14 | 0.09 |
| **Colour (ADMI)[a]** | 2000 | 1000 | 8 | 325 | 400 | 600 | 600 |
| **pH** | 8.0 | 7.0 | 10 | 10 | 8 | 8 | 11 |
| **Temperature (°C)** | 28 | 62 | 21 | 37 | 39 | 20 | 38 |

[a] ADMI ('American Dye Manufacturers Institute') colour values result from a special procedure for determination of colour in dyeing wastewaters (Allen et al., 1972; Little. 1978)

## Control parameters

- Hydraulic retention time
- Establishing bypass systems to perform maintenance emptying and solids and accumulated debris extraction

Image of a regulation-homogenization tank

## Operating problems

- Lack of ventilation when much organic matter arrives
- Accumulation of sediment and sand in the bottom of the tank (lack of energy)
- Extraction problems in the extraction of thick or settled materials

Image of a regulation-homogenization tank

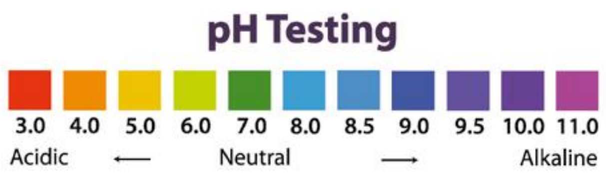
Image of a regulation-homogenization tank

# pH neutralization

## General description and types

Neutralization is the process of adjusting the pH of water through the addition of an acid or a base, depending on the target pH and process requirements. Most part of the effluents can be neutralized at a pH of 6 to 9 prior to discharge.

> **There are three critical components of any pH control system: mixing intensity or turnover time in the reactor, response time of the control system, and the ability of the chemical metering system to match process requirements. If any one of these components is not properly designed, significant problems in system performance can be anticipated**




> **Some of the important chemical processes, where pH plays a significant role and where pH adjustment through neutralization is often required, are metal adsorption and biosorption, chemical precipitation, water softening coagulation and water oxidation**

### Buffer capacity

The Word 'buffer' stands for the stubbornness against any change. In environmental chemistry, buffers are always defined in the context of pH. PH buffers are those that resist any changes in solution pH when an acid or a base is added into the solution. They are very important in chemical neutralization processes.

> **In natural waters and wastewaters if the buffering capacity of the flow to be neutralized is not taken into account, the actual amount of neutralizing chemical required may vary widely and causes operational problems**

## Sizing criteria

A proper engineering design should be based upon a variety of factors as optimum process parameters, laboratory scale tests and finally, cost analyses.

### System design: batch or continuous

Neutralization can be carried out in either batch or continuous mode. In batch mode, the effluent is retained until its quality meets specifications before release. Several processes can be simultaneously carried out when the process is performed batchwise.

> **Batch processes are good for small scale treatment plants or small waste volume. For large volumes, a continuous neutralization process is typically used**

Continuous flow-through systems are used when:

- Influent flow is relatively constant and sudden variations are not expected
- The influent flow characteristics are essentially constant

Effluent chemistry is not very critical. An example is when the process is a part of multi-stage neutralization process.

Batch neutralization systems are used when:

- There are large fluctuations in influent properties (e.g., flow and pH)
- The influent wastewater contains concentrated acids or bases
- The effluent quality has stringent discharge limits

| Design parameters on a neutralization system | |
|---|---|
| **Chemical storage tank** | Liquid - use stored supply vessel<br>Dry – dilute in a mix or day tank |
| **Reaction tank** | |
| Size | Cubic or cylindrical with liquid depth equal to diameter |
| Retention time | 5 to 30 min (lime-30 min, the others less) |
| Influent | Locate at tank top |
| Effluent | Locate at tank bottom |
| **Agitator** | |
| Propeller type | Under 3.8 m$^3$ tanks |
| Axial-flow type | Over 3.8 m$^3$ tanks |
| Peripheral speeds | Tanks less than 3.8 m$^3$: 0.76 m/s<br>Tanks over 3.8 m$^3$: 0.36 m/s |
| **pH sensor** | Submersible preferred to flow-through type |
| **Metering pump or control valve** | Pump delivery range limited to 10 to 1; valves have greater ranges |

Most part of the process water and industrial effluent treatments requires a pH regulation as part of the treatment line. Some of the possibilities for pH regulation process locations on textile industry water lines are summarized below:

- **Process water pre-treatment:** After water softening process (hardness removal), it is commonly required the pH regulation of alkaline streams.

  Besides, it will be required after metal precipitation processes (in basic media).

  Metal adsorption and biosorption processes are especially dependent on pH values in the low range.

> **If this process application is desired, acid water neutralization pre-treatment is recommended so as to maintain the pH level above 6**

- **Mill effluent pre-treatment:** Generally, in the dyeing industry, effluents are highly alkaline and require the addition of acid. However, provision should be made to be able to add both acid and alkali, as some dyeing processes may give acid effluents and addition of alkali may be needed

  PH regulation processes use to be located in the homogenization tank of the ETP, along with its outlet.

| Parameter | Minimum | Maximum |
|---|---|---|
| pH | 1.8 | 12.6 |
| Total alkalinityl (mg $CaCO_3$/L) | 17 | 800 |

Alkalinity and pH ranges in textile mill wastewaters

> **The alkalinity and PH range in the textile mills ETP inlet flows must be checked (see table above)**

- **ETP treatment line:** PH regulation is useful inside effluent treatment plants with physico-chemical treatments. Since the addition of flocculants decrease alkalinity, lime is dosed to prevent abnormal decrease in pH value, which may affect the flocculation and also helps to precipitate metal hydroxides in this treatment step. These processes normally require, after primary clarification, a pH neutralization step.

  In some cases, neutralization system is designed in order to elevate pH well enough to provide the necessary alkalinity to compensate the effect of a downstream process, like biological nitrification (Goel, 2005).

pH regulation addition system on a physico-chemical treatment ETP (Arteixo - Spain)

> **In secondary treatments, the biological system pH has to be generally maintained between 6.5 – 8.5 in order to assure an optimum biological activity**

The process provides on its own certain neutralization and buffering capacity as a result of $CO_2$ production, which reacts with caustic and acid materials. The neutralization degree depends, therefore, on the BOD removal ratio and the acidity or alkalinity present on the wastewater.

pH regulation system on a textile mil ETP (Zhejiang Lifeng 100 m³/h)

## Process operation troubleshooting

### Safety precaution

Proper precautions must be taken to protect workers when handling NaOH, HCl or other chemicals used to correct the pH, as they are strongly corrosive and potentially dangerous. HCl is

# pH neutralization

corrosive to concrete and steel so precautions need to be taken to ensure that the acid is not spilt onto the fabric of the ETP (Khan, 2006).

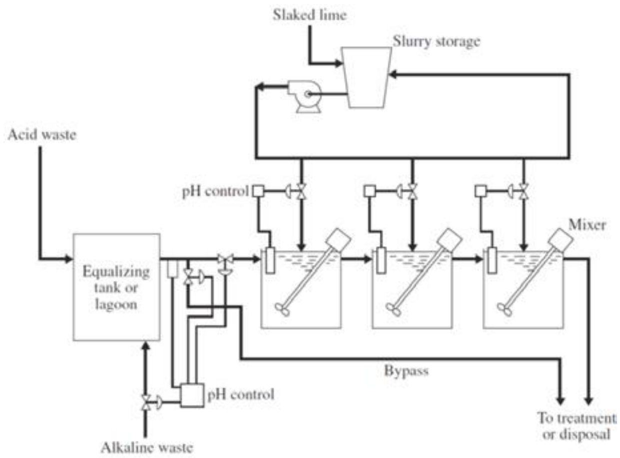
### Automatic control

The automatic control of pH for wastestreams is one of the most troublesome, for the following reasons:

1. The relation between pH and concentration or reagent flow is highly nonlinear for strong acid-strong base neutralization, particularly when close to neutral (pH 7.0). The nature of the titration curve as shown below, favours multistaging in order to ensure close control of the pH
2. The influent pH can vary at a rate as fast as 1 pH unit per minute
3. The wastestream flow rates can double in a few minutes
4. A relatively small amount of reagent must be thoroughly mixed with a large liquid volume in a short time interval
5. Changes in buffer capacity (i.e., alkalinity or acidity) will change neutralization requirements

> **If effluent pH is normally 2 units above or under the objective pH level, system is normally designed as a multistage**

In reaction tank 1, the pH may be raised to 3 to 4. Reaction tank 2 raises the pH to 5 to 6 (or any other desired endpoint). If the wastestream is subject to slugs or spills, a third reaction tank may be desirable to effect complete neutralization. A slug discharge is any discharge of a non-routine, episodic nature, including but not limited to an accidental spill or a non-customary batch discharge, which has a reasonable potential to cause interference or pass through, or in any other way violate the ETP's ordinances, local limits, or permit conditions.



Multistage neutralization process

## Control parameters

The pH of the water after the equalization tank as well as water after coagulation, flocculation and biological treatment, and discharge water should be monitored regularly.

> **For monitoring, a pH meter gives much more accurate result than pH paper, especially when the effluent is highly colored, and therefore pH paper should not be used.**
>
> **An automatic pH controller should be used so that the pH can be automatically tested and adjusted.**

If an automatic pH controller system is not fitted samples must be taken regularly (at least every 2 hours) to ensure the efficient functioning of the ETP. Ideally the fitting of an automatic system should be considered as it will significantly improve the operation of the plant and will prove to be cost effective.

Spare pH meters and electrodes should be kept in stock to replace damaged electrodes without delay as pH control is crucial to the success of the ETP. The pH electrodes should be selected carefully and should be guaranteed by the manufacturer to be suitable for use in an industrial ETP since not all electrodes can withstand conditions in an ETP (Khan, 2006).

# Coagulation-Flocculation

## General description and types

The total solids content of natural or wastewater is one of the most important physical parameters. The total solids are composed by:

- Floating materials
- Suspended solids
- Filterable solids:

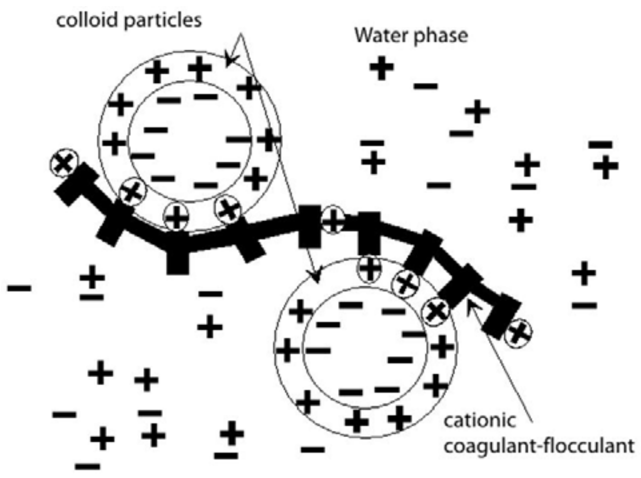
    o Colloidal dispersion substances: particles with a diameter ranging from $10^{-3}$ to 1 µm. They cannot be removed by sedimentation. Turbidity and colour are often associated with these particles

    o Dissolved substances: organic and inorganic substances together with ions that are dissolved in water

**Coagulation** is known as the process of destabilization of colloids as the properties that made them stay in suspension are removed. The colloidal particles have surface charges generating electrostatic repulsive forces between one another and avoiding the possibility to agglomerate forming flocs, what could facilitate sedimentation. Colloidal particles are considered as partially ionized on their surface and capable to move under the action of an electric field.

The basic mechanism of destabilization is removing the electrical charge. With this purpose, coagulation chemical reagents are used which are capable to:

- Neutralize the charge of the colloids
- Form aggregates of particles




Frequently coagulants:

- **Aluminium sulphate:** $(SO_4)3Al_2$, on market is in granular or liquid form

- **Ferric chloride:** $FeCl_3$, used in wastewater. It is commonly found in liquid form at concentrations 37% - 47%

- **Ferrous and ferric sulphate:** $FeSO_4 \cdot 7H_2O$ and $(SO_4)Fe_2 \cdot 3H_2O$; are supplied in solid form

- **Polymers:** Few applications on coagulation. Its use is widespread in flocculation

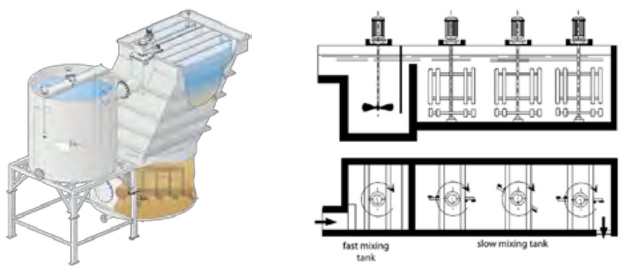
- **Polyaluminum chloride (PAC)** is currently widely used. It improves the properties of the aluminum sulfate, $Cl3_{n-m}(OH)_mAL_n$

The **flocculation** process is the aggregation of these destabilized colloid particles. Aggregation is facilitated when the particles are getting contacted and if there is something to create links between them maintaining this contact. The first is accomplished by mixing and the second by addition of flocculants.

Among the different types of flocculants can be cited:

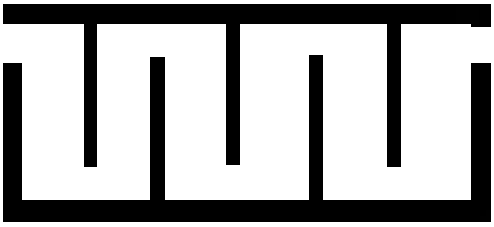
- **Polymers:** Frequently used in the flocculation process. Polymers are organic and inorganic compounds with a high molecular weight. Depending on their origin, polyelectrolytes are divided into two main categories: naturally, such as starch, cellulose and alginates, etc., or synthetic, consisting of simple monomers which are polymerized to form chains of very high molecular weight such as polyacrylamide (PAM).

- **Activated silica:** The activated silica is formed by a solution of polysilicic acid obtained from silicic acid process. It is not very stable, so it must be prepared 'in situ'. Until the recent development of polyelectrolytes, it was considered the best flocculant in association with aluminum salts.




**Coagulation-flocculation mixing facility**

Another slow mixing system involves the use of long channels or labyrinth deposits. They are common in chlorination processes.



Deposit with slow labyrinth mixing system. Plain view

In order to improve the performance of coagulants and flocculants other chemicals called adjuvants are used. They have the following objectives:

- **pH correction:** Each coagulant has an optimum working pH
- **Oxidation of compounds:** the process improves if some organic compounds (that can interfere with the process) are removed by oxidation. For this purpose, Chlorine, Potassium Permanganate, Ozone and other reactives can be used as oxidants
- **Add weight to particles:** So called gravimetric agents. They are applied in waters with low initial turbidity. It seeks to improve sedimentation rates. Activated carbon in powder, lime, clays, or polymers can be used

## Sizing criteria

| Hydraulic retention time | | |
|---|---|---|
| Rank | Coagulation 2 to 5 min<br>Flocculation 20-30 min | |
| Adopted value | Total time<br>25 minutes | Total time<br>40 minutes |
| Flow rate<br>($m^3/h$) | Area requirement<br>($m^2$)<br>2m water depth | |
| **5** | 1 | 2 |
| **10** | 2 | 3 |
| **20** | 4 | 7 |
| **30** | 6 | 10 |
| **40** | 8 | 13 |
| **50** | 10 | 17 |
| **60** | 13 | 20 |
| **70** | 15 | 23 |
| **80** | 17 | 27 |
| **90** | 19 | 30 |
| **100** | 21 | 33 |

**Area requirements for the implementation of coagulation-flocculation process**
*Source: University of A Coruña*

In all coagulation-flocculation process, it is necessary to conduct laboratory tests in order to determine:

- Most suitable chemicals
- Coagulant and flocculant dose
- Optimum pH
- Coagulation and flocculation times (hydraulic retention times)
- Sedimentation rate
- Sludge production volume
- Raw and treated water quality

> **Hydraulic retention times in coagulation and flocculation reactors are the two main parameters**

# Coagulation-Flocculation

## Control parameters

- The mixing for coagulation can be accomplished by mechanical agitators or by air injection to form medium or coarse bubbles. In the latter case the required air is about 1 to 1.5 $m^3$ air/$m^3$·h

- In the final equipment sizing should consider a margin for the spatters (40/50 cm)

- If a cylindrical section coagulator is adopted, it is necessary to install circuit breakers, to lessen the effect of the vortex created by the stirrer, which would lead to an energy loss by water entrainment. These circuit breakers are normally installed in a total number of three or four, and their width ranges between 5 and 10% of the tank diameter

- It should be noted that, in the coagulation process, secondary type precipitation may occur; corresponding to compounds present in the wastewater, such as phosphates, carbonates, etc. This effect can lead to precipitation of corresponding insoluble compounds, carrying some additional reagent consumption and increasing theoretically expected sludge production

- In the case of using lime as a neutralizing agent, being a solid-liquid type reaction, hydraulic retention times should arise, as the reaction rate is considerably lower

- Agitation in the flocculation deposit can be carried out by low-speed stirrers or by air injection through medium-bubble diffusers. In the latter case the required air is about 0.5 to 0.75 $m^3$ air/ $m^3$·h

- In the case of mechanical stirring, it is important to have a speed control in the flocculation process in order to adjust the speed according to the type of formed floc

- Inlet and outlet should be located at opposite positions

- Both coagulator and flocculator, are usually oversized on a range of 15 - 20% of the theoretical volume obtained by calculation.

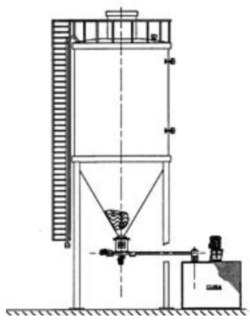
- Monitoring of the chemical feed system to detect clogging of the lines and maintenance of the mixers ranks is very important.

- Appropriate mixing energy is an important part of optimization of the chemical dose. Excess dosing with coagulant to compensate for inefficient mixing is not only uneconomical in terms of the chemical usage, but also expensive in terms of sludge production.

- Most drive failures are caused when the unit is started at the top rotational speed. O&M manuals should note that the mixers should be started at low speed to avoid very high torque force and high power requirement.

- Storage of reagents:

  o The silos must have arm filters and vibratory systems to avoid the 'silo effect' that prevents the descent of the material through the hopper



**Silo with incorporated arm dosing system**

  o The bags are common in small facilities and for reagents used in low doses. It is recommended not to stack substances exceeding 1.5 meters in height

  o Deposits, generally of cylindrical shape, are made of non-corrosive materials (plastics, polyester resin and glass fiber, etc.) and may be with vertical or horizontal axis

- Dosage:

  o The treatment plant should have a range of reagent use between 15 and 20 days considering the maximum dose and peak flows

  o The usual reagent dry addition system consists in a hopper that can be supplemented by a volumetric or a gravimetric system. Volumetric pumps may include a paddle or a screw drive. The dosage is usually controlled by the rotational speed

  o When using liquid reactives, it is also common to use a preparation tank, from which dosage is performed

Reagents preparation and dosing system

# Primary clarifier

## General description and types

The main objective of primary clarification is to remove SS from wastewater under the sole influence of gravity. In particular, settleable solids and floatable materials elimination is intended. Wastewater passes through the settling unit at a low velocity so that solids with a density significantly higher than water can settle. Additionally, materials with less density than water (e.g. oil and grease) will float.

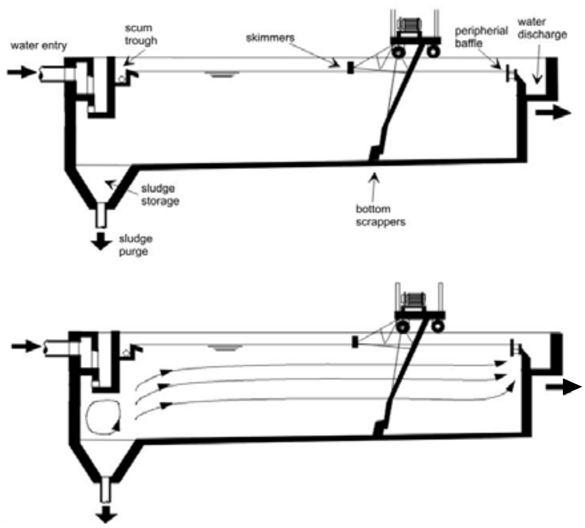
A primary clarification unit produces a less turbid effluent (due to SS removal), and a primary sludge. This sludge uses to have an organic fraction; therefore, a BOD reduction is also achieved in this step. Process magnitude reduction depends on the type of process unit and raw water characteristics.

Overall, the adoption of primary clarification units represents fewer problems on the downstream biological process operation.

In general, the primary clarification is not recommended when the biological process has a low, or very low, organic load rate, e.g. extended aeration processes. This means, assuming that settleable organic matter forms part of the substrate to be degraded by biological reactor biomass.

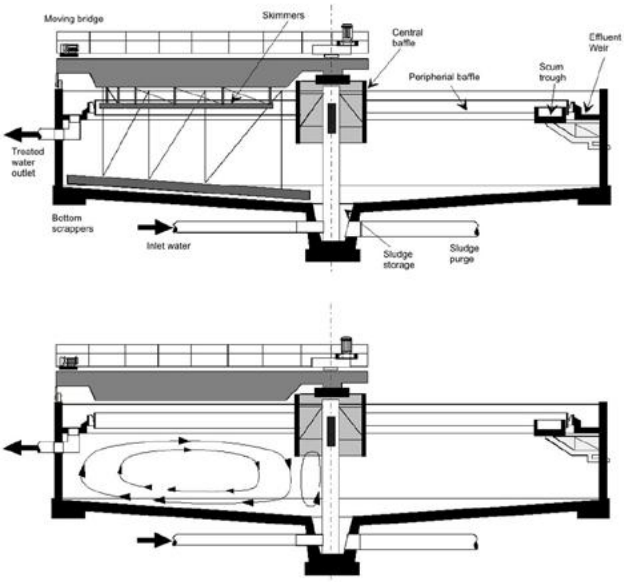
Static clarifiers without sludge recirculation are those of general use. Primary sludge normally contain organic matter that can be degraded on an anaerobic process with gas production, leading to particle floatation, and odour generation. It is a kind of sludge which needs further stabilization.

With regard to plain form of a clarifier, it may be rectangular or circular. The following figures present images and diagrams of different primary settlers.

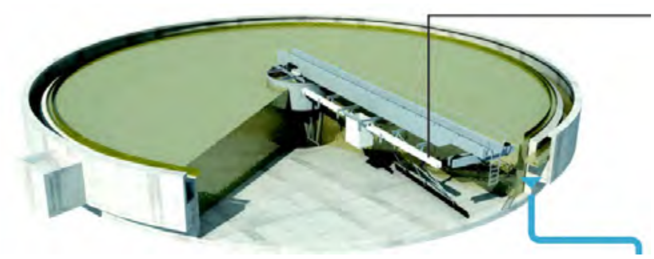



General diagrams of a rectangular clarifier with moving bridge

As reflected on the images, clarifiers can be process unit with many industrial equipment: moving arm, bottom scrappers and skimmers (bottom and surface respectively), baffles, etc. The main purpose of this equipment is the continuous removal of sludge and floatable matter that accumulates the unit.




General diagrams of a circular clarifier with moving bridge



Circular plain settling

## Sizing criteria

### Design parameters

The most important sizing parameters in the primary clarifiers design are Surface Hydraulic Loading Rate (HLR), Hydraulic Retention Time (HRT) and Weir Overflow Rate (WOR).

### Design criteria

Generally, limit values are established for surface loading rate, HRT and tank efficient depth, which are related to one another (see proposed values in the following table). HRT is in a range between 1.5 and 2.5 hours. Several sources recommend not to prolong HRT unduly because organic matter tends to rot quickly generating significant operating problems. This makes that sometimes, necessary theoretical tank depth can reach values as low as 2.0 to 2.5 meters.

> **The value of the weir overflow rate has an established limitation to avoid sludge drag-out from the bottom of the clarifier. This way it can be stated a maximum of 10 $m^3/h/m$**

> **Furthermore, a yield of 50% reduction in SS is an attainable design goal (range: 50 to 70%). $BOD_5$ can be reduced from 20 to 40%**

In order to avoid interferences caused by the sludge blowdown system, the bottom scrapers maximum speed is limited, which in the case of a circular clarifier is given by the peripheral speed. Similarly, the maximum retention time of the sludge is limited in the concentrator to avoid anaerobiosis and consequent process disruption, mainly the sludge flotation.

In addition to the above-mentioned, there are other practical design criteria of primary settling, for example:

- The central baffle in a circular clarifier with central feed normally has dimensions which usually comply with the following relations:
- 1) diameter is normally from 0.05 to 0.20 of clarifier diameter, 2) its depth is between 1/3 and 1/5 of the maximum depth of the clarifier.
- The slope of the floor of a rectangular clarifier is usually 1%. In a circular clarifier it could be up to 10%.
- In rectangular clarifiers length/width ratio is between 1.5 and 7.5 (usually 3). In circular clarifiers the radius/height is usually between 2.5 and 8.

> **Check if these design criteria is implemented in the existing primary clarifier**

# Primary clarifier

| Summary of design values for primary settling | | |
|---|---|---|
| **Parameter** | | **Value** |
| **Removal efficiency[(1)]** | SS | ≥ 60 % |
| | $BOD_5$ | ≥ 30 % |
| **HLR** | $Q_{ave}$ | ≤ 1.0 m/h |
| | $Q_{max}$ | ≤ 1.5 m/h |
| **HRT** | $Q_{ave}$ | ≥ 2 h |
| | $Q_{max}$ | ≥ 1 h |
| **WOR ($F_{peak}$)[(2)]** | | ≤ 10 $m^3$/h/m |
| **Side water depth [(2)]** | | ≥ 2.50 m (maximum 5 m) |
| **Overhead space** | | >= 0.50 m |
| **Primary sludge concentration** (for calculation) | | 1% |
| **Primary sludge extraction period** | | 10 h/day |
| **Bottom scrappers velocity** | | circular < 120 m/h |
| | | **rectangular < 60 m/h** |
| **Bottom slope** | Circular (with scrappers) | 8 % |
| | Rectangular (with scrappers) | 2 % |
| **Central baffle** (circular, central feeding) | Diameter | 10 % a 20 % of clarifier diameter |
| **Scum baffle** | Depth | 1 to 2 m |
| | Depth | ≥ 30 cm |
| **Sizing[(3)]** | Length/width ratio | 3 - 5 |
| | Maximum length | 40 m |
| | Maximum width | 12 m |
| | Maximum diameter | 40 m |
| **Sludge sump storage time[(4)]** | | < 5 h |

(1) In case of wastewaters with a high sedimentable solids fraction, maximum removal efficiency could be higher
(2) With the aim of minimizing the sludge drag-out with the effluent
(3) Maximum limitation taking into account constructive effects, climatology, etc.
(4) In order to avoid sludge rot and hydrolyzing

*Source: Tejero, I.; Suárez, J.; Jácome, A.; Temprano, J. (2004), 'Introducción a la Ingeniería Sanitaria y Ambiental', 2 Vols. A Coruña (España). ISBN: 84-89627-68-1*

### Sludge production

Primary sludge concentration is limited to 1% for calculations. Sludge extraction period will be 10 hours/day.

### Removal efficiency

For the load and/or effluent concentration calculation, the following removal efficiencies are determined:

SS = 50 %
$BOD_5$ = 20 %

### Area requirements

| Primary clarification surface requirements estimation | | |
|---|---|---|
| **HLR ($m^3/h/m^2$)** | **1** | **1.5** |
| **Q ($m^3$/h)** | **Area requirements ($m^2$)** | |
| **5** | 5 | 3 |
| **10** | 10 | 7 |
| **20** | 20 | 13 |
| **30** | 30 | 20 |
| **40** | 40 | 27 |
| **50** | 50 | 33 |
| **60** | 60 | 40 |
| **70** | 70 | 47 |
| **80** | 80 | 53 |
| **90** | 90 | 60 |
| **100** | 100 | 67 |

*Source: University of A Coruña*

## Process operation troubleshooting

In order to avoid septic conditions that make sludge float and release gases that could resuspend an already settled sludge fraction, a continuous purge is required.

Digestion gases by refloated sludge ($CO_2$, methane, etc.) are difficult to extract and can pass-through the primary clarifier reaching downstream processes.

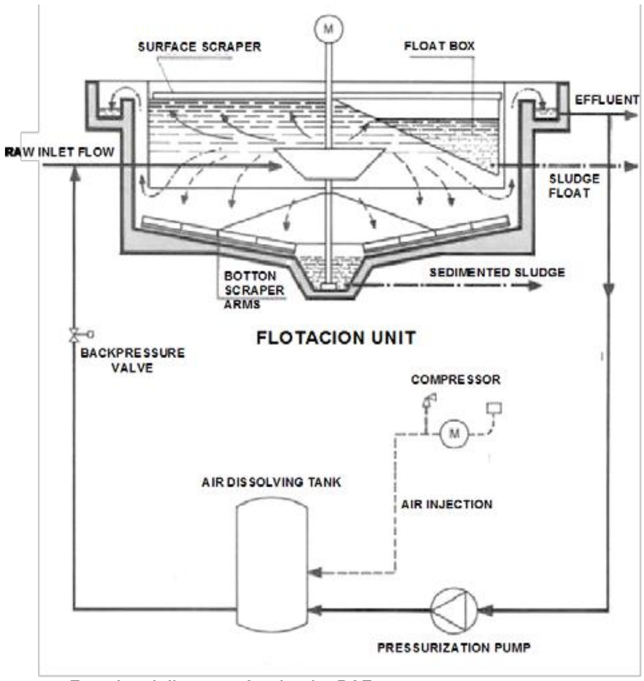
# Dissolved air flotation

## General description and types

DAF is a kind of 'induced flotation' applying the capacity of certain solid or liquid particles to join with air bubbles forming particle-gas clusters less dense than liquid phase. Although it is more complex this is the flotation system producing the best separation efficiency. DAF process consists of creating air microbubbles (30 to 120 microns in diameter) inside wastewater, which get attached to the particles to be removed. In this way, floatable aggregates (with joint density lower than water) are formed. In order to achieve microbubble formation, a first pressurization of a volume or a water flow (treated or untreated) is carried out, leading to the dissolution of air until oversaturation, and then this flow is depressurized in the flotation tank to atmospheric pressure, where dissolved air excess is released in the form of numerous microbubbles.

The pressurisable water flow can be the entire inflow of wastewater, part of this water flow or water already treated by the process (effluent). This results in DAF three types of usable process, called full flow, partial flow of recirculated flow (R-DAF, the most used in wastewater treatment).

In the market there is equipment that does not use pressure tank; in this case the necessary air pressure is injected into the recirculating loop. Drive line of the recirculating pump is mounted in a zig-zag pattern, thereby increasing turbulence and residence time, so that the dissolution of air is improved.




Functional diagram of a circular DAF system

> **DAF process typically requires the pre-addition of chemical reagents. In general, it will be necessary to coagulate and flocculate previously.**

Thus, in practice, the DAF unit will result as a part of a physical chemical process.

## Sizing criteria

### DAF Process

The effectiveness of a dissolved air flotation system is based on the ratio of kilograms of air used per kilograms of removed solids. This ratio varies between 0.005 and 0.09 kg air/kg solids removed. The exact value to use depends among other factors, on:

- The pressure of the system, typically ranging between 4 and 7 atmospheres
- The concentration and nature of the suspended solids, oil and grease to be separated
- Other wastewater characteristics, such as pH

Recirculation DAF systems are dimensioned considering that flow recirculation depends on:

- The amount of suspended solids, oil and grease present in the wastewater
- Water flow to be treated
- Conditions of pressure and temperature

The depth varies between 1 and 3 meters, depending on the type of device for distributing pressurized water inside the flotation chamber. The pressure chamber will have a retention time of 2-3 minutes.

| Overloadflow rate (m³/m²·h) | | |
|---|---|---|
| **Rank** | **2.5 to 10** | |
| **Adopted value** | **2.5** | **10** |
| **Q (m³/h)** | **Area needed (m²)** | |
| **1** | 2 | 0.5 |
| **10** | 4 | 1 |
| **20** | 8 | 2 |
| **30** | 12 | 3 |
| **40** | 16 | 4 |
| **50** | 20 | 5 |
| **60** | 24 | 6 |
| **70** | 28 | 7 |
| **80** | 32 | 8 |
| **90** | 36 | 9 |
| **100** | 40 | 10 |

**Necessary area estimation for DAF process**
*Source: University of A Coruña*

## Coagulation-flocculation

DAF units with prior coagulation-flocculation improve yields in comparison with simple flotation or primary settling units. Regarding suspended solids, $BOD_5$ and oils and grease, the following yields can be achieved:

| | |
|---|---|
| **SS Reduction (%)** | 65-80 |
| **$BOD_5$ reduction (%)** | 45-50 |
| **Oil & grease reduction (%)** | 70-90 |

**DAF achievable yields with coagulation + flocculation**
*Source: Tejero, I.; Suárez, J.; Jácome, A.; Temprano, J. (2004), 'Introducción a la ingeniería sanitaria y ambiental', 2 Vols. A Coruña (España). ISBN: 84-89627-68-1*

Coagulation step destabilizes colloids, while flocculation produces suspended solids and destabilized colloids aggregates. On these aggregates or flocs, depressurized air bubbles are able to act. Coagulant and flocculant doses depend on the characteristics of the wastewater, the following minimum doses are commonly considered for design purposes:

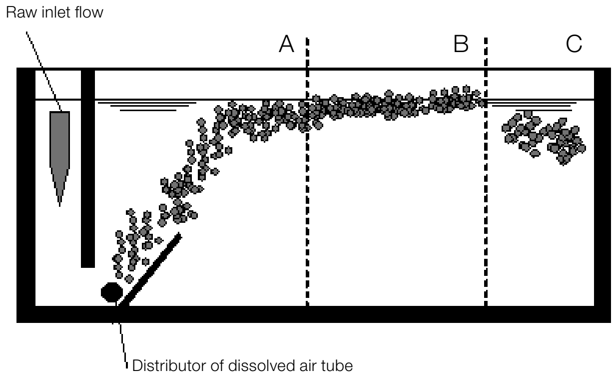
- Coagulant > 50 mg/L
- Flocculant > 5 mg/L

**Physico-chemical process based on coagulation-flocculation + DAF**
*Source: WWTP Cee - Coruña*

## Flotation chamber

The float chamber may be rectangular or circular.

- **Rectangular:** it is recommended to install a screen with an inclination angle of 60° respect to horizontal and 30 to 50 cm in length, as shown in the following figure.

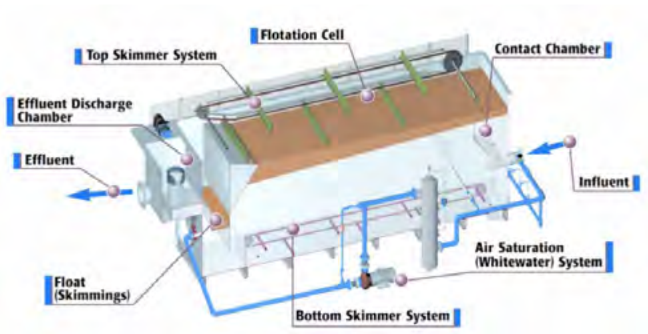



**Rectangular flotation chamber**
*Source: CEPIS, 1992*

The width of the chamber depends on the type of equipment used for scraping the floating material and rarely exceeds 8 meters. The length can vary between 4 and 12 meters whenever A or C scenarios do not occur (see figure). In case A, the length between this point and the raw inlet flow is insufficient, and in case C, the length between this point and the raw inlet flow so that there is sedimentation of floatable material due to an excess in tank length.

# Dissolved air flotation

Rectangular flotation tanks are provided with surface endless chain sweepers so as to extract foams.

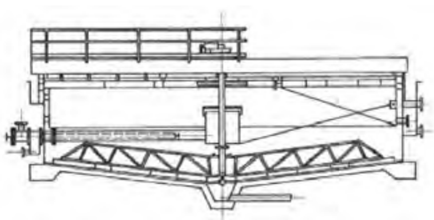



**Elements of a DAF system with rectangular flotation chamber**
*Source: Ross, C., Valentine, GE et al.; 2013*

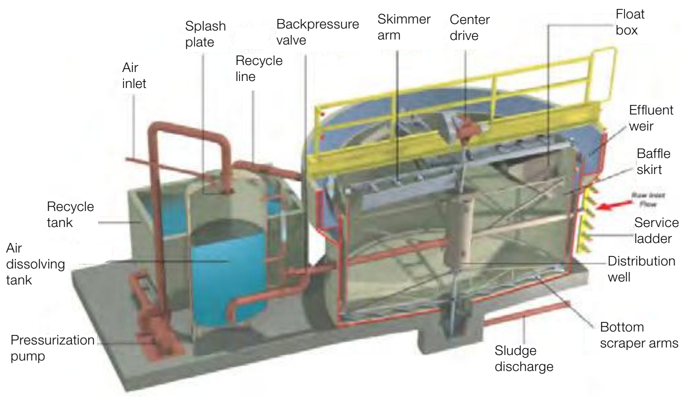
**Detail of skimmers removing the floating sludge**

- **Circular:** the skimmer arms are radial. The following figure shows the outline of a circular flotation chamber sample. The mixture between pressurized water and water to be treated occurs near to the flotation chamber inlet point, which in the centre has a circular conduct, which conveys water to the top and avoids short-circuiting. The supernatant is continuously swept away to one or more collection gutters. While the water makes a downward movement, goes through the bottom of the intermediate cylinder and is collected in the trough located at the periphery of the outer cylinder.

The clarified liquid is removed from the surface, protected by weir baffles that prevent floating materials to flow dowstream.



**Circular flotation chamber**




**Elements of a DAF system with a circular flotation chamber**
*Source: Advanced Energy Solutions SAE Ltda*

> **Maximum diameter of the flotation tank: 20m**

> **The pressurization chamber must have at least: safety valve, level control, purge and pressure gauge**

| Parameters | Value |
|---|---|
| Air/solids ratio (kg/kg) | 0.03 - 0.09 |
| Working pressure (atm) | 2.5 (4 to 6) |
| Pressurization rate* (%) | 10 – 40 |
| Hydraulic load (m/h) | 2.5 - 10 (3.5 to 3) |
| Hydraulic retention time (HRT) (min) | 20 – 40 (40 – 60) |
| Solids load (mass load) kg/m²/h | 4.5 – 5<br>Non limiting |

*Pressurization rate = percentage of pressurized flow relative to the flow of raw water to be treated

*Source: Sainz Sastre, J. A. (2007) 'Tecnologías para la sostenibilidad Procesos y operaciones unitarias en depuración de aguas residuales'. Colección EOI Medio Ambiente. Flotación por aire disuelto. Apuntes Curso EOI. (Coruña – España). Editado por Fundación EOI. ISBN: 978-84-88723-58-1.*

*Tejero, I.; Suárez, J.; Jácome, A.; Temprano, J. (2004), 'Introducción a la ingeniería sanitaria y ambiental', 2 Vols. A Coruña (España). ISBN: 84-89627-68-1*

## Control parameters

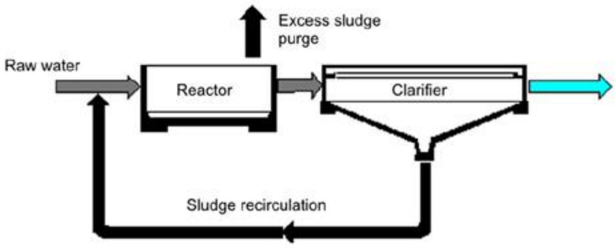
### Parameters for controlling the process efficiency

- Solids concentration in influent and effluent
- Effluent turbidity
- Bubble type observation
- Concentration of sludge removed by the scrapers
- Skimmers advance velocity
- Check pressure and flow pressurization equipment
- Attention to air solubility with high salinity conditions, since it is lower and with high temperature, which also decreases

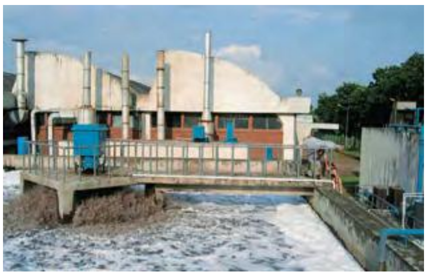
# Activated sludge

## General description and types

The activated sludge is a secondary treatment of wastewater that uses bacterial culture with the aim of biodegradation or oxidation of contaminants. All activated sludge process is a system comprising tank bioreactor with aeration equipment and secondary settling tank. Both tanks connected through the sludge return.




- **Biological reactor:** Controlled growth of a biomass is promoted. The biomass is suspended within the liquid with aeration equipment. Other types of biological treatments uses biomass attached to a carrier or a reactor filler (the so-called biofilm process, for example, biological filters, bio-discs, underwater beds, etc.).



- **Secondary clarifier:** conduct the final solid-liquid separation to obtain the secondary effluent, which will be discharged to the receiving environment. The optimal secondary clarifiers design is essential for the proper operation and performance of the biological process. If the solids are not retained by the settler: 1) contribute to the BOD increase in the effluent, and 2) modify the sludge age in the biological reactor. The secondary clarifier, while clarifying water should achieve some sludge thickening in order to optimize recirculation.

  A secondary clarifier is primarily divided into two zones: one at the top, which is often called clarified water area, and one in the deep end, called thickening or sludge concentration zone.

## Sizing criteria

### Biological reactor

Key parameters

- **BOD:** the higher the organic load, the larger the amount of oxygen consumed. The amount of oxygen consumed is determined after 5, 7 or, less commonly, 30 days. The corresponding parameters are called $BOD_5$, $BOD_7$ and $BOD_{30}$.

- **Food to microorganism (F/M) ratio:** is the organic matter mass (as kg of $BOD_5$) fed for 1 day in the reactor per kg of biomass present.

$$F/M = \frac{(F_{av} \cdot L_0)}{(V \cdot X)} \qquad Ec.\ 1$$

  Where:

  $F_{av}$ = average daily inflow ($m^3/d$)

  $L_0$ = average daily concentration $BOD_5$ influent to reactor ($kg/m^3$)

  X = concentration of suspended solids in the mixed liquor (kg $MLSS/m^3$)

  F/M = food to microorganism ratio (kg $BOD_5$/kg MLSS/d) or ($d^{-1}$)

- **Organic load:** Kg of organic matter (as $BOD_5$) fed for 1 day per reactor per cubic meter of reactor.

- **Cellular retention time (or sludge age):** Corresponds to the residence time of the biomass in the reactor. It is expressed in days, being the parameter that selects the type of bacterial culture to develop.

- **Oxygen requirements:** Oxygen depends on organic matter consumption, endogenous respiration demand and total nitrification.

- **Sludge production:** Due to cell growth (positive term in the balance sheet), the decay of a fraction of biomass (negative term in the balance sheet) and non-biological solids accumulation by factors such as adsorption, entrapment, etc.

> **In any case, the specific sludge production, Pfa, will not be less than 0.8 kg SS (suspended solids)/ kg $BOD_5$ eliminated**

- **Sludge recirculation rate:** is the ratio between the sludge recirculation volumetric flow, QR, and treatment volumetric inflow.

> **In any case, the capacity of the sludge recirculation system will not be less than 200% of the daily average total inflow**

## Secondary clarification

Key parameters

- **Surface hydraulic loading rate:** is based on the real flow rate circulating through the unit (outflow). Thus, the sludge recirculation flow rate, which also enters the clarification unit, is not taken into account because it is removed by the bottom of the settler, and thus does not influence the surface hydraulic loading rate

- **Solids loading rate:** defines required surface for suitable sludge thickening in the bottom of the unit (compression zone)

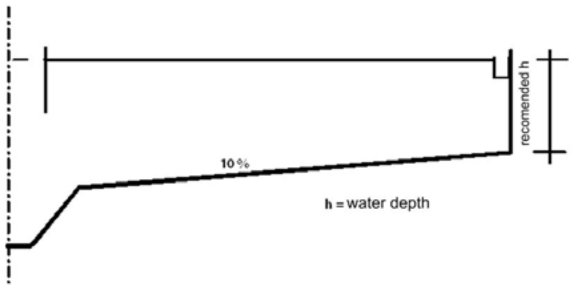
- **Weir overflow rate:** corresponds to the effluent flow rate per linear meter of weir outle

**Geometrical characteristics**
To define the geometric features it should differentiate between settlers 'with' and 'without' bottom scrapers.

**Clarifiers with scrapers**
The secondary clarifiers with bottom scrapers may be circular or rectangular. Table below shows the water height versus diameter for circular clarifiers.

| Diameter (m) | Water depth side-wall (m) |
|---|---|
| **< 12** | 3.50 |
| **12 to 21** | 4.00 |
| **21 to 30** | > 4.00 |

**Diameter of secondary clarifier according to the water depth side-wall**
*Source: WEF, ASCE, EWRI (2010). 'Design of municipal wastewater treatment plants'. Fifth edition. Water Environment Federation, American Society of Civil Engineering/Environmental & Water Resources Institute. McGraw-Hill: New York.*




**Secondary clarifier with scraper scheme**

In rectangular clarifiers a length/width ration greater than 3 but less than 6 is usually observed.

The bottom slope so as to facilitate the sludge carryover to the sludge sump will be:

Circular: 10%
Rectangular: 1%

> **The residence time of the sludge in the sump should be less than 3 hours**

In circular clarifiers the diameter of the central baffle is 1/5 to 1/6 of the diameter of the unit itself. The height will be 1/3 of the maximum depth.

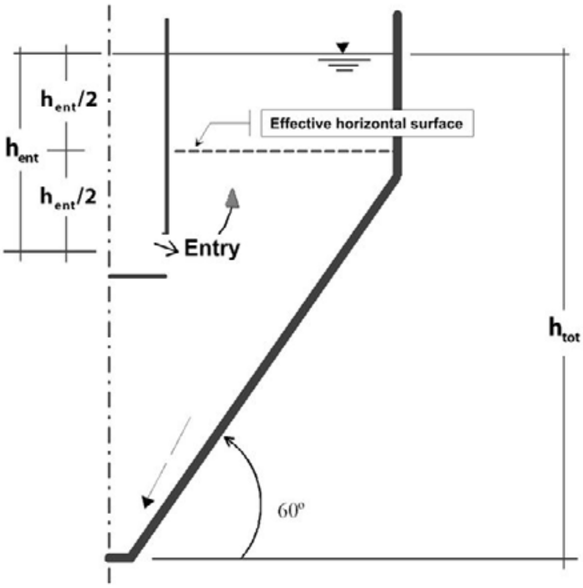
**Clarifiers without scrapers (truncated cone)**

> **Clarifiers with truncated cone shape, also called vertical flow clarifiers. For technical and constructive reasons, the diameter will not be greater than 5 m**

The slope of the conical wall area responds to an angle greater than or equal to 60° (see figure next page).

# Activated sludge

For these vertical flow clarifiers, the effective horizontal surface is set at the midpoint of the height between the unit water entry (that is, out of the central baffle) and the elevation of the free water level (see figure below).




Schematic of a vertical flow secondary clarifier

## Process operation troubleshooting

### Changes in the inflow and the characteristics of the wastewater

A common problem is the increased inflow resulting in a shorter aeration of the activated sludge or in a loss of the final clarification due to hydraulic overload. To address this problem, we can regulate the flow recirculation and sludge disposal, maintaining the optimum amount of solids in the aeration tank. Changes in the characteristics of the raw wastewaters may be caused by isolated or seasonal discharges.

### Changes in temperature

Temperature influences the performance of the activated sludge system. The effects are significant when the temperature change is greater than 6°C.

### Changes in the sampling program

Data on system performance can be greatly affected by changes in the sampling program. When the results vary widely from day to day, the following aspects should be checked: sampling locations, sampling hour and laboratory procedures.

### Sludge bulking

Normally, the interstitial fluid going through the solids is crystalline, with high quality, but the settling time is not sufficient for a complete removal of solids in the secondary clarifier. To prevent sludge bulking, it is necessary to carefully control the following issues:

a. Suitable CRT or sludge age: bulking effect can usually be corrected by decreasing the sludge age

b. Dissolved oxygen level: occurrence of low dissolved oxygen levels should be prevented

### Insufficient aeration capacity

If the secondary effluent is turbid, wit h a yellowish colour, it is a symptom of poor aeration. Aeration time has to be increased. If you cannot increase the concentration of dissolved oxygen, this may be due to three reasons:

a. There is an aeration system malfunction, so it is necessary to find and fix the fault

b. The aeration system is undersized. In such case, making an improvement in the treatment plant is required

c. The habit of keeping an excessive amount of sludge in the reactor has been acquired. In that case, it can be corrected by reducing the sludge return, or increasing the wasted sludge

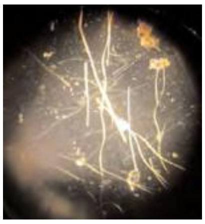
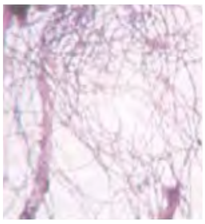
A quick and easy way to check if the wastewater is treated well is to fill a clear container (Imhoff cone or cylinder) with secondary clarifier effluent and observe their appearance (figure below).

Yellowish secondary clarified effluent

### Filamentous growth

The occurrence of filamentous growth may be caused by an unsuitable age of the sludge, or by an imbalance of nutrients, such as lack or abundance of nitrogen, phosphorus or carbon. If allowed to stabilize, filamentous growth will pose a difficult problem to solve. It can be controlled by maintaining an appropriate sludge age and in special cases, supplying the lack of nutrients.

Filamentous growth
*Source: University of A Coruña*

**Example of filamentous growth observed at microscopy**
*Source: University of A Coruña*

### Septic sludge

Any type of sludge can become septic if left too long in places like channels or wells. Septic sludge rises slowly and is likely to cause foul odors. Furthermore, it can disrupt the aeration tank, even in small quantities. In the secondary clarifier, the sludge can become septic due to four causes:

a. Sludge recirculation is too slow: the solids are maintained too much time in the final clarifier, allowing them to become septic

b. Scrapers clarifier mechanism is stopped, so that the sludge is not transferred to the sludge pit

c. Drain pipes for wasted sludge are clogged

d. The sludge recirculation pump is stopped, or the valve is closed

### Toxic compounds

Toxicity causes inhibition or death of the active microorganisms, leading to disturbances in the system and in the effluent. The operator has little control over its causes.

Under this circumstance, the sludge disposal must be immediately stopped, and all available solids must be returned to the aeration tank. The toxic compounds such as heavy metals, acids, insecticides and pesticides should never be discharged into the sewer system without proper control.

### Flotation sludge due to gasification

Do not confuse the rise of the sludge by gasification with bulking. In gasification, sludge settles satisfactorily, but once sedimented, it arises to the surface in the form of spots or pea-sized small particles. Generally, it is accompanied by a fine brown foam, which appears on the surface of the aeration tank and secondary clarifier.

If you have sludge on the surface of the settler and the origin is not known, there is a simple way to check whether it is gasification or not. When V30 determination is being made, do not throw the tested sample and leave it during a few hours. If, after some time, part of the mud rises and bubbles appear, then it can be ensured that there is a problem of gasification. This problem can be resolved by increasing the sludge recirculation flow (to remove the solids from the settler quickly) and reducing aeration.

**Floated sludge after several hours of testing V30**
*Source: University of A Coruña*

### Foam formation

In some treatment plants foaming in the aeration tank has been a problem. Several theories have been proposed to explain this phenomenon, such as the presence of detergents, polysaccharides and excessive aeration. But it is normal that white foams occur in a reactor start up due to the non-degradation of detergents. Furtherly, when biomass is generated in the reactor these foams will disappear.

To control foams:

a. A higher concentration of suspended solids in the mixed liquor must be maintained

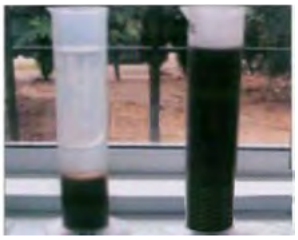
b. During periods of low inflow, air supply should be reduced, in order to maintain the level of dissolved oxygen

Most installations are equipped to spray water along the aeration tank to remove foams.

# Activated sludge

**Biological reactor with foams during startup**
*Source: University of A Coruña*

**Biological reactor with foams after a period of stable performance**
*Source: University of A Coruña*



**The correct value of V30 (left) and high (right)**
*Source: University of A Coruña*

**High V30**
*Source: University of A Coruña*

## Control parameters and strategies

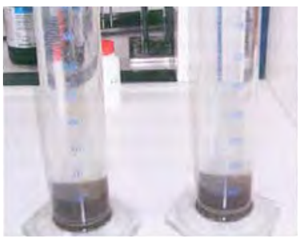
### Control of microorganisms levels

The efficiency of an activated sludge process depends on the amount of microorganisms (MLSS) existing in the system and its conditions. The V30 is a parameter that indicates whether the biological process operates properly. The recommended determination frequency is every 2 days and for its realization; a 1L Imhoff cone or cylinder and a glass rod are needed.

**V30 determination steps:**

1. Take a sample of aerated tank mixed liquor while aeration is operating
2. Pour the mixed liquor in the Imhoff cone, shake slowly with the rod and leave the sludge to settle for 30 minutes
3. After this time, read V30 level in millilitres of settled sludge per sample litre (mL/L)
4. It is advisable not to empty the cone until the next day to check if the mud rises. If so, this indicates that there is excessive aeration

**Float mud**
*Source: University of A Coruña*



**Small value of V30**
*Source: University of A Coruña*

**Interpretation of results:**

**V30 < 250:** means there is little sludge in the reactor. Therefore, sludge purge should be lowered

**V30 between 250 and 650:** indicates that the operation is correct

**V30 > 650:** means that there is a lot of sludge in the reactor or the sludge does not settle properly. In this case, the sludge purge should be increased

### Aeration control

A certain level of dissolved oxygen (DO) should be maintained in the aeration tank. When MLSS concentration and activity increase more airflow is required. To measure DO concentration a luminescent probe type is used. DO ranges between 0.5 and 2 mg/L are acceptable.

### Daily checks in the reactor and in the settler

The tasks to control and perform are:

- The appearance of the compartments of aeration and final settling
- Proper operation and lubrication of the aeration unit
- Correct operation of the sludge recirculation pipeline system
- Hosing the walls of the aeration tank and the final compartment
- Brushing weirs
- Remove grease and other floating materials such as rubber and plastic pieces

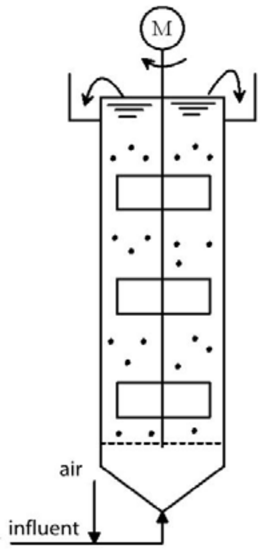
# Fluidized bed

## General description and types

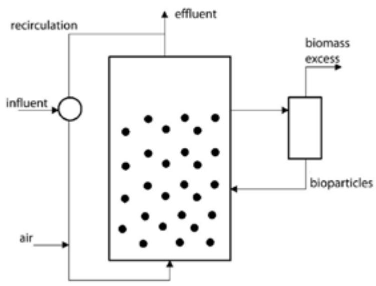
Fluidized beds are biofilm reactors with a wide range of applications in biological aerobic, anoxic and anaerobic treatment. These systems employ small particulate materials as a support medium for the growth of the attached biocenosis. Support-biofilm assembly (bioparticle) is kept in suspension inside an upward vertical flow whose velocity is high enough to overcome the force of gravity. Bioparticles are in continuous relative movement but are not transported by the flow, that is, they are not washed off from the reactor. Applications of this technology include: anaerobic digestion, oxidation of organic matter, nitrification and denitrification of industrial and urban wastewater.

An upward water flow through a sand bed, granular activated carbon, anthracite, polypropylene particles, etc., when it circulates at high speed, will cause fluidization. The support material of a fluidized bed has an extremely large specific surface, and reaches in minutes the treatment level that any conventional biological treatment process achieves in several hours. Bioparticles suspension maximizes the surface contact between the microorganisms and the wastewater.

The most typical fluidized reactor bed consists in a bed of great height, whose lower part introduces water, through a distribution system, at a high enough velocity to fluidize or expand the bed.




Typical phase fluidized bed reactor scheme



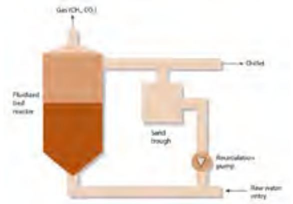

Typical phase fluidized bed reactor scheme

In general, the sedimentation rate of the bioparticles is far superior to that of activated sludge flocs. Moreover, bioparticles are retained in the reactor and the effluent has a very low concentration of suspended solids which allows its discharge without clarification. However, as the biomass grows, bioparticles may turn larger, increasing bed expansion. To avoid excessive expansion of the bed, which could increase the suspended solids in the effluent, the bioparticles are routinely removed, and a separating unit, for example a sieve, purges excess biomass and clean support particles are returned to the reactor. Thus, a stable amount of biomass can be maintained in the system while the effluent contains low concentration of suspended solids.

In the textile sector, the majority of applications are developed by anaerobic beds. It takes advantage from the high organic matter concentration to generate biogas. Moreover, depending on the bed material, it can achieve colour removal objectives.

However, it is important to consider also some problems with this type of treatment:

- Anaerobic bacteria are slow-growing
- It may require heating equipment when biogas production decreases
- Most part of the process elements, if not all, require to be installed inside a shed
- Although low COD effluent concentrations are achievable (up to 100 mg/L, depending also on influent COD), it is always safer to get better quality effluent with an aerobic process
- The operation of the anaerobic process should be performed by highly trained and experienced staff

Anaerobic


Aerobic

## Sizing criteria

> **The specific surface area in fluidized beds depends on the size of granular media (0.3 to 1.4 mm) and the bed expansion degree (from 50 to 100%), but generally ranges from 1000 to 3000 m²/m³**

This large surface area allows biomass concentrations of 15,000 mg VSS/L in aerobic beds or reaches up to 40,000 mg VSS/L in anoxic beds (Grady et al., 1999; Grady et al., 2011).

In fluidized bed reactors, both the amount of biomass retained and the total biofilm area are very large because biofilm support particles are of small diameter (0.5 to 1.4 mm). Therefore, they are able to treat wastewater with an extremely short hydraulic retention time or at high organic load. Thus, fluidized bed reactors can be operated with a retention time of just over 10 minutes, or with a volumetric load of about 10 kg $BOD_5/m^3$/day.

On the other hand, careful operations are required to form and maintain a stable fluidized bed. If the upward velocity is greater than the free settling of a single particle, the particle will be ejected from the biotower. Therefore, the upward speed needed for a proper fluidized bed operation will be within a narrow range between the minimum fluidization velocity and the free settling velocity of the particles composing the bed.

> **Generally, the acceptable range of upward velocity is 30 to 60 m/h**

The organic matter removal performance will range from 70 to 95%.

### Area requirements for biological fluidized bed reactor

The following table presents minimum area demand for a biological fluidized bed reactor filled with granular activated carbon (GAC) of 1.5 mm in diameter. The area was calculated for different sizes of textile factories in terms of water treatment flow rate. It is considered that the treatment prior to fluidized bed reactor includes: flow rate and concentration tank homogenization, screening, sieving and primary sedimentation. In this approach influent $BOD_5$ concentration to fluidized bed is theoretically 300 mg/L.

> **The upward velocity shall not exceed 30 m/h, for a maximum expansion of 60%**

| Flow (m³/h) | Area (m²) | Volume (m³) | Height (m) | R |
|---|---|---|---|---|
| 400 | 3.07 | 15.36 | 5.0 | 0.01 |
| 1000 | 7.68 | 38.40 | 5.0 | 0.01 |
| 2000 | 15.36 | 76.80 | 5.0 | 0.01 |
| 4000 | 30.72 | 153.60 | 5.0 | 0.01 |

**Example area, volume, height and recirculation rate of expanded bed reactor**
*Source: University of A Coruña*

Considering the internal aeration variant (air-lift and/or diffusers) the reactor effluent can have a concentration of suspended solids that do not comply with discharge common limits. In this case, a solid-liquid separation can be done by simple sedimentation; among other processes like simple sedimentation static circular or rectangular clarifiers.

Fluidized beds bioparticles concentration at the reactor outlet can reach or exceed 200-400 mg/L. When the clarifier unit diameter is less than 5 meters, it is recommended to use truncated cone shaped clarifiers without scrapers, also called vertical flow clarifiers.

### Area needed for the secondary clarification

So as to estimate the required clarification area, the hydraulic loading rate 0.6 m/h at average flow rate is used as design criterion.

| Inflow (m³/h) | Area (m²) |
|---|---|
| 400 | 28 |
| 1000 | 69 |
| 2000 | 139 |

*Source: University of A Coruña*

# Fluidized bed

### Total area required for secondary treatment

Finally, the area needed for the ‘secondary treatment’ is obtained by adding the area of reactor over the settling. Results are presented in the table below:

| Inflow ($m^3/h$) | Area ($m^2$) |
|---|---|
| 400 | 30 |
| 1000 | 71 |
| 2000 | 142 |

*Source: University of A Coruña*

## Process operation trouble shooting

The key advantage of the fluidized bed is its high surface area for biofilm growth. This produces a high concentration of active biomass, high reaction rate and reduced area requirements. However, due to the high concentration of biomass, aerobic processes may be limited by the oxygen demand.

Another disadvantage is the recirculation degree required to maintain an upward velocity which allows bed expansion and fluidization of bioparticles, increasing the energy costs for pumping.

Most problems in the distribution elements can be attributed to clogging issues. This can be avoided by removing solids in the influent and designing an element that prevents the return of the support material.

A common trouble is the stratification of the bed when the size of the support material is not sufficiently uniform. Smaller bioparticles will be accumulated near the top of the bed, being less exposed to detachment, which generates biofilm accumulation resulting in a density decrease in relative terms.

The use of a medium with good uniformity coefficient minimizes and/or effectively prevents stratification of the bed. Other control measures include the design of a conical section at the top of the reactor so as to settle down light particles, sieve installation, etc.

## Control parameters

### Height of the bed

The maintenance of these facilities includes to control the height of the bed which requires a continuous purge of biomass. Otherwise, bioparticles without proper size can be generated and of the expanded bed height may become excessive.

The most common procedure is to purge the biomass from the bed top zone. This induces to bed stratification. The bed is maintained in a dynamic state by continuous purge of large bioparticles on top and a return of clean support material, which migrates to the bottom of the bed where it contacts with a high concentration substrate.

This assumes that the support material has good size uniformity. If the material has poor size distribution, the stratification conditions are not related with the bioparticles size. In the latter case, the larger support media would remain near the bottom of the bed and the smaller would accumulate on top. Consequently, this material could be always purged and recycled, which is clearly inadequate. Thus, it is very important that the support material has excellent size uniformity.

### Air supply control

In biological reactors, dissolved oxygen (DO) concentration control is a point of great importance, in order to reach an efficient oxidation of organic matter (ranges between 3 and 4 ppm). Aeration in large plants is usually automated, so that, depending on the DO probe measuring values, the aeration equipment will start or stop.

### Clarification and purge control

When more than one clarification line is installed, a proper distribution of reactor effluent among all clarificators must be ensured.

Furthermore, sludge on the secondary clarifier should be prevented from a long retention time. With this purpose, sludge purge pumping times should be regulated. In general, an hourly purge is recommended.

Even though an installation is working properly, a certain amount of detached biofilm and/or low density flocs will float to the top of the clarifier. A surface baffle prevents these materials from flowing out the unit together with the treated water.

### Daily maintenance operations in the reactor and the secondary clarifier

Tasks to control and perform are:

- Observe water appearance in reactors and decanters
- Adequate maintenance and lubrication of aeration unit
- Brush clarifier’s outlet weirs
- Removal of oil and grease and other floating materials such as pieces of rubber and plastic

# Upflow anaerobic sludge blanket reactor (UASB)

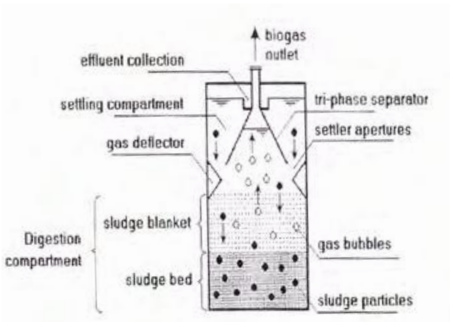
## General description and types

The upflow anaerobic sludge bed reactor (UASB) is a type of biological treatment of the wastewater. It is based on the following elements:

### Reactor

It is inoculated with sufficient quantities of anaerobic sludge, which is the most important phase of the operation of the reactor. The feeding rate of the reactor should be increased progressively, according to the success of the system response.

The quality of the biomass to be developed in the system will depend on an appropriate operational routine and, consequently, on the stability and efficiency of the treatment process.




Schematic drawing of a UASB reactor

### Sludge Bed

After some months of operation, the anaerobic sludge becomes highly concentrated which is called sludge bed (40 to 100 g TS/L). This sludge is developed close to the bottom of the reactor.

The sludge is very dense and has excellent settling characteristics.

Sludge ages in UASB reactors usually exceed 30 days, leading to stabilization of the excess sludge removed from the system.

### Sludge Blanket

It is an area of more dispersed bacterial growth and it is developed above the sludge bed, with solids presenting lower concentration and settling velocities. The concentration of sludge in this area usually ranges between 1 and 3%.

The system is self-mixed by the upflow movement of biogas bubbles and by the liquid flow through the reactor. During the start-up of the system, when the biogas production is usually low, some form of additional mixing, such as by the recirculation of gas or effluent, may become necessary. Substrate is removed throughout the bed and sludge blanket, although removal is more pronounced at the sludge bed.

### Three-phase separator

This three-phase separator (gases, solids and liquids) is located in the upper part of the reactor to allow sludge retention and return through the upflow movement with the gas bubbles. The installation of the gas, solids and liquid separator guarantees the return of the sludge and the high retention capacity of large amounts of high-activity biomass, with no need for any type of packing medium.

### Sedimentation chamber

There is a sedimentation chamber around and above the three-phase separator, where the heaviest sludge is removed from the liquid mass and returned to the digestion compartment, while the lightest particles leave the system together with the final effluent.

### Effluent collection

The effluent is collected from the reactor in its upper part, within the sedimentation compartment. The devices usually used for the collection of effluent are plates with V-notch weirs and submerged perforated tubes.

The anaerobic process through UASB reactors presents several advantages in relation to conventional aerobic processes: compact system, with low land requirements, low sludge production and energy consumption and satisfactory COD and BOD removal efficiencies, amounting to 65 to 75%. The major limitations are in relation to the long time necessary for the start-up of the system and the need for a post-treatment stage.

## Sizing criteria

One of the most important aspects of the anaerobic process applying UASB reactors is its ability to develop and maintain high-activity sludge of excellent settling characteristics.

The main criteria for reactors treating organic wastes are presented below:

**Volumetric hydraulic load and hydraulic retention time:** volume of wastewater applied daily to the reactor, per unit of volume. The hydraulic retention time is the reciprocal of the volumetric hydraulic load.

> **Check that the volumetric hydraulic load do not exceed the value of 5.0 m³/m³·d, equivalent to a minimum hydraulic retention time of 4.8 hours**

The design of reactors with higher hydraulic loading values (or lower hydraulic retention times) can be detrimental to the operation of the system in relation to the following main aspects:

- Excessive loss of biomass, that is washed out with the effluent, due to the resulting high upflow velocities in the digestion and settling compartments
- Reduced solids retention time (sludge age), and a consequently decreased degree of stabilization of the solids
- Possibility of failure in the system, once the biomass residence time in the system becomes shorter than its growth rate

**Organic loading rate:** the amount of organic matter applied daily to the reactor, per volume unit.

**Biological loading rate (sludge loading rate):** the amount of organic matter applied daily to the reactor, per unit of biomass present. The loads should be gradually increased, according to the efficiency of the system. The maximum biological loading rate depends on the methanogenic activity of the sludge.

> **Check that the initial biological loading rate during the start-up of an anaerobic reactor range from 0.05 to 0.15 kg COD/kg VS·d depending on the type of effluent treated**

**Upflow velocity and reactor height:** relation between the influent flowrate and the cross section of the reactor. The maximum upflow velocity in the reactor depends on the type of sludge present and on the loads applied:

- Reactors operating with flocculent sludge and organic loading rates ranging from 5.0 to 6.0 kg COD/m³·d, the average upflow velocities should amount to 0.5 to 0.7 m/hour, with temporary peaks up to 1.5 to 2.0 m/hour lasting for 2 to 4 hours
- Reactors operating with granular sludge, the upflow velocities can be significantly higher, amounting to 10 m/hour

> **Check that the upflow velocity is within the indicated range**

The COD and BOD removal efficiencies are substantially affected by the hydraulic retention time of the system, ranging from 40 to 70% for COD removal and from 45 to 90% for BOD removal.

Other considerations of the different elements of UASB reactors:

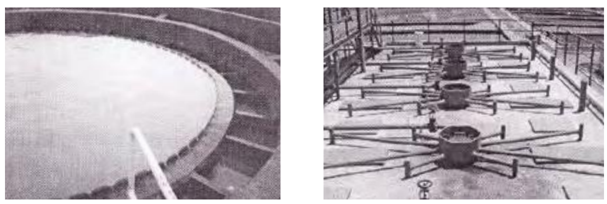
### Influent distribution system

To obtain a good performance from UASB reactors, it is essential that the influent substrate is evenly distributed in the lower part of the reactors, to ensure a close contact between the biomass and the substrate.

> **Check that preferential pathways (hydraulic short circuits) are avoided through the sludge bed**

This is particularly important when the process is used in the treatment of low-concentration and/or low-temperature wastewater, as in those situations the biogas production can be too low to allow appropriate mixing within the digestion compartment.

**Distribution compartments:** It is the equal division of the influent flow to the several distributing tubes by small compartments (boxes) fed by weirs. Each box feeds a single distribution tube extending to the bottom of the reactor. These compartments, installed in the upper part of the reactor, ensure the uniform distribution of sewage throughout the bottom of the tank, besides enabling the visualization of occasional increments in the head loss, in each distributor. Once an increased head loss is detected in a distributor, the tube can be easily unblocked by using appropriate rods.



Influent distribution structures in: a circular reactor (left side) and a rectangular reactor (right side)

**Distribution tubes:** the distribution is done by tubes which have the following main requirements:

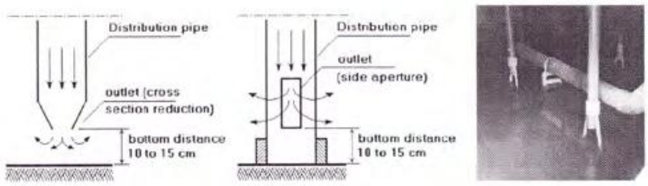
- The diameter should be large enough to enable a descending wastewater velocity lower than 0.2 m/s, so that the air bubbles occasionally dragged to inside the tube can go back upwards (opposite the direction of the wastewater). The introduction of air bubbles in the reactor

# Upflow anaerobic sludge blanket reactor (UASB)

should be avoided for the following reasons: (i) they may cause the aeration of the anaerobic sludge, harming methanogenesis; and (ii) they may cause a pontentially explosive mixture with the biogas accumulated close to the three-phase separator.

**> Check if there is air bubbles in the reactor**

- The diameter should be small enough to allow a higher flow velocity at its lower end (bottom of the reactor), which favours good mixing and greater contact with the sludge bed. Besides that, a higher velocity helps avoid the deposition of inert solids close to the discharge point of the tube. The requirement is somehow incompatible with the previous ones, once a reduced diameter of the tube hinders the upward movement and the release of air bubbles, besides increasing their possibilities of blocking. A solution that can be adopted is the reduction of the tubing section just close to its lower end, thus keeping an area large enough to avoid blockage.



Examples of distribution tube ends

## Three-phase separator

The main objective of this separator is to maintain the anaerobic sludge inside the reactor, allowing the system to be operated with high solids retention time (high sludge age). This is initially achieved by separating the gas contained in the liquid mixture, enabling as a consequence, the maintenance of optimal settling conditions in the settling compartment. Once the gas is effectively removed, the sludge can be separated from the liquid in the settling compartment, and then returned to the digestion compartment.

**Separation of gases:** Aiming at avoiding sludge flotation and the consequent biomass loss from the reactor, the dimensions of the separator should be such that they allow the formation of a liquid-gas interface inside the gas collector sufficient to allow the easy release of the gas entrapped in the sludge. The biogas release rate should be high enough to overcome a possible scum layer, but low enough to quickly release the gas from the sludge, not allowing the sludge to be dragged and consequently accumulated in the gas exit piping.

**> Ask if the minimum release rates of 1.0 $m^3$ gas/ $m^2$·hour and maximum rates from 3.0 to 5.0 $m^3$ gas/ $m^2$·hour**

**Separation of solids:** After the separation of the gases, the liquid and the solid particles that leave the sludge blanket have access to the sedimentation compartment. Ideal conditions for sedimentation of the solid particles occur in this compartment, due to the low upflow velocities and the absence of gas bubbles. The return of the sludge retained in the sedimentation compartment to the digestion compartment does not require any special measure, as long as the following basic guidelines are met:

- Installation of deflectors, located immediately below the apertures to the sedimentation compartment, to enable the separation of the biogas, and allow only liquid and solids to enter the sedimentation compartment

- Construction of the sedimentation compartment walls with slopes always higher than 45º adoption of depths of the sedimentation compartment ranging from 1.5 to 2.0 m

## Gas system

The biogas produced in the reactor should be collected, measured and, later, either used or burnt. The biogas removal system from the liquid-gas interface inside the reactor consists of:

- Collecting piping
- Sealed compartment with hydraulic seal and biogas purge
- Biogas meter
- Biogas reservoir

## Sludge sampling and discharge system

The reactor should comprise a group of valves and piping that allows both sampling and discharge of the solids present in the reactor.

The sampling system usually consists of a series of valves installed along the height of the digestion compartment, to enable the monitoring of the growth and quality of the biomass in the reactor. One of the most important operational routines in the treatment system is the evaluation of the amount and activity of the biomass present in the reactor, by means of two basic mechanisms:

- Determination of the solids profile and mass of microorganisms present in the system
- Evaluation of the specific methanogenic activity of the biomass

The sludge discharge system is intended for the periodical removal of the excess sludge produced in the reactor, also allowing the removal of inert material that may accumulate at the bottom of the reactor.

> **At least two sludge withdrawal points should be planned, one close to the bottom of the reactor and another approximately 1.0 to 1.5 m above the bottom to allow a higher operational flexibility**

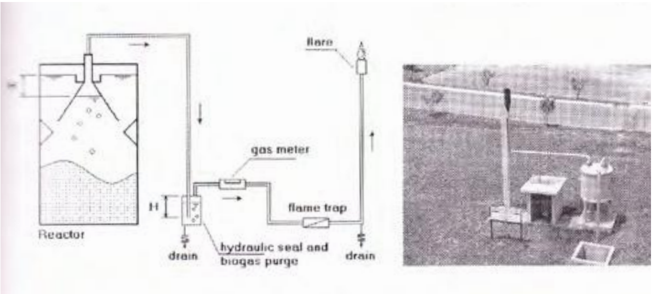



Diagram of a gas system in UASB reactors (left side) and view of a hydric seal and gas burner (right side)

The solids accumulation rate depends essentially on the type of effluent being treated and is greater when the wastewater has a higher concentration of suspended solids, especially non-biodegradable solids.

> **The values of efficacy coefficient of the solids production reported for the anaerobic treatment of domestic sewage are in the order of 0.10 to 0.20 kg TSS/kg $COD_{app}$**

Green to Wear · Supporting guide

# Textile mills process and management

# Textile mills process and management

Green to Wear
Supporting guide

# Metering and energy management

## Current status and limitations

Measurement of the energy and water used in textile mills is critical in order to account the associated costs and also to identifying the benefits of the efficiency measures.

Based on experience of NRDC (NRDC Guide to Metering in Textile Mills) and the audits carried out so far by Inditex as part of the GtW program, textile mills are not generally metering their energy and water use effectively. Most of the mills audited had only meters in the incoming supplies and in some cases only one per energy type supplied by utilities.

Generally, the lack of meters in the mill's energy consuming sub- systems doesn't allow understanding the patterns and trends of energy use in different parts of the mill.

Some mills audited did have metering infrastructure but were not collecting and analyzing the data adequately to improve the energy and water consumption.

## Objectives and advantages

The main objective of Metering is to provide a simple overview of main patterns of energy and water use to evaluate overall energy efficiency of production and report to stakeholders. Other advantages and objectives are:

- Provide detailed data on energy and water use to customers seeking to understand more about the life cycle performance of their products
- Provide a baseline of energy and water use in specific workshops and by specific equipment before efficiency measures are put in place, in order to evaluate the effectiveness of those measures
- Evaluate new equipment to ensure it is performing to manufacturer specifications
- Provide real-time data on performance of existing energy- and water-intensive processes and equipment to evaluate whether they are being operated efficiently and without equipment malfunction. Similar equipment or processes running in different workshops can be benchmarked against each other, or against a database of historical resource use to further increase performance insight
- Use portable temporary meters to spot-check performance of subsystems where issues are suspected and validate other meter and billing data
- Integrate benchmark resource consumption with other information systems (e.g. customer orders) for estimating and forecasting upcoming energy demands and energy production/consumption needs.

Use intelligent control systems to integrate sensor data such as external air temperature, indoor temperature, etc. to adjust consumption expectations and goals.

GtW Indicator

**Poor performance C**
Check if the mill has flow-meters in use to monitor at least water consumption or total discharge

GtW Indicator

**Good performance B**
Check that at least 80% of the production is coming from washing machines with water level meters and temperature controllers in use in each front loading washer and no belly washers

## Metering technology

This section provides an overview of the technology available to help mills measure energy and water consumption. The focus is on hardware to sub-meter the different sub-systems and process. The section includes also a table summarizing the meters characteristics to measure the main energy supplies.

### Electricity meters

**Mechanical meters** are the most common electricity meters found in older textile mills. Mechanical meters require manual reading and logging of consumption data and ideally should only be used in lines with low energy.

**Electrical smart meters** can record consumption over set intervals of an hour or less, and can be integrated with a computer server through a network for regular logging and analysis. The more in depth information gathered by smart meters makes them essential on main lines for billing purposes, but these meters should be used as widely as possible across a factory.

Both mechanical and smart meters gather information from electrical lines via Current Transformers. Where smart meters are replacing a mechanical meter, the existing CT can be used, which reduces the overall price of switching to smart meters.



**Electrical meters (and sub-meters)**
*Sub-meters are installed on this LV Switch Panel, using current transformers on the outgoing cables inside the panel*

## Water meters

**Mechanical meters** use a spinning part installed into the water pipe to record accumulated flow. Because these meters create pressure reductions within the pipe, they are not commonly used for large volume measurements but may be used for smaller flow in end-use applications.

**Electromagnetic flow meters** are much more accurate and do not disrupt water flow, they measure velocity based on the relative disruption of an electrical current passing perpendicular to the water flow. These meters should be used on major inlet and outlet pipes to the facility and workshops.

**Ultrasonic flow meters** are a cheaper option for nonintrusive metering, and can be easily installed without removing pipes. The ultrasonic meters do not accurately read flow through thick pipes or high flows and should not be relied on for billing main.



**Installation of water flow meter in the waste water line of an audited mill**

GtW Indicator

**Poor performance C**
Check if the mill has flow-meters in use to monitor at least water consumption or total discharge

## Steam and heat meters

**Orifice flow meters** are accurate enough to be used for billing purpose, and are recommended for use throughout the factory. They are designed for maximum flows up to 30 bar and 300ºC well above normal textile mill operation conditions. Installation should be done in straight pipe sections with sufficient length.

**Steam V-cone flow meters** are more accurate, and remain so at higher temperatures and pressures. V-cone meters can be used when testing new equipment, configurations, or validating energy savings.

**Heat meters** can be used to measure energy transported in liquids using flow meters and temperature sensing probes an integrator to combine the variables and output consumption in kilowatt hours.

## Portable meters for energy

Portable meters (with a data logging capability) can be a cost-effective alternative to analyse problems in areas where permanent metering can not be installed or would not be reasonable financially. Once a problem is corrected, the portable meters can be easily removed and redeployed elsewhere.

*Source: Weschler Instruments*


**Portable energy meters**

# Metering and energy management

**Meters of energy supplies**

| Fuel type found in textile mills | Description | Unit of measurement | Calculation to provide usable reading | Installation method | Average cost range (US$) | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|
| **Natural Gas** | Natural Gas From utility's network use in textile mills mainly to produce steam and in some countries to for the electrical production | M3/h or ft3/h | Kwh reading resulting from the metered volume and calorific value | In-line (flow)<br>Strap onto pipe | 300- 1500<br>600-2000 | Technology is simple and proven | Installation of additional metering can be expensive and disruptive |
| **Electricity** | Generated on- or off site | kwh | N/A | Direct meter or Current transformers | 120-1200 | Capability to obtain data break-downs easily | For loads larger than 10A transformers may be required |
| **Solid Fuel** | Coal, Wood, Biomass, etc. | Kg/h, Kg/day or month | Kwh derived from volume/ weight and calorific Value | Stock level<br>Integral heat generator feed system | N/A<br>200-2000 | If planned in advance management of data easy | Accuracy questionable |
| **LPG Gas** | Usually from tank (bottled for ancillary uses) | Litres/hour | Kwh derived from volume and calorific Value | Tank level monitor<br>In-line (flow) | 100-500<br>200-2000 | Single source supply makes metering simpler | Tank level monitoring is difficult to create consumption profiles |
| **Oil** | Fuel or gasoils | Litres/h | Kwh derived from volume and calorific Value | Tank Level Monitor<br>In-line flow | 100-700<br>200-2000 | Flow metering can be used to create a profile | Tank level monitoring is difficult to create consumption profiles |
| **District heating** | External Hot water supply or steam (and to lesser extent cooling) | M3/h-ft3/h or or kwh. For steam ton/h | Depending on meter type kwh derived form flow and dT | In-line (flow)<br>Strap onto pipe | 400-1600<br>900-2400 | Heat metering recognizes the actual consumption | Installation and operation can be expensive |

*Source: Prepared by Arup based on 'CIBSE Building energy metering TM39: 2009' by CIBSE and 'NRDC Guide to Metering in Textile Mills' by Natural Resources Defense Council*

## Metering and Energy Management

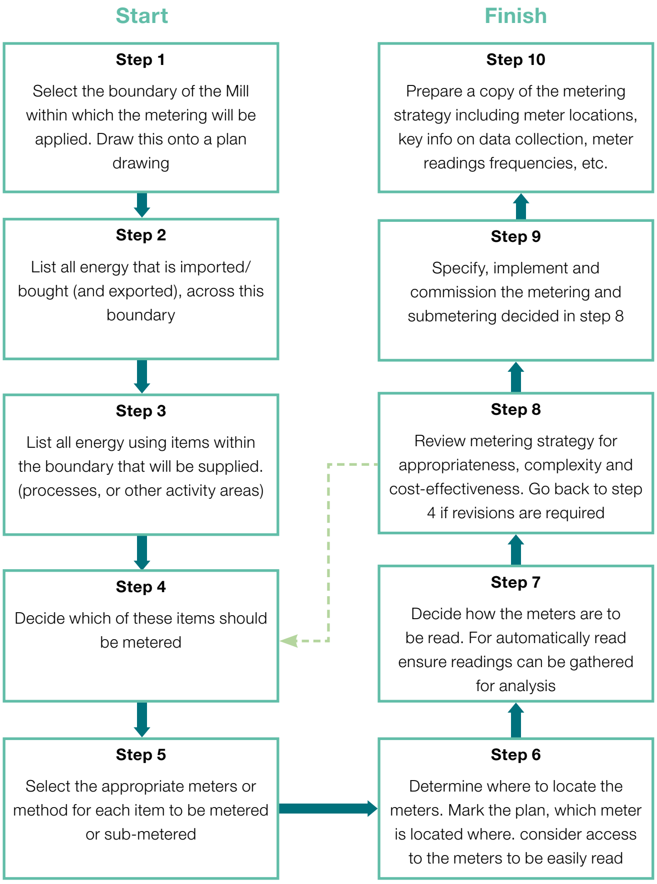
Some mills audited did have metering infrastructure but were not collecting and analysing the data adequately or not using to do Measurement and Verification (M&V) activities. M&V is the process of using measurement to reliably determine actual savings created by an energy management project, program or single measures.

As savings cannot be directly measured, the savings can be determined by comparing measured use before and after implementation of a project, making appropriate adjustments for changes in conditions such as variable production outputs.

Good metering is a fundamental energy monitoring & targeting tool and an essential part of the energy management of a textile mill. End use metering of the different processes helps to establish the breakdown of energy use so that areas of significant use can be identified and patterns of use monitored. Ideally, all energy consumption should be directly metered but this is not always practical or cost effective.

## Setting up metering strategy

The following steps are recommended in order to set up a metering strategy:




*Source: Prepared by Arup based on 'CIBSE Building energy metering TM39: 2009' by CIBSE*

## Energy Management plan and ISO 50001

An energy management plan provides the framework for setting and reviewing energy objectives and targets and will help mills to establish the commitment to continual improvement in energy performance.

Depending of the level of development and the energy efficiency measures in specific mills the implementation of the ISO 50001 certification, or at least the use of the standard as guide to establish an energy management system EnMS will be beneficial. The first step will be to draft an energy management plan.

The energy management plan could be a simple document establishing Energy Performance Indicators (KPIs) appropriate for monitoring and measuring the overall and energy break downs describing the energy performance of the Mill and the improvement objectives established periodically. The plan and indicators must be communicated to the top management and any worker involved with energy management. It will also include a commitment to comply with specific energy requirements established in the Plan to which the Mill subscribes, related to its energy use, consumption and efficiency.

Along with monitoring and measurement, energy KPI and targets should be periodically re-evaluated to ensure that continual improvement is achieved and energy management action plans are implemented to achieve the objectives.

### Examples of KPIs

Example 1: Conserve energy and maximize energy efficiency of Mill operations.

- Reduce the Mill operational energy by at least X kWh/year
- Conduct a Dyeing pilot project to assess various energy efficiency technologies
- Increment to XX % the heat recovered by 2015
- Reduction in gas consumption on steam boiler by more than 10% with respect to year 2015

Example 2: Investigate opportunities to participate in renewable energy or waste heat recovery projects.

- Conduct a waste heat assessment to determine feasibility of heat recovery of dyeing process and central generation and estimated costs of implementation
- Install photovoltaic or solar water heaters systems on the Administration and General Services Buildings
- Pursue funding for sustainable biomass projects

### Operational control

As part of the Energy Management system an Energy Operational control should be established. It requires the organization to identify and plan operations and maintenance activities which are related to its significant energy uses in order to ensure that they are carried out under specified conditions.

In order to identify operational controls, the energy system team should systematically review all of its significant energy uses to identify those which are not already controlled or where existing controls may be insufficient, and to subsequently ensure that control procedures are in place for all such areas.

The Energy management System (that could be based on ISO 50001) will provide opportunity to improve the energy efficiency and to develop solutions that save money as well as helping to conserve natural resources.

# Automatic control

Textile manufacturing is based on process machinery directly involved in the product production (weaving, dying, printing, and washing), and support or utility machinery, that provide the resources required by the process machinery (compressed air, electricity, steam…) or provide the thermal conditions for the employees working in the mills.

Automatic controls are the collection of hardware (equipment) and software that allows to control processes, facilitate efficient manufacturing and provide a comfortable environment for occupants. Controls are essential to the proper operation of any system and should be considered in the design process or as mill enhancements.

Some benefits of automatic controls are:

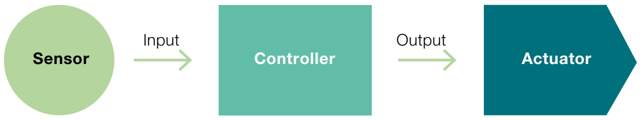
- **Product increased quality and standardization:** Under constant or changing conditions, controls can adjust processes to achieve batch-to-batch uniformity and repeatability
- **Higher production rates:** Making processes more efficient, reducing downtime and re-processing
- **Reduction in the use of resources:** Machinery will only use the required amount of resources (energy, water, chemicals and materials), reducing the amount of final products rejected, 'Right the First Time'
- **Reduction in the use of energy:** Machinery is only activated when it is required for manufacturing or occupant comfort. Controls can also adjust production to demand.
- **Reduction in maintenance costs:** Efficient operation will reduce maintenance costs and will increase the life expectancy of equipment and systems
- **Increase productivity:** By providing a comfortable and safe work environment
- **Reduce human errors:** Manual operation is always susceptible to human error



Controls can be as simple and low-cost as a time switch that ensures a compressor or equipment is not left enabled off working hours, or as complicated and expensive as to control the entire manufacturing process carried out in the mill, adjusting outputs to measured variables or other influencing factors. When designing for automatic control it is important to evaluate the benefits obtained against the capital and maintenance costs involved in installing them.

The main components of any control system are:

- **Sensors:** which measure a physical state such as temperature or pressure
- **Controllers:** which monitor the sensed variables and determine if it is required to make any change in the system according to the programmed logic
- **Actuators:** which effect the controller commands




## Automatic controls applied to process machinery

Automatic controls produce benefits in two main areas:

- **Resource demand reduction:** Textile production consumes a great amount of energy, water and chemicals, some of these with increasing scarcity and costs. By automating processes, it is possible to control and monitor the use of these resources allowing to optimize their use. Reducing the amount of resources required, in addition decreases the amount of waste and pollutants generated.
- **Increased quality:** Batch-to-batch uniformity and repeatability are terms of high importance in textile production. The result of most textile processes can be dependent on many different parameters, which sometimes are out of the control of the mill. Measuring and controlling these parameters makes possible to provide operators with complete control at every stage, making it easier the 'Right the First Time' quality approach, increasing quality and reducing reprocessing costs and delays.

  RFT is a parameter that gives information about the performance of the dyehouse and its production quality control and quality management. It indicates the rejection rates and the number of re-operations which shows the efficiency and productivity of the mill.

The use of an automatic control to monitor production parameters has to be considered by the mill in order to improve their RFT. Also record keeping and controls of this parameter help to define more initiatives to be implemented.

GtW Indicator

**Best in class A**
Check if the RFT value (lab to bulk) is higher than 85%

The RFT parameter can be measured by the facilities using different criteria. Usually it can be expressed as RFT percentage bulk to bulk or lab to bulk. The difference between both is that the bulk to bulk is calculated from one bulk of production and another and the lab to bulk is calculated from the laboratory to the first bulk.

The auditor will pay special attention to the "lab to bulk" during the visit since this figure is essential to reduce the number of reoperations.

If the mill has daily values of RFT, the monthly average of this parameter has to be higher than 85%.

At the same time, an automatic control allows to analyse historical data for problems which may have occurred in earlier batches and avoid them in the future.

Since the actual status (actual function, temperature, speed) of all machines is constantly updated and displayed, it is possible to control every process (processes can be started, halted or stopped).

Automatic controls can be applied to single processes or to the entire mill production. The higher automation of the process, the higher quality of the final product.

GtW Indicator

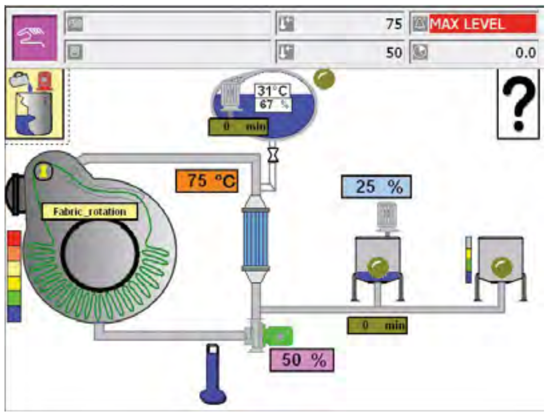
**Good performance B**
Check if at least 80% of the production is coming from dyeing or finishing machines with automated control

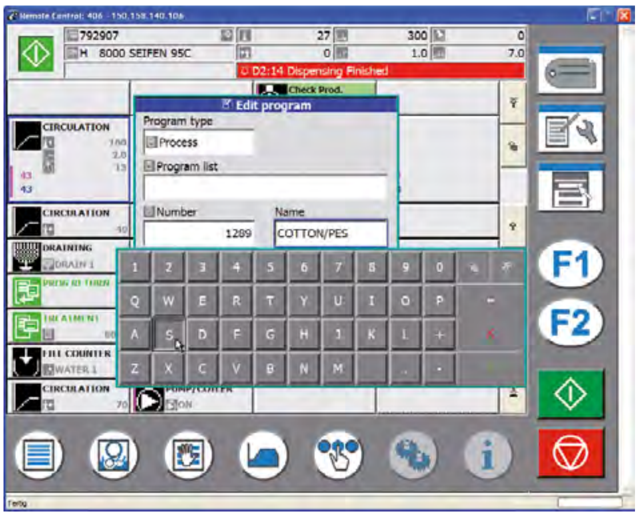
GtW Indicator

**Best in class A**
Check if there is central automation to monitor and control the processes

- **Simple controls** can range from time controllers to de-energize machines off working hours, avoiding the standby losses, to a sensor that controls an electrical resistance output according to water temperature.

- **Advanced controls** can receive information from many sensors, and through a controller calculate how to alter system parameters to optimize its performance. These systems can gather all the information in a central monitoring system that shows systems status in real time.




Source: SedoTreepoint

# Automatic control

## Automatic controls applied to central plant equipment

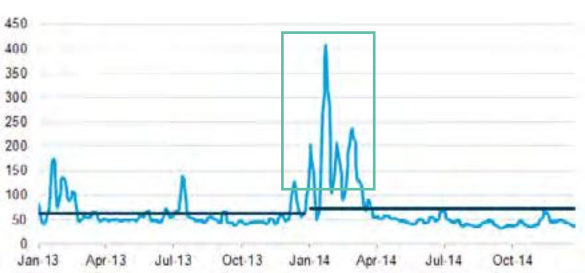
Process machinery may require one or more of the following sources of energy in order to complete their processes:

- **Electricity:** Grid sourced or provided by a generator
- **Steam:** Steam boiler
- **Hot water:** Boiler
- **Cold water:** Chiller, cooling tower or similar
- **Compressed Air:** Air compressor

These energy sources can be designed to supply to a specific process, or be centralized to supply to different processes. Since some of these equipment is very energy intensive (compressor, steam boiler, etc.), it is important to monitor and control its functioning in order to optimize energy consumption.

The capacity of central equipment is designed to cope with peak conditions, when all connected equipment is working at peak consumption and all outside parameters are in its worst case conditions, which in most cases only happen for a very limited amount of time. Most operation is off design as process machinery load, outside temperature, humidity and other variables are constantly changing throughout the day/season.

Monitoring demand and end-use conditions makes possible to adjust central equipment output to that actually needed, avoiding energy waste or process machinery working out of optimal conditions (i.e. reduced steam pressure or temperature). Monitoring the energy consumption of the different processes also allows to trend energy use, making possible to benchmark their efficiency and detect malfunctioning.




As with the process machinery, the simplest control for this equipment is a timer control, de-energizing air compressors, or steam boilers out of working hours. During working hours there are different ways to meet demand:

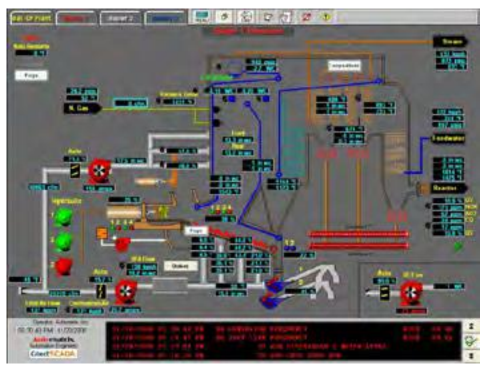
- **Cycling or on/off control:** Equipment runs controlled by a sensor that enables/disable it according to the sensed parameter. The problem of this type of control is the short-cycling which keeps the system operating at the inefficient condition and wears the components quickly

- **Staging:** Several small units are installed instead of one large unit. When conditions call for half the design capacity, half of the units will operate and the other half will be disabled

- **Modulation:** Most of the new efficient equipment is provided with controls that allow to turn-down output according to demand. Equipment has a limited turn-down ratio, so under a very variable load, staging may be required


Four air compressors provide compressed air to the system

Since this type of control equipment is also used in commercial buildings, technology is highly developed to monitor and control this type of processes, allowing to monitor in real time all working parameters of these systems.



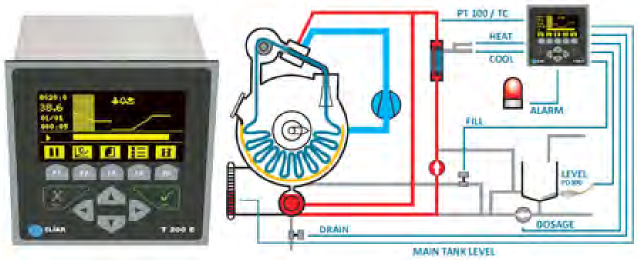
*Source: Automatrix Inc.*

### Chemical dosing

The way in which different chemical products (dyes, auxiliaries, sal, etc.) are dispensed determines its use and the results at the end of the textile process. A more accurate chemical dosing is also crucial in later stages as the wastewater treatment and final discharge.

For example, reactive dyes demand high levels of salt. However, high salt levels not only make future recycling and treatment of water challenging but it also make wash off of dyes more difficult.

Automatic dispensing systems for chemicals and dyestuffs are directly connected to the products inventory. When batches are planned, the required quantities of chemicals and dyestuffs are reserved and checked in the inventory.




*Source: Sun Instrumentation & Control*

After the weighing or dispensing is finished, the reservations are cancelled and all the registered product consumptions are updated in the inventory and stored against the corresponding batch.

A chemical dosing system is the most effective way to control the dosing process. The use of an auto-dispenser for chemicals will improve the chemical weighing and reduce chemical consumption by 10%.

GtW Indicator

**Best in class A**
Check if dyes and auxiliaries (chemicals including salt) are automatically dispensed

# Traceability

The textile value chain is complex and difficult to control. A comprehensive system of reporting and monitoring of both internal and external processes can make the best decisions in a changing environment.


Adequate knowledge of the extended value chain can better understand the business risks and facilitates the identification of the weakest links in the chain of supply of services and commodities. On the other hand, knowledge of the processes of suppliers is a source of good practices and innovative actions that can be incorporated into the business.

The implementation of practices of transparency and traceability allows the generation of trust relationships in the value chain, building long-term relationships with suppliers and increasing the value added by each link in the supply chain.

Although traceability is a much broader, for the purpose of this standard, we understand traceability as the ability to monitor the raw material used in the wet process mill two steps behind, hence the supplier of the supplier.


**Number of suppliers in 2014**

For example if the mill is doing a garment washing & finishing, the need to know and register the garment supplier (the cut and sewing factory) but also the fabric supplier. If the mill is dyeing fabric, they need to know the knitting or weaving factory and the yarn supplier / fiber spinning factory.

| | |
|---|---|
| 1 | Fiber sourcing & processes (natural, artificial or syntetic) |
| 2 | Fiber Spinning |
| 3 | Yarn dyeing (if required) |
| 4 | Knitting or weaving |
| 5 | Fabric pre-treatment, dyeing, finishing or printing (if required) |
| 6 | Cut & Sewing |
| 7 | Garment washing & finishing or printing (if required) |

The raw materials traceability template should have the information presented in the Annex III of the *Ready to Manufacture Standard* but should also include the name of the supplier.

GtW Indicator

**Good performance B**
Check if the mill has a recorded traceability control (two steps behind) of the raw material (fiber, yarn, fabric and garment)

Example of traceability template

| GENERAL INFORMATION | | | |
|---|---|---|---|
| Delivery Note Nº[1] | | | |
| Nº Boxes/Pallets[2] | | | |
| Delivered Goods | ☐ Garment ☐ Fabric ☐ Yarn ☐ Fibre | | |
| Date | | | |
| Supplier´s Name | | | |
| Location (province) | | Location (country) | |
| Sub-Supplier's Name – nº1 | | | |
| Location (province) | | Location (country) | |
| ☐ Garment | ☐ Fabric | ☐ Yarn | ☐ Fibre |
| Sub-Supplier's Name – nº2 | | | |
| Location (province) | | Location (country) | |
| ☐ Garment | ☐ Fabric | ☐ Yarn | ☐ Fibre |
| Sub-Supplier's Name – nº3 | | | |
| Location (province) | | Location (country) | |
| ☐ Garment | ☐ Fabric | ☐ Yarn | ☐ Fibre |
| Sub-Supplier's Name – nº4 | | | |
| Location (province) | | Location (country) | |
| ☐ Garment | ☐ Fabric | ☐ Yarn | ☐ Fibre |

| GOODS DETAILS | | | | |
|---|---|---|---|---|
| ID. | Article Description[3] | Quantity [4](Units/Weight/Length/Area) | Batch Number[5] | Composition Analysis[6] |
| Item 1 | | | | |
| Item 2 | | | | |
| Item 3 | | | | |
| Item 4 | | | | |
| Item 5 | | | | |
| Item 6 | | | | |
| Item 7 | | | | |
| Item 8 | | | | |
| Item 9 | | | | |
| Item 10 | | | | |
| Comments | | | | |
| Name and signature:[7] | | | | |

[1] Identification code assigned to the goods sent by the customer, once they are received at the mill warehouse.
[2] Number of units in which goods sent by the customer are received at the mill warehouse.
[3] Breakdown of the articles received in the shipment sent by the customer to the mill warehouse.
[4] Amount of the different types of articles received in the shipment from the customer.
[5] Identification code of each one of the yarn, fabric or garment lots coming from the same supplier produced in the same facility and, by means of the same productive process, regardless the date and the number of deliveries.
[6] Result of the composition analysis or its identification code that the raw material (except leather) supplier should provide with the delivery of every batch.
[7] Name and signature of the person in charge of controlling the incoming and outgoing raw materials at the warehouse.

# Transparency

It is important that the facility follows local limits and permit conditions with regard to its environmental management. These requirements include but are not limited to the facility's wastewater discharge, air emission, waste disposal, and noise management.

The facility should take measures to ensure its legal compliance, and keep relevant documentation, such as legal compliance checklist, monitoring reports, internal/external audit reports, corrective action plans, inspection record by government authorities, etc.

GtW Indicator

**Very poor performance D**
Check that the mill has no repeated non compliance in case of direct discharge or discharge to a municipal ETP (enforcement actions or fines)

GtW Indicator

**Poor performance C**
Check that the mill has no enforcement actions/ fines regarding discharge of the final effluent in the last 12 months and authorised discharge

Requiring information disclosure on pollution management encourages facilities to pollute less. This yields many positive business benefits, including:

- Improving pollution management and reducing expenditure on fines
- Reducing employee injury or illness
- Promoting a positive reputation for the facility in local communities
- Allowing business to distinguish themselves as environmental leaders


Several systems have been developed to disclose and improve pollution management but the environmental information disclosure in the form of a Pollutant Release and Transfer Register (PRTR) is widely known. As defined by the UNECE, a Pollutant Release and Transfer Register is a national or regional environmental database or inventory of potentially hazardous chemical substances and/or pollutants released to air, water and soil and transferred off-site for treatment or disposal. PRTR are a means to implement the Right-to-Know principle and report on chemical management performance.

PRTR systems have been adopted by EU, Australia, Canada, Chile, Japan, Mexico, Norway, Switzerland and United States of America. Countries currently developing PRTRs include Cambodia, Thailand and China, but also there are voluntary initiatives like the Chinese Institute of Public and Environmental Affairs (IPE). The IPE is a platform that contains pollution databases that help companies and the public monitor corporate environmental performance.

In China, some of the environmental violation records (enforcement actions/fines/complaints from neighbourhood) could be found on IPE website. It is required that before conducting the onsite audit, the Chinese auditors should look up the facility information on IPE website to see if the facility has any violation records regarding its pollution discharge. Also, auditors should check on IPE whether the facility has disclosed its hazardous chemical discharge (PRTR or DETOX).

For more information on the Right-to-Know Chemical Disclosure Methodology Research please see:

GtW Indicator

**Poor performance C**
Check that the mill has no environmental violation records on IPE's website (just for China)

GtW Indicator

**Best in class A**
Check if the mill discloses its hazardous chemical discharge (mandatory or voluntary)

http://www.roadmaptozero.com/df.php?file=pdf/RightToKnowDisclosureMethodologies.pdf

For the purpose of discharge disclosure, total Pollutant released to water estimation is calculated as: total waste water pollutant concentrations * total waste water discharge flow for period (sum of all discharge points) OR Total Pollutant Discharge Estimation = Mass Balance Calculation

The source of pollutant concentration data could be found in:

- Inspection data from the Environment Protection Bureau (manual sampled),
- Real time automatic monitoring data from the Environment Protection Bureau
- Third-party monitoring data (manual sampled)
- Self-declared data (manual sampled)
- According to Mass Balance from Third-party
- According to Mass Balance, self-declared

# MRSL and chemical inventory

## Inditex's Manufacturing Restricted Substances List

Inditex's Manufacturing Restricted Substances List (hereinafter, The MRSL) specifies the restrictions and bans regarding chemical substances used as an input at the main stages of the production processes of Inditex goods.

The MRSL is regularly reviewed and updated, at least every 12 months, and revised and extended, as credible information on hazardous substances is identified using an intrinsic hazards methodology (e.g. Greenscreen methodology), as it is required by the precautionary principle.

This list has to be enforced by Inditex's supply chain, including suppliers and mills. Their fulfillment is checked by the Ready to Manufacture programme.

RTM is the first world programme of Good Manufacturing Practices (GMP) intended specifically to prevent the inclusion or production of undesired substances during product manufacturing as a consequence of the technological processes used or the quality of the auxiliary chemical substances.

More information can be found on http://www.inditex.com/en/sustainability/product/health_quality_standards

As part of this programme, mills have to ensure that the concentration of APEOS in formulations used to process Inditex's orders do not exceed the limit of the MRSL (100 ppm).

Similarly, mills have to manage its chemical inventory in order to comply with the Manufacturing Restricted Substances List (MRSL). Auditors will have to check the RTM scoring and that the mill has all measures in practice.

GtW Indicator

**Good performance B**
Check if the chemical inventory list is properly recorded and managed to meet the MRSL

The auditor will check the RTM scoring during the visit. If it is green, it means that the chemical inventory complies with the MSRL. In case it is red, it does not meet the requirements.

## Chemical inventory

There is a wide variety of chemicals and auxiliaries involved to assist the wet processes. Their diversity in terms of the chemical supplier, the function in the textile process, the chemical substances, the consumption, etc., make a chemical inventory essential.

Chemical management by a chemical inventory:

- Contributes to meet textile brands' Manufacturing Restricted Substances Lists
- Facilitates the chemical management and the related waste management
- Reduces risks and facilitates responses in case of emergency
- Helps to plan and manage the textile processes
- Optimizes the textile products, which means higher productivity

During the audit, the mill has to show its chemical inventory. This will have to record at least the following information: chemical supplier, product name, MSDS available, function of the product and monthly consumption or stock (kg).

GtW Indicator

**Poor performance C**
Check if full chemical inventory list is available

If the chemical inventory is not available, the mill will have to prepare this document according to the guidelines above mentioned.

If the chemical inventory is not complete, the mill will have to include the missing information and use that format from then on.

## Root cause analysis

Even though the mills implement the MRSL and manage their chemical products by a chemical inventory, some priority substances might be detected in the wastewater.

If the concentration of MRSL substances in the wastewater is higher than 0,1 ppm (heavy metals and any value > 0,1 ppm due to the incoming water are excluded), the mill will have to evaluate these failures through a 'Root Cause Analysis'. This method of difficulties solving delimits the problem until the root cause of faults or problems are identified.

The strategy to eliminate the presence of these hazardous chemical substances in wastewater includes the following steps:

1. Check the RTM score
2. Analyse chemical products and raw materials accordingly
3. Phase out hazardous products and identification of non risk alternatives

### Check RTM score and analyse accordingly

The auditor will check the RTM score with the mill. Since this programme prevents the inclusion or production of undesired substances during product manufacturing, weaknesses that were identified by RTM audit, will help to orient the Root Cause Analysis.

**RTM score RED:** The mill will have to check its chemical inventory and analyse the high-risk products according to the following table:

| Root cause analysis | | | | | |
|---|---|---|---|---|---|
| Chemical group detected in wastewater | What? | How much? | Who? | When? | How? |
| APEOs | For **textile**:<br>Spinning<br>Lubricants<br>Antistatics<br>Dispersing agents<br>Emulsifiers<br>Detergents<br><br>For **leather**:<br>Degreasing agents<br>Fatliquors<br>Retanning agents | 1 analysis of the chemical product per year [1] | Dyeing and printing mills, laundries, tanneries<br>or the<br>Chemical suppliers/ providers | After reception of the chemical product at the mill warehouse and before starting production | Lab criteria |

**[1] If the same product is provided by different suppliers, it will be considered as a different product and should be analysed as many times as suppliers has.**

Likewise, main risk chemical products where SCCPs, phthalates or chlorobenzenes may be found are mentioned bellow:

| Hazardous substances may be found in | |
|---|---|
| Chemical group detected in wastewater | What? |
| SCCPs | For **textile**:<br>Spinning<br>Lubricants<br>Antistatics<br>Dispersing agents<br>Emulsifiers<br>Detergents |
| Phthalates | For **textile**:<br>Pigments<br>Print pastes |

| Hazardous substances may be found in | |
|---|---|
| Chemical group detected in wastewater | What? |
| Chlorobenzenes | For **textile**:<br>Dyeing carriers<br>Dyestuffs<br>Leveling agents<br>Deodorizers<br>Fumigants<br>Degreasers<br>Insecticides<br>Herbicides<br>Defoliants |

- If hazardous chemical substances are detected, these high risk products will have to be removed from its chemical inventory

- If hazardous chemical substances are not detected, the mill will have to test non high risk products from its chemical inventory

**RTM score GREEN:** The mill will have to look for the source of this unintentional contamination in its non high risk chemical products and its raw materials. For this purpose, it is suggested to sample representative chemical products and raw materials and test them for the priority chemical groups that were detected in wastewater.

**No RTM score:** According to the precautionary principle, if the mill has not been visited by the RTM programme, they will have to carry out this root Cause Analyses as if they have got RED score. In this case, the mill will have to prioritize the analysis of chemical products with high risk of APEOs presence. All these analysis will be conducted by Inditex proposed laboratories.

## Phase-out and identification of non-risk alternatives

If the analysis of the chemical products and the raw materials detect hazardous chemical substances, the mill will implement corrective actions.

These measures include:

- Substitution of non-compliant chemicals with hazardous substances free alternatives
- Confirm absence of hazardous substances in the starting raw materials used in production

Chemical and raw material suppliers can confirm this by providing a test report to the mill.

# Waste Management

## General description and types

Wastes generated at industrial facilities usually include domestic waste, general industrial waste, and hazardous waste.

In textile printing and dyeing mills, the commonly seen hazardous wastes consist of (and are not limited to): waste chemical containers for dyestuff, auxiliaries, and other chemical commodities; waste fabrics from printing and dyeing processes; waste oily rags/glove from equipment maintenance; waste film from roller engraving (for printing); waste dyestuff; waste fluorescent lamp tubes and toner cartridges; burning residue from boilers; and sludge from ETP.

## Hazardous waste handling and storage

The mills should keep a complete inventory for the hazardous wastes generated onsite. Hazardous waste should be collected and disposed of by qualified companies, and transferring manifests should be kept.

In some cases, the used chemical containers are collected and recycled by the chemical vendor. If the mills can make sure the recycled chemical containers are put into good use, it is acceptable to hand over these used containers to the vendor, instead of dispose of them as hazardous waste.

Hazardous wastes should be put in appropriate containers and stored in designated storage facilities. The ground inside the hazardous storage facility should be paved. Safety lighting and adequate ventilation should be provided. Leakage prevention measures should be equipped in the storage facility, such as secondary containment and spill kits.

Incompatible wastes should not be mixed. Hazardous wastes should be strictly segregated from other wastes. The containers of hazardous wastes should be affixed with identification labels per local legal requirement.

GtW Indicator

**Good performance B**
Check that the mill has a hazardous waste inventory and sends this waste to an authorized agent. Check also that the waste is properly managed (segregation, labelling, isolation and ventilation and leakage prevention)

*(Note: for China only)*

## Burning

After mechanical dewatering process, the common water content in the ETP sludge generated from printing and dyeing mills is around 80%. Due to the difference on raw materials, product type, and processing technics, the composition of sludge generated in textile industry vary greatly. Generally speaking, sludge generated from printing and dyeing processes contain residues of dyestuff, sizing agent, auxiliaries, and other chemical commodities.

It is not recommended, however sludge with higher organic contents could be incinerated together with coal in boilers after filter-pressed and dried. However such operation should be carried out with the permission of local environmental authority. The mill that burns coal/sludge should use a filter before discharging the flue gas into the ambient environment.

GtW Indicator

**Poor performance C**
If the mill burns waste, check that it does so in an authorized manner

# Preventive maintenance tables

## Preventive maintenance

Preventive maintenance is a systematic process of preserving the Mill process function by selecting and applying effective maintenance tasks. Contrary to the traditional approach to scheduled maintenance, the periodicity of which is determined by elapsed time or time of use, a preventive starts by considering what could cause a failure or underperformance of the equipment and what could be the consequences of each of the possible failures.

The preventive maintenance approach allows deciding what must be done to ensure that any or the equipment or process machinery continues to perform as intended. The equipment performance can be defined in terms of output, throughput, energy/water consumption, range and capacity etc.

Preventive Maintenance of the mill equipment directly affects operating costs while in the long term keeping capital and revenue costs under control.

In order to incorporate reliability as one of the drivers of the preventive maintenance the following activities need to be undertaken:

- Familiarisation with the operations, maintenance activities, available data and Mill process risk tolerance levels
- Define functions and associated performance standards for the different processes
- Identify potential functional failures and failure modes
- Identify effects of failures and quantify their criticality in terms of process performance and/or safety

Select appropriate maintenance strategy to ensure the required reliability, taking into account cost (e.g. spares costs, maintenance costs, equipment ageing and repair times), safety, environmental and operational consequences.

Other benefits:

- Reducing the total costs associated with equipment failure and downtime
- Improving process machinery availability
- Optimising spare parts inventory and capital expenditure programme
- Identifying component failure significance
- Comprehensive identification of failure modes
- Identifying areas for potential enhancement

GtW Indicator

**Best in class A**
Check if there is a preventive maintenance program in place (including maintenance routines, frequency of preventive checks, etc.)

As an example a leak detection program should be part of the preventive maintenance strategy.

Although individual water leaks may not seem important in the overall consumption, they can be responsible for a surprisingly significant loss of resources over the course of time. By correct preventive maintenance leaks in water systems can be reduced at very low cost and instant payback.

GtW Indicator

**Good performance B**
Check if steam and water leakages are frequently monitored and tested

# Boiler

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **Important – Read manufacturer's Instructions** | | Seek advice and training from local distributor | Each type of boiler has specific requirements. Dismantling of boiler and annual maintenance should be carried out by registered, trained and experienced boiler technicians. |
| **1. a) Before proceeding with dismantling of boiler** | 12m | Check casing for damage or breakages. Inspect for loose fittings or connections and any sign of leaks. | Check for asbestos containing materials prior to dismantling any equipment If asbestos present cease work and report to supervisor to have a simple analysed |
| **b) Test fire** | 12m | Record settings of the burner firing. | |
| **2. Gas electrical & ventilation systems** | 12m | Check that all are in accordance with current legislation and Codes of Practice. | Local electrical isolator should be fitted. Supply to the boiler must be direct i.e. not fed through a time switch. |
| **3. Isolate boiler for gas and electrical supplies** | 12m | Record any work which needs rectification or replacement. | |
| **4. Gas valve** | 12m | Disconnect thermocouple from the gas valve and pilot tube from burners. | |
| **5. Remove burners and pilot assembly and baffles if fitted** | 12m | Brush all accessible flueways thoroughly from top to bottom, clean all deposits from the burner box, refit baffles and flue cover - checking cover seal. Check for cracking and wear. | Cleaning should be thorough and carried out as per the manufacturer's instructions. |
| **6. a) Pilot assembly** | 12m | Remove. | |
| **Pilot head** | | Remove and clean ports. | |
| **Pilot injection** | | Remove and clean. | Clean as described by the manufacturers e.g. by blowing through or washing. Note: Do not use a pin as this will damage the injector. |
| **Thermocouple tip** | | Replace/clean with fine wire brush, reassemble pilot. | Make sure thermocouple head lines up with the pilot flame. |
| **b) Oxy-pilot assembly** | 12m | Replace. | |
| **7. Lint filter (if fitted)** | 12m | Remove from burners and clean. | |
| **8. Filters** | 12m | Refit. | |
| **Burners, Gas valve, thermocouple and pilot tube** | | Check adjust and refit along with main burner. | |
| **9. Boiler and installation** | 12m | Open gas cock and test for gas soundness, reconnect electrical services. Test controls operation, relight pilot and run up boiler. | Test flame setting and thermocouple sensitivity and check burner gas pressure against manufacturer's settings, adjust if required. If in doubt check gas supply standing pressure at the meter. |
| **10. a) Safety check – products of combustion** | 12m | Ensure that no products of combustion are entering the area of the building where the boiler is situated. This should be checking the operation of the flue and examine the combustion ways to ensure tightness. | NB - Undetected CO is poisonous, life threatening and also causes energy waste.<br>Flames should be bluish and burning in a stable manner.<br>The burner should be quiet in operation, no excessive noise should occur when the burner ignites or shuts down.<br>NB in domestic premises, consider the installation of a BS approved CO detector. |

# Boiler

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **b) Safety check - Electrical** | 12m | Check electrical installation for safety and that local isolator is fitted. | If not, provide written report to client. |
| **11. Documentation** | 12m | Provide written report. | The report should be signed by the servicing engineer and the client/responsible person/clients representative.<br>Premature failure of the plant will result if a satisfactory service is not carried out. Depending on the nature/urgency of the fault and the type of premises this report may be verbal.<br>NB Gas work must be carried out by a competent engineer qualified as required by the Gas Safety (Installation & Use) Regulation. |
| **12. Unsafe installations** | 12m | Recommendations. Label and take out of service | If after servicing the appliance is considered unsafe the client should be advised that it must be taken out of use.<br>If approval for this action is refused an appropriate label must be attached to the appliance. A written report should also be signed by the client/responsible person/clients representative. |

# Steam boilers

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **Important – Read manufacturer's Instructions** | | Seek advice and training from local distributor | Each type of boiler has specific requirements. Dismantling of boiler and annual maintenance should be carried out by registered, trained and experienced boiler technicians.<br>Check for asbestos containing materials prior to dismantling any equipment If asbestos present cease work and report to supervisor to have a simple analysed. |
| **1. Status** | 12m | Check operating status. | Before proceeding with maintenance programme check with client that boiler can be taken off-line. |
| **2. Condition** | 12m | Check exterior for signs of damage, leakage from valves, manholes and any loose fittings. | Leakage can lead to corrosion with subsequent costly refurbishment or replacement of equipment. |
| **3. Safety circuits** | 12m | Check operation. | Safety system includes low and high level alarms, and pressure relief valves. |
| **4. Combustion Check** | 12m | Ensure system on load and carry out combustion tests. | Test should include smoke, draught chamber and flue, flue gas temperature, CO, $CO_2$ and $O_2$. Readings should be checked with boiler instrumentation and noted. |
| **5. Thermostats, pressure sensors and gauges, and thermometers** | 12m | Check for correct operation and settings | |
| **6. Shut down** | 12m | Shut off and isolate steam, water, fuel, and electrical services. | Purge fuel lines and vent boiler to ensure safe conditions. |
| **7. Ventilation** | 12m | Check that ventilation fans and louvres are functioning properly. | Check that there is adequate ventilation in the boiler house and the conditions comply with the relevant regulations and standards. |
| **8. Boiler flueways, combustion chamber and connecting flue** | 12m | Open, remove by brushing and/or vacuum all soot and scale. | Soot, ash and other fouling deposits impede heat transfer thus wasting energy and putting up costs. |
| **9. Fire tubes** | 12m | Open boiler end doors and clean fire tubes by brushing or rotary scouring equipment. | In multipass boilers it is important to clean all passes. |
| **10. Refractory linings** | 12m | Check condition and report. | |
| **11. Boiler flueways, doors and chamber** | 12m | Reseal, check for air leaks, seal as necessary. | |
| **12. Flue** | 12m | Carry out smoke test. | |
| **13. Waterside** | 12m | Remove manholes, clean out scale and residues. Replace, reseal and ensure bolts are tight. | If there are considerable deposits of sludge and scale, this indicates poor water treatment which if allowed to continue will lead to boiler failure and energy wastage. Waste Disposal Regulations may apply. |
| **14. Boiler** | 12m | Refill, reconnect and bring on line. | Refit casing if necessary and thoroughly clean down. |

# Electrical Generators and CHP

## Power generation - stand-by generator

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **1. Condition** | 6m | Visually inspect for oil leaks, loose guards etc. | These checks should be carried out monthly by client's operators. |
| **2. Drive belts** | 6m | Check: coolant level and oil level. | These checks should be carried out monthly by client's operators. |
| **3. Shut down switches** | 6m | Check fan and alternator drive belts for wear, tension and alignment. | |
| **4. Low water switch** | 6m | Check operation of low oil and high coolant shutdown switches. | |
| **5. Coolant** | 6m | Check operation. | |
| **6. Injector pump drive belts** | 12m | Check coolant level. | PH (acidity) and SG (specific gravity) should be checked regularly by the operator. |
| **7. Operation and auto-change facility (where applicable)** | 12m | Check wear and tightness. | |
| **8. Sump heater** | 12m | Check operation and starting sequence. | |
| **9. Fuel transfer pump** | 12m | Check operation. | |

# Electrical Generators and CHP

## Power generation – combined heat & power

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **CHP** | Daily | Performance monitoring check | |
| | | Visual inspection of plant for leaks and unusual noises | |
| | Monthly | Check fluid levels. | 500 -700 Operating hours |
| | | Visually inspect for fluid leaks, unusual noises, loose fittings. | |
| | | Check running records for plant performance trends. | |
| | | Check starter battery condition. | |
| | | Change oil filter. | |
| | | Send oil sample for analysis. | |
| | | Check gas inlet filter. | |
| | | Check cylinder compression. | |
| | | Adjust valve clearances. | |
| | | Check gas pressure, adjust gas/air ratio. | |
| | | Inspect and lubricate control linkages. | |
| | | Clean and adjust gap of spark plugs. | |
| | | Check/adjust ignition timing. | |
| | | Clean distributor cap and rotor arm terminals. | |
| | | Check exhaust system back-pressure. | |
| | | Check exhaust emissions. | |
| | | Check operation of auxiliary equipment, pumps, fans and other equipment. | |

# Electrical Generators and CHP

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **CHP** | Bi Monthly | Change oil. | 1,000 to 1,500 Operating hours |
| | | Check and renew spark plugs if necessary. | |
| | | Check and reset valve clearances. | |
| | | Renew air intake filter. | |
| | | Examine alternator air intake filter, replace if necessary. | |
| | | Check condition and tension of any belt drives. | |
| | | Check starter motor operation. | |
| | | Check operation of monitoring system and controls. | |
| | Six Monthly | Check condition and performance of engine enclosure ventilation system. | 4,000 Operating Hours |
| | | Check condition of alternator, pumps and fan bearings using bearing condition monitoring equipment. | |
| | | Inspect heat dump radiators. | |
| | Annual | Change engine coolant. | |
| | | Clean exhaust gas heat exchangers. | |
| | | Check condition of all wring and measure electrical insulation resistance. | |
| | Four Annually | Inspect, overhaul and replace engine major mechanical parts: cylinder heads, valves, pistons, cylinder liners etc. | 30,000 Operating Hours |
| | | Inspect auxiliary pumps, fans and equipment; overhaul if required. | |
| | | Inspect alternator and bearings. | |
| | | Dismantle and thoroughly clean alternator. | |

# Electrical Power Factor (PF) correction

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **1. Visual Checks** | 6m | Ensure cables, fuses & contactors show no sign of heating or corrosion. | |
| | | Ensure no fuse is blown or tripped. | |
| | | Ensure cables, connectors and terminals are attached correctly and have not come lose due to vibration. | |
| | | Ensure all earth connections are present. | |
| | | Ensure capacitors and chokes show no sign of heating, corrosion or leaking. | |
| | | Ensure capacitors and chokes are attached correctly and have not come lose due to vibration. | |
| **2. Manual Checks - Controllers** | 6m | Ensure display panel indicated no errors. | |
| | | Scroll through on screen menus and ensure all correct valves are displayed. | |
| | | Ensure operation of contactors by manual operation of the controller. | |

# Air compressors and distribution

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **1. Capacity Test** | 12m | Pump up receiver from zero atmospheric pressure to working pressure and note time taken. | Any marked difference from the manufacturers specification may indicate leakage or compressor faults. |
| **2. General Conditions** | 12m | Check the following:<br>condition of guards, interstage cooler drains, bearers and holding down bolts, hand operated valves, moisture traps. | Check for tightness of glands and seats. |
| **3. Status** | 12m | Switch off and isolate electricity. | Where receivers are subject to Statutory Tests and Examinations for purposes of insurance, major overhauls should coincide with such tests and examinations. Any recommendations made by the Insurance Inspector must be completed before the receiver is returned to service. |
| **4. Oil** | 12m | Note level and change using recommended lubricating oil. | |
| **5. Belt and Drive** | 12m | Check tension and condition of belts and drives | Ensure spare belts are available. |
| **6. Condensate removal** | 12m | Check condensate drainage system and clean as necessary. | Note: This should be checked daily as part of the normal in house maintenance procedures.<br>The condition of the condensate is an indication of the condition of the compressor. |
| **7. Pressure relief valve** | 12m | Operate and check valve for condition, operation, setting and leak tightness. Adjust if necessary. | |
| **8. Air filter** | 12m | Clean. | Poor condition can indicate main air intake problems. |
| **9. Electrical connections** | 12m | Check and tighten all connections. Check condition of wiring and insulation. | For associated equipment, see – MOTORS, PUMPS, FANS. |
| **10. Gauges** | 12m | Check operation. | Defective gauges should be reported with a recommendation that they be replaced. |
| **11. Pipes and connections** | 12m | Check external condition and leak tightness.<br>Tighten connections as necessary. | With soldered or brazed joints, these may have to be remade. To prevent internal scaling use dry, oxygen free nitrogen (OFN) during the jointing process. |
| **12. Controls** | 12m | Check operation of pressure switches and auto change over solenoids. | |
| **13. Offloaders, mechanical and electrical** | 12m | Check operation. | |
| **14. Main air intake air quality** | 12m | Check air source for possible contamination and dangerous gases. | If air quality affected by location of intake, report to client. Repositioning may be necessary. |
| **Refrigeration type** | | | |
| **1. Pipe connections** | 3m | Check for leak tightness, remedy as necessary. | |
| **2. Electrical wiring and conduits** | 12m | Check condition and contacts. Make good as necessary. | |
| **3. Discharge air dewpoint** | 12m | Measure and record. | Compare with manufacturer's recommended figures. |

# Air compressors and distribution

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **4. Condensate trap bowl** | 3m | Drain, clean with soapy water and replace. | |
| **5. Evaporator fins** | 3m | Clean and straighten. | Report any severe damage. |
| **Water cooled after coolers.** | | | |
| **1. Pipe connections** | 12m | Check for leaks. | |
| **Water absorption type** | | | |
| **1. Drying medium** | 3m | Remove from container, check condition and treat as necessary. | Desiccants such as anhydrous calcium chloride, silica gel types or activated alumina, may require different treatment. |
| **2. Cleaning** | 3m | Where applicable, dismantle and clean with dry oxygen free nitrogen. Examine, test, refit or renew items listed under notes. | Items:- Insert casing-felt pads-perforated discs-spring-gauzes-strainers-cotton wool-'U' pin-external casing-desiccant as directed. |
| **3. Discharge air quality** | 3m | Check and record.<br>Air dewpoint<br>Air temperature | Too high a temperature can cause break-up of desiccants. |
| **4. Re-activation drying time** | 3m | Time change-over period. | Compare with manufacturer's recommendation. |
| **Water adsorption type** | | | |
| **1. Cartridge** | 36m | Change complete container. | |
| **Compressed air network distribution** | | | Note: The Pressure Systems and Transportable Gas Containers Regulations will apply to the complete system. |
| **1. Filter and pressure reducing station** | 3m | Check particle filters and change as required.<br>Check oil filter and change as required.<br>Check pressure reducing valve settings.<br>Check low pressure safety valve. | Presence of excessive oil indicates a need for a thorough examination of the compressor. Client should be advised. |
| **2. Moisture drain** | 3m | Check operation. | If 'autotype', check level valve opens and closes outlet, if manual, check valve is not blocked. |
| **3. Valves** | 12m | Check external condition, operation, leak tightness of glands and seats, spindles and handwheels. | |
| **4. Safety and reducing valves** | 12m | Examine external condition check operation, settings and leak tightness. | |
| **5. Drains and trap** | 12m | Check external condition, operation and leak tightness. | |

# Air compressors and distribution

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **6. Filters and strainers** | 12m | Check external condition, operation and leak tightness. | |
| **7. Gauges** | 12m | Check operation, condition and leak tightness. | Any defective gauges should be reported with a recommendation that they be replaced. |
| **8. Pipes and connections** | 12m | Check external condition, and leak tightness. Ensure correct 'sign-writing' (colour coding). | Pay particular attention to supports, hangers and brackets. Uncontrolled vibration can lean to pipe breakage. |
| **9. Pipe insulation** | 12m | Check condition of insulation on drain legs, etc. and make good if defective. | |

# Electrical motors

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **Motors** | Weekly | Inspect commutator and brushes<br>Check oil levels and bearings<br>Check oil rings<br>Inspect the shaft for signs of oil leakage<br>Inspect starter, switches and fuses<br>Check the start up time for the motor | Look for sparking, seating contact, evidence of contamination<br>Follow manufacturers recommendations |
| | 6m | Clean the motor thoroughly<br><br>Check brushes<br>Inspect brush holders<br>Check oil quality in sleeve bearings<br>Check grease in antifriction bearings<br>Check operating speed<br>Verify end play<br>Check electrical connections<br>Check enclosure<br>Check foundation connections<br>Check insulation resistance | Blow out dirt (25-30 psig air): wipe down commutator brushes<br>Inspect for wear: verify proper position and pressure<br><br>Follow manufacturers recommendations<br><br>Look for signs of grout degradation or loosening of shims |
| | 12m | Regrease antifriction bearing<br>Check air gap<br>Check bearing clearances<br>Clean undercut slots in the commutator | Follow manufacturers recommendations |

# Chillers

## Air Cooled Chillers

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **1. Operating pressure** | 3m | Check pressure and pressure switches using gauges. | |
| **2. Solenoid valves** | 3m | Ensure that they do not by-pass. | Compressor should not cycle on low pressure switch. |
| **3. Head pressure control devices (fan speed and sequencing)** | 3m | Check operation. | These could be three phase. |
| **4. Motor Mountings** | 12m | Check for security and tightness. | (See also MOTORS) |
| **5. Condenser coil** | 3m<br>12m | Inspect and clean.<br>Test for refrigerant leak and oil staining on the end of the coils. | Check for damage to fins, comb out and chemically clean if necessary. Blow out with dry, oxygen free nitrogen. |
| **6. Casing** | 3m | Clean and secure. | Remove any rust spots and treat. Check fan guards. Ensure all bolts/screws etc. are in place and tight. |
| **7. Sediment** | 3m | Remove, if substantial build up has occurred, investigate cause. | Substantial build up may indicate significant corrosion and cause should be identified. |
| **8. Alignment and wear of belt drives, where applicable** | 3m | Check pulley alignment and belt wear. | Drive belt replacement intervals need to be established. |
| **9. Head pressure control damper** | 6m | Lubricate control damper bearings. | |
| **10. Air Filters** | 6m | Check and replace if necessary. | |
| **11. Flexible Connections** | 12m | Check and repair/replace as necessary. | Report faults to client. |
| **12. Electrical connections** | 12m | Check and tighten as necessary. Check condition of flexible conduits, wiring and insulation. | |
| **13. Pipework** | 12m | Inspect connections, pipes and supports for damage, loose or missing fittings. Repair as necessary. | Report faults to client. |

# Chillers

## Water Cooled Chillers

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **1. Compressor full load operation** | 12m | Record inlet and outlet temperature on water side. Pressure drop across condenser, head pressure and condensing temperature. | Any marked difference to the design figures could indicate internal fouling of the condenser and may require additional work. |
| **2. Flow protection device** | 12m | Check. | |
| **3. Pump** | 12m | Check and record pressure drop across pump. Check for leakage, bearing noise and unusual bearing temperature. Lubricate according to manufacturers instructions. Check motor current. | |
| **4. Water strainers** | 12m | Check and clean. | On open systems more frequent cleaning will be necessary. Check that condenser water is sterile before opening any drains and valves.<br>Note: System could contain legionella bacterium. Technician should take suitable precautions. |
| **5. Condenser Tubes** | 12m | Check condition, if dirty open. If necessary clean with acid treatment. Inspect for alkaline deposits and/or corrosion. | If tubes are heavily scaled, refer to water treatment contractor for explanation as to why system is not effective. Acid can be used for scale removal by specialist if absolutely necessary. |
| **6. Condenser Shell** | 12m | Check for presence of non-condensable gases, purge or vent if necessary. | Presence of non-condensable gases will indicate a possible leak on the vacuum side of the refrigerant circuit. Take care not to release CFCs. |
| **7. Isolating Valves** | 12m | Check external condition, leak tightness of glands and seats, operational spindles and handwheels. | Repack as necessary. |
| **8. Winter Shutdown** | 12m | Isolate condensers and drain down. | Seek advice from water treatment specialist to protect from freezing. |

# Cooling towers

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **Initial Safety Precautions** | | Protective clothing and positive pressure respirators. | Personnel should wear positive pressure respirators when contamination is suspected or the condition is not known. Note:- respirator seal may not work with beards. |
| | 6m | Cooling water analysis. | |
| **Cleansing and disinfection procedures** | | | Where cooling towers are situated in rural areas and only in use during the summer months the frequency of maintenance can be extended to twelve months. |
| **1. Site liaison** | 6m | Advise client that you are on site. | Report to security personnel where appropriate. |
| **2. Warning notices** | 6m | Post at approaches to cooling tower and enclosure. | It is essential that anyone approaching the cooling tower is warned and notices should state:<br>Restricted area - do not enter. |
| **3. Windows and air inlet** | 6m | Close any in the vicinity of the work. | |
| **4. Close down system** | 6m | Isolate chillers(s) cooling towers and circulating pumps. | If this involves entering vicinity of cooling tower and if tower is not regularly maintained, don protective clothing including positive pressure respirators. |
| **5. Electrical equipment** | 6m | Ensure that all electrical equipment is isolated except pumps. | Cooling tower fans and any adjacent air intake fans should be isolated in accordance with H&S requirements. |
| **6. Automatic dosing equipment continuous drains and water supply** | 6m | Close water supply, circulate for fifteen minutes, isolate pumps and drain to waste. | |
| **7. Bio-dispersant** | 6m | Add at a recommended concentration. | Use of the bio-dispersant breaks down the bio-film which is usually present on most surfaces. |
| **8. Hardness of water** | 6m | Check pH which should be between 7 and 8. If higher contact water treatment specialist for advice. | A pH above 8 indicates high alkalinity which require neutralising. If sodium hypochlorite is used at a high pH foaming will result which will prevent correct disinfection. |
| **9. Disinfection** | 6m | Add sodium hypochlorite to chlorinate, bring up concentration to either 5 ppm or 30 ppm. (see notes) | |
| **10. Cooling water pumps** | 6m | Replace fuses to pumps and switch on and run for 6 or 2 hours (see note 9).<br>After 15 minutes, close down pumps, check chlorination level and if needed add sodium hypochlorite to reinstate chlorine level. | It is probable that once the water starts to circulate the free chlorine level will fall, hence sodium hypochlorite must be added to maintain the chlorination at 5 or 30 ppm during the running cycle. |
| **11. Drain system** | 6m | Switch off pumps, remove fuses and drain complete system. | When starting to drain, open water supply to assist in neutralising system. Then shut off water supply and allow to drain. It is essential that the whole system is completely drained. Check for drain cocks on pipework serving chiller. |
| **12. Tower packing and drift eliminators, etc.** | 6m | Dismantle so far as is practicable and clean. See comment in 13 below. | If packing shows signs of deterioration - replace. When replacing drift eliminators ensure that these are correctly fitted and secured. |

# Cooling towers

| ITEM | FREQ. | ACTION | NOTES |
|---|---|---|---|
| **13. All surfaces** | 6m | All accessible surfaces to be cleaned with a wire brush. To remove all deposits thoroughly chemical cleaning may be necessary. | Ensure all scale, rust and other mineral and organic deposits are removed. Any rust areas should be treated and repainted. |
| **14. All components** | 6m | Every part of the system must be cleaned i.e. feed tank, ball valve, softener etc. | If any part of the system is left uncleaned contamination of the whole system may result. |
| **15. Disposal of loosened deposits** | 6m | Sweep out all loosened deposits and place in plastic sacks with the tops securely fastened. | Ensure safe removal of sacks from site. |
| **16. Wash down** | 6m | Clean with low pressure hose. | Waste Disposal Regulations may apply. |
| **17. Chlorination** | 6m | Close drain valves, open water supply, fill system and chlorinate to 5 ppm. Replace pump fuses, switch on pumps and run system for six hours. | If possible close valves from tower to chiller during wash down. If a high pressure hose has to be used, tent tower to prevent any spray drift. |
| **18. Drain system** | 6m | Repeat actions indicated in note 12. | Ensure that chlorination concentration remains at 5 ppm throughout 'run' period. |
| **19. Re-fill system** | 6m | | Note:- If chlorine concentration exceeds 2 ppm prior to activating water treatment regime, drain and refill. |
| **20. Attenuators** | 6m | Clean, derust and repaint as required. | |
| **21. Activation of water treatment and dosing** | 6m | Contact water treatment organisation. | Water treatment organisation will activate system and take samples for analytical tests. |
| **22. Protective clothing** | 6m | Remove and bag before returning through occupied parts of the building. | |
| **23. Complete system** | 6m | Restart. Check frost protection is operational. | |
| **24. Windows and air inlets** | 6m | Re-open windows and restart ventilation fans. | Remove warning notices. |
| **25. Records** | 6m | Record all activities carefully in the form of duplicate job sheets. | Give client one copy of the report and retain the other. |
| **26. Completion** | 6m | Advise client on completion of work. | Check out at security. |
| **27. Bacterial checks** | 6m | Take sample for TVC count. | Note:- weekly dip slides will indicate bacteria levels. A high bacterial level does not necessarily mean the Legionella bacteria are present. |

Green to Wear · Supporting guide

# Annex I. Green to Wear standard

# Sustainable Manufacturing for Green to Wear products

INDITEX

Environmental Sustainability Standard for wet process mills (Pre-treatment, Dyeing, Printing, Finishing, Washing, Tanneries and Fake leather)

# Environmental Sustainability Performance
# BEST IN CLASS "A"

## Categories

**A** — Sustainable mill that is able to efficiently manage the inputs and outputs and increase productivity.
As a premium, it can be communicate to the consumer if any of the BAT are in place

**B** — Room for improvement but a good mill with good environmental management
As a premium, it can be communicate to the consumer if any of the BAT are in place

**C** — High risk of being out of the business due to the unsustainable way of managing the resources and the impacts.

**D** — Mill with a very poor performance that cannot work for Inditex due to the high environmental impact of its practices

| NEED TO HAVE B + ABOVE PRACTICES IN PLACE | |
|---|---|
| Process Control | 1. Water and energy consumption monitoring track record. |
| | 2. Central automation to monitor and control process. |
| | 3. Preventive maintenance program in place. |
| | 4. Right the First Time (lab to bulk) >85%. |
| Water savings | 5. Reuse at least 30% of the process water after treatment. |
| | 6. Dyes and auxiliaries (chemicals including salt) automatic dispenser systems. |
| Waste Water | 7. Internal or external (by 3rd party or government) weekly analysis of the ETP inlet and outlet for at least 4 parameters: COD, BOD, pH & TSS. |
| | 8. Voluntary (IPE's website or similar platforms) or mandatory by law disclosure of hazardous chemicals discharged. |
| Energy | 9. Cogeneration by heat recovery of electrical generation exhaust and cooling* |
| | 10. Boiler efficiency higher than 95%. |
| | 11. Heat exchangers to recover heat from wastewater. |

* If electricity is generated in the mill

# Environmental Sustainability Performance GOOD PERFORMANCE "B"

## Categories

**A** Sustainable mill that is able to efficiently manage the inputs and increase productivity.
As a premium, it can be communicate to the consumer if any of the BAT are in place

**B** Room for improvement but a good mill with good environmental management.
As a premium, it can be communicate to the consumer if any of the BAT are in place

**C** High risk of being out of the business due to the unsustainable way of managing the resources and the impacts.

**D** Mill with a very poor performance that cannot work for Inditex due to the high environmental impact of its practices

| MILLS CLASSIFIED AS B (they are not C or D) WILL HAVE TO ADD ONE PRACTICE PER YEAR | |
|---|---|
| Process Control | 1. Traceability of the raw material (fiber, yarn, fabric & garment) recorded*. |
| | 2. Water level meters and temperature controllers in use in each front loading washer and no belly washers. |
| | 3. Chemical Inventory list properly recorded and managed to meet the MRSL**. |
| | 4. Automated control in each dyeing or finishing machine. |
| | 5. Liquor ratio is referred in the individual process recipe and annual average consumption < 140 l/kg fabric. |
| Water Savings | 6. Batch rinsing instead of continuous flow washes. |
| Waste Water | 7. External analysis (by 3rd party or government) of the own ETP effluent for at least 4 parameters: COD,BOD, pH and TSS. If the annual discharge is above 700,000 $m^3$/yr the frequency required is monthly, if below, quarterly. |
| | 8. MRSL substances in effluent before treatment < 0,01 ppm. (Heavy metals and any value > 0,01 ppm due to the incoming water are excluded). |
| Solid Waste | 9. The mill has a hazardous waste inventory and sends this waste to an authorized agent. The waste is properly managed (segregation, labelling, isolation and ventilation and leakage prevention). |
| Energy | 10. Exhaust air from combustion monitored and tested as per local legislation requirements. |
| | 11. Steam and water leakages monitored and tested frequently. |
| | 12. Insulation of all the tanks and the steam pipes. |
| | 13. Driers with automated control system (including moisture measuring) and heat recovery on stenters |

*The supplier of his supplier: Two steps behind of traceability will be required. For example, if the mill washes garments, they have to know their garment supplier and the fabric supplier)
**Checked through RTM compliance.

**The mill has to improve constantly to have all the 12 practices in place progressing at least one practice per year, otherwise it will became a "C" in the next audit.**

# Environmental Sustainability Performance
# POOR PERFORMANCE "C"

## Categories

**A** Sustainable mill that is able to efficiently manage the inputs and increase productivity.
As a premium, it can be communicate to the consumer if any of the BAT are in place

**B** Room for improvement but a good mill with good environmental management
As a premium, it can be communicate to the consumer if any of the BAT are in place

**C** High risk of being out of the business due to the unsustainable way of managing the resources and the impacts.

**D** Mill with a very poor performance that cannot work for Inditex due to the high environmental impact of its practices

* These practices do not apply in mills with external district heating.

** Not applicable to just washing mills

| ANY OF THIS PRACTICES IN PLACE MEANS POOR PERFORMANCE | |
|---|---|
| Process Control | 1. The mill has environmental violation records on IPE. |
| | 2. No flowmeters in use to monitor at least water consumption or total discharge. |
| | 3. No official authorization for water supply use. |
| | 4. No full chemical inventory list available. |
| Water savings | 5. Inefficient use of water (if COD before treatment < 300 mg/l for dyeing mills or COD before treatment < 100 mg/l for dyeing & washing mills). |
| | 6. The mill (only for exhaust dyeing mills) uses winch dyeing machines with liquor ratio > 1:7. |
| | 7. The mill does not reuse condensate*. |
| | 8. The mill does not reuse non-contact cooling water in all the installation. |
| Waste Water | 9. Mill wastewater is not treated with at least biological treatment before discharge to natural media (direct discharge) **. |
| | 10. Discharge to a municipal effluent treatment plan without at least a pre-treatment (indirect discharge) **. |
| | 11. Direct discharge or discharge to a municipal effluent treatment plan does not meet the parameters applicable by law. |
| | 12. No internal or external (by 3rd party or government) analysis of the effluent available (direct or indirect discharge). At least an annual analysis of COD. |
| | 13. MRSL substances in effluent before treatment > 0,1 ppm. (Heavy metals and any value > 0,1 ppm due to the incoming water are excluded). |
| | 14. Enforcement actions/fines regarding discharge of the final effluent in the last 12 months or unauthorized discharge. |
| Solid Waste | 15. The mill does burn waste in an unauthorised manner. |
| Energy | 16. The mill burns coal/sludge without using a filter and without controlling the emissions as per local legislation requirements. |
| | 17. Not insulation of the 80% of the steam pipes. |

# Environmental Sustainability Performance
# VERY POOR PERFORMANCE "D"

## Categories

**A** Sustainable mill that is able to efficiently manage the inputs and increase productivity.
As a premium, it can be communicate to the consumer if any of the BAT are in place.

**B** Room for improvement but a good mill with good environmental management
As a premium, it can be communicate to the consumer if any of the BAT are in place

**C** High risk of being out of the business due to the unsustainable way of managing the resources and the impacts.

**D** Mill with a very poor performance that cannot work for Inditex due to the high environmental impact of its practices. Need to change.

**Mills with a "D" ranking have 6 months time to upgrade or install a well manage Effluent Treatment Plant. After this period if it is requested, a new environmental audit will be performed.**

| ANY OF THIS PRACTICES ARE BANNED FOR INDITEX SUPPLIERS | |
|---|---|
| Waste Water | 1. Direct process wastewater discharge to the environment (including improper bypass channel for the mill effluent). |
| | 2. Effluent Treatment Plant does not properly treat the 100% of the process wastewater. |
| | 3. Repeated non compliance in case of direct discharge or discharge to a municipal ETP (enforcement actions or fines). |

For more information please contact environmental@inditex.com

INDITEX

### SPECIFIC PRACTICES FOR TANNERIES

**Good Performance "B"**

- Traceability of raw material (fresh hides/skins, salted hides/skins, wet-blue/wet-white leather and crust leather).
- Automated control in each drum/tanning vessel.

### SPECIFIC PRACTICES FOR FAKE LEATHER

**Very Poor Performance "D"**

- Collection devices for DMF are not installed
- DMF recovery devices are not installed

**Guidance for giving information to the customers about products manufactured with less environmental impact processes.**

- Only products manufactured in suppliers ranked as an "A" or "B" and with a BEST AVAILABLE TECHNOLOGIES (BAT) in place can be labeled as less environmental impact products if those products have been manufactured with those BAT.
- The current Best Available Technologies for Inditex are:
    - Ozone for garment finishing.
    - Reuse of 100% of the process wastewater after treatment (excluding losses as evaporated wastewater during the water recycling process).
    - Generate and use more than 80% of the thermal energy that consumes the mill through renewable energy (excluding biomass not meeting Inditex´s forest policy).
    - Generate and use more than 40% of the electrical energy that consumes the mill through renewable energy (excluding biomass not meeting Inditex´s forest policy).
    - Jet dyeing machines with liquor ratio ≤ 1:5 at exhaust dyeing mills.
    - Cold pad batch dyeing

Green to Wear · Supporting guide

# Annex II. Manufacturing Restricted Substances List (MRSL)

The document at hand specifies the restrictions and bans regarding chemical substances used as an input at the main stages of the production processes of Inditex goods.

The Manufacturing Restricted Substances List (hereinafter, The MRSL)[1], has to be enforced by Inditex's supply chain, involved in wet processing operation units; including but not limited to dyeing mills, printing mills, finishing and washing mills.

In order to summarize all Inditex chemical restrictions the document refers to The Product Restricted Substance List (hereinafter, The RSL)[2], which is described in detail in the Clear to Wear Reference Manual (hereinafter, CTW)[3].

## Key definitions

**Inditex's goods:** All clothing products, footwear, accessories and/or home textiles supplied to Inditex.

**Input:** All preparations directly applied as auxiliary agents, drugs, dyes and pigments to manufacture Inditex's goods.

**Usage ban:** Chemical substances that must not be used as an input component at any stage of the production processes of Inditex's goods. Note that even if Inditex's goods are produced in compliance with the MRSL, textiles may carry traces of residues due to unavoidable impurities of these substances on the input. The limits of these traces should always be in compliance with The RSL.

**Discharge Quality Standard:** The discharge quality standard is the group of parameters, including but not limited to COD, BOD, pH, heavy metals, and their limits, set by the applicable laws and regulations at the discharging point of the production units. The discharge quality standard has been extended to include certain parameters not contemplated by the applicable laws/regulations and present in the inputs to manufacture Inditex's goods.

After hundreds of water samples in wet processes mills, outliers reveal an intentional use of any MRSL substances (not including heavy metals). These outliers have been defined as hazardous substances with a concentration higher than 0.1 ppm or 100 times the median. Any substance with a concentration lower than 0.01 ppm (having a proper chemical management according to RTM) is regarded as unintentional contamination mainly from the incoming water.

More information on http://www.wateractionplan.com/ (Section Engaging with our supply chain/Results)

**Best current technical detection limits:** Best current technical detection limits mean the best detection limit that technology allows to be achieved at the time for the sample in question with enough reasonable scientific evidences.

**Ready to Manufacture (RTM):** It is the first world programme of Good Manufacturing Practices (GMP) intended specifically to prevent the inclusion or production of undesired substances during product manufacturing as a consequence of the technological processes used or the quality of the auxiliary chemical substances.

## Control of RSL/MRSL compliance

The verification and control of The RSL/MRSL compliance by Inditex's suppliers will be carried out through the following activities:

1. **Product testing:** All Inditex articles will undergo a Three Level Risk Assessment by Inditex Health & Safety staff (Pre-Production, Manufacturing and Recepcion controls) in order to guarantee the compliance with The RSL.

2. **Ready to Manufacture audits:** All Inditex Supply Chain will undergo a self audit and/or third independent technical audit to guarantee the compliance with Ready to Manufacture (hereinafter, The Code of Manufacturing). The Code of Manufacturing covers the minimum requirements and best practices to manufacture Inditex´s goods in order to meet both RSL and MRSL requirements. The standard includes, among others, checking and testing chemical formulations used to manufacture Inditex's goods.

3. **Discharge Quality Standard audits:** The relevant Inditex Supply Chain will undergo a random discharge water sampling without prior notice to the suppliers in order to check compliance with the Discharge Quality Standard requirements and the MRSL. In case of non compliances detected trough water testing, a deep chemical assessment will be carried out to identify the source of the contamination.

[1] *For more details see Annex I*
[2] *For more details see Annex II*
[3] *http://www.inditex.com/en/sustainability/product/health_quality_standards*

The Discharge Quality Standard audits will cover Inditex key suppliers by the end of 2014 and are focus on wet process mills and address two main topics: Discharge quality and chemical inventory.

These facilities will be selected in accordance with the results of the product testing, the Ready to Manufacture audits, the importance of the supplier for Inditex and their geographic location.

The audit regime consists of at least three visits a year; the chemical inventory used in the factory will be checked at least twice a year. The discharge quality will be checked through water sampling at least once a year.

The following issues within the sampling process should be underscored:

- Where there is no equalization tank in the discharge, a composite sample during 6-8 hours is directly collected in the discharge rate.
- Analytical methods used by the Laboratory and the detection limits for each substance included in the MRSL are shown in Annex III[4].

After getting the results from the water sample, results and the potential grounds for them are reviewed by the experts. Where unacceptable concentration levels of priority chemical compounds are present in the water, a short- term Corrective Action Plan is set immediately. To define the short-term actions; another thorough analysis of the chemical inventory used in the factory is needed.

Finally, upon completion of the training of the Environmental, Health and Safety Manager and the implementation of corrective actions, further analysis will be carried out at the factory, for the purposes of determining whether any of the chemical compounds which were found at a unacceptable level are still present in the discharge. Lastly, results of this process will be published, including annual discharge of hazardous chemicals if any.

## Revision of The MRSL

The MRSL will be regularly reviewed and updated, at least every 12 months, and revised and extended, as credible information on hazardous substances is identified using an intrinsic hazards methodology (e.g. Greenscreen methodology), as it is required by the precautionary principle.

The hazards screening methodology includes at least:

1. The full criteria and methods applied and full data behind results must be open to public scrutiny
2. The screening methodology approach must take account of the hazards of accessory chemical and/or breakdown products which are generated through the use or release of any one particular chemical ingredient
3. The screening methodology must recognise the importance of physical form e.g. nanomaterials, polymers and whole products where applicable
4. Where there are legitimate reasons for concern regarding the intrinsic hazards of a chemical, even if information is insufficient to verify those hazards, action must be taken to obtain sufficient information to enable adequate assessment of the chemical. When there is no information on the chemical the ‘hazardous until proven non-hazardous’ assumption should apply

The methodology for prioritizing of hazardous chemicals has been set in the framework of the Zero Discharge of Hazardous Chemicals Joint Roadmap. For more information please see ZDHC Framework for Prioritising Hazardous Chemicals in the Textile Industry on the following link:

http://www.roadmaptozero.com/programme-documents.php

## Annex I: Manufacturing Restricted Substances List (MRSL)

| Name of Chemical | | CAS No. | Restriction or usage ban |
|---|---|---|---|
| **Alkylphenols (APs) & Alkylphenol Ethoxylates (APEOs)** | | | |
| Octylphenol (OP) | | Multiple CAS possible | Usage ban |
| Nonylphenol (NP) | | Multiple CAS possible | |
| Octylphenolethoxylates (OPEOs) | | Multiple CAS possible | |
| Nonylphenolethoxylates (NPEOs) | | Multiple CAS possible | |
| **Phthalates** | | | |
| Butyl benzyl phthalate (BBP) | | 85-68-7 | Usage ban |
| Dibutyl phthalate (DBP) | | 84-74-2 | |
| Di-2-ethylhexyl phthalate (DEHP) | | 117-81-7 | |
| Di-n-octyl phthalate (DNOP) | | 117-84-0 | |
| Di-iso-nonyl phthalate (DINP) | | 28553-12-0 & 68515-48-0 | |
| Di-iso-decyl phthalate (DIDP) | | 26761-40-0 & 68515-49-1 | |
| Diethyl phthalate (DEP) | | 84-66-2 | |
| Dimethyl phthalate (DMP) | | 131-11-3 | |
| Di-iso-butyl phthalate (DIBP) | | 84-69-5 | |
| Dimethoxyethyl phthalate (DMEP) | | 117-82-8 | |
| **Brominated Flame Retardants** | | | |
| Polybromobiphenyls (PBBs) | | Various | Usage ban |
| Tris(2,3-dibromopropyl) phosphate (TRIS) | | 126-72-7 | |
| Polybromodiphenyl ethers (PBDEs) | | Various | |
| Bis(2,3-dibromopropyl) phosphate | | 5412-25-9 | |
| Tetrabromobisphenol A (TBBPA) | | 79-94-7 | |
| Hexabromocyclododecane (HBCDD) | | 3194-55-6 | |
| 2,2-Bis(bromomethyl)-1,3-propanediol (BBMP) | | 3296-90-0 | |
| **Chlorinated Flame Retardants** | | | |
| Tris(2-chloroethyl) phosphate (TCEP) | | 115-96-8 | Usage ban |
| Tris(1,3-dichloro-isopropyl) phosphate (TDCP) | | 13674-87-8 | |
| **Arylamines** | | | |
| 4-Aminobiphenyl | | 92-67-1 | Usage ban // Restrictions according with the RSL and with the Discharge Quality Standards |
| Benzidine | | 92-87-5 | |
| 4-Chloro-o-toluidine | | 95-69-2 | |
| 2-Naphthylamine | | 91-59-8 | |
| o-Aminoazotoluene | | 97-56-3 | |
| 2-Amino-4-nitrotoluene | | 99-55-8 | |
| 4-Chloroaniline | | 106-47-8 | |
| 2,4-Diaminoanisole | | 615-05-4 | |
| 4,4'-Diaminodiphenylmethane | | 101-77-9 | |
| 3,3'-Dichlorobenzidine | | 91-94-1 | |
| 3,3'-Dimetoxybenzidine | | 119-90-4 | |
| 3,3'-Dimethylbenzidine | | 119-93-7 | |
| 3,3'-Dimethyl-4,4'-diaminodiphenilmethane | | 838-88-0 | |
| p-Cresidine | | 120-71-8 | |
| 4,4'-Methylen-bis-(2-chloroaniline) | | 101-14-4 | |
| 4,4'-Oxydianiline | | 101-80-4 | |
| 4,4'-Thiodianiline | | 139-65-1 | |
| o-Toluidine | | 95-53-4 | |
| 2,4-Toluilendiamine | | 95-80-7 | |
| 2,4,5-Trimethylaniline | | 137-17-7 | |
| o-Anisidine | | 90-04-0 | |
| 2,4-Xylidine | | 95-68-1 | |
| 2,6-Xylidine | | 87-62-7 | |
| 4-Aminoazobenzene | | 60-09-3 | |
| **Allergenic Dyes** | | | |
| Disperse Blue 1 | C.I. 64500 | 2475-45-8 | Usage ban |
| Disperse Blue 3 | C.I. 61505 | 2475-46-9 | |
| Disperse Blue 7 | C.I. 62500 | 3179-90-6 | |
| Disperse Blue 26 | C.I. 63305 | 3860-63-7 | |
| Disperse Blue 35 | C.I. 63600 | 12222-75-2 | |
| Disperse Blue 102 | C.I. 111945 | 12222-97-8 | |
| Disperse Blue 106 | C.I. 111935 | 12223-01-7 | |
| Disperse Blue 124 | C.I. 111938 | 61951-51-7 | |
| Disperse Brown 1 | C.I. 11152 | 23355-64-8 | |
| Disperse Orange 1 | C.I. 11080 | 2581-69-3 | |
| Disperse Orange 3 | C.I. 11005 | 730-40-5 | |
| Disperse Orange 11 | C.I. 60700 | 82-28-0 | |
| Disperse Orange 37/76/59 | C.I. 11132 | 13301-61-6 12223-33-5 51811-42-8 | |
| Disperse Orange 149 | --- | 151126-94-2 | |
| Disperse Red 1 | C.I. 11110 | 2872-52-8 | |
| Disperse Red 11 | C.I. 62015 | 2872-48-2 | |
| Disperse Red 17 | C.I. 11210 | 3179-89-3 | |
| Disperse Yellow 1 | C.I. 10345 | 119-15-3 | |
| Disperse Yellow 3 | C.I. 11855 | 2832-40-8 | |
| Disperse Yellow 9 | C.I. 10375 | 6373-73-5 | |
| Disperse Yellow 23 | C.I. 26070 | 6250-23-3 | |
| Disperse Yellow 39 | C.I. 480095 | 12236-29-2 | |
| Disperse Yellow 49 | --- | 54824-37-2 | |
| **Forbidden Azo Dyes** | | | |
| **Turkish Decree, Indian Notification** | | | |

| | | |
|---|---|---|
| Acid Orange 45 | C.I. 22195 | 2429-80-3 |
| Acid Red 4 | C.I. 14710 | 5858-39-9 |
| Acid Red 5 | C.I. 14905 | 5858-63-9 |
| Acid Red 24 | C.I. 16140 | 98493-59-5 5858-30-0 |
| Acid Red 26 | C.I. 16150 | 3761-53-3 |
| Acid Red 73 | C.I. 27290 | 5413-75-2 |
| Acid Red 85 | C.I. 22245 | 3567-65-5 |
| Acid Red 114 | C.I. 23635 | 6459-94-5 |
| Acid Red 115 | C.I. 27200 | 6226-80-8 |
| Acid Red 116 | C.I. 26660 | 6245-62-1 3953-74-0 1573-46-2 |
| Acid Red 128 | C.I. 24125 | 6548-30-7 |
| Acid Red 148 | C.I. 26665 | 6300-53-4 |
| Acid Red 150 | C.I. 27190 | 6226-78-4 |
| Acid Red 158 | C.I. 20530 | 8004-55-5 |
| Acid Red 167 | --- | 61901-41-5 |
| Acid Red 264 | C.I. 18133 | 6505-96-0 |
| Acid Red 265 | C.I. 18129 | 6358-43-6 |
| Acid Red 420 | --- | |
| Acid Violet 12 | C.I. 18075 | 6625-46-3 |
| Acid Violet 49 | C.I. 42640 | 1694-09-3 |
| Acid Brown 415 | --- | 97199-27-4 |
| Acid Black 29 | --- | 12217-14-0 |
| Acid Black 94 | C.I. 30336 | 6358-80-1 |
| Acid Black 131 | --- | 12219-01-1 |
| Acid Black 132 | --- | 12219-02-2 |
| Acid Black 209 | --- | 72827-68-0 |
| Azoic diazo component 11 | C.I. 37085 | 27165-08-0 |
| Azoic diazo component 12 | C.I. 37105 | 99-55-8 |
| Azoic diazo component 48 | C.I. 37235 | 20282-70-6 |
| Azoic diazo component 112 | C.I. 37225 | 92-87-5 |
| Azoic diazo component 113 | C.I. 37230 | 119-93-7 |
| Basic Red 111 | --- | 118658-98-3 |
| Basic Red 42 | --- | 12221-66-8 |
| Basic Brown 4 | C.I. 21010 | 8005-78-5 |
| Developer 14 (Oxidation base 20) | C.I. 76035 | 95-80-7 |
| Direct Yellow 1 | C.I. 22250 | 101985-05-1 6472-91-9 494-77-9 |
| Direct Yellow 24 | C.I. 22010 | 6486-29-9 |
| Direct Yellow 48 | C.I. 23660 | 6459-97-8 |
| Direct Orange 1 | C.I. 22370 | 54579-28-1 |
| Direct Orange 6 | C.I. 23375 | 6637-88-3 |
| Direct Orange 7 | C.I. 23380 | 2868-76-0 |
| Direct Orange 8 | C.I. 22130 | 64083-59-6 |
| Direct Orange 10 | C.I. 23370 | 6405-94-3 |
| Direct Orange 108 | C.I. 29173 | 6358-79-8 |
| Direct Red 1 | C.I. 22310 | 2429-84-7 |
| Direct Red 2 | C.I. 23500 | 992-59-6 |
| Direct Red 7 | C.I. 24100 | 25188-28-7 2868-75-9 |
| Direct Red 10 | C.I. 22145 | 2429-70-1 |
| Direct Red 13 | C.I. 22155 | 1937-35-5 |
| Direct Red 17 | C.I. 22150 | 25188-32-3 2769-07-5 |
| Direct Red 21 | C.I. 23560 | 6406-01-5, |
| Direct Red 22 | C.I. 23565 | 6448-80-2 |
| Direct Red 24 | C.I. 29185 | 25188-08-3 6420-44-6 |
| Direct Red 26 | C.I. 29190 | 25188-35-6 3687-80-7 |
| Direct Red 28 | C.I. 22120 | 573-58-0 |
| Direct Red 37 | C.I. 22240 | 3530-19-6 |
| Direct Red 39 | C.I. 23630 | 6358-29-8 |
| Direct Red 44 | C.I. 22500 | 2302-97-8 |
| Direct Red 46 | C.I. 23050 | 6548-29-4 |
| Direct Red 62 | C.I. 29175 | 6420-43-5 |
| Direct Red 67 | C.I. 23505 | 6598-56-7 |
| Direct Red 72 | C.I. 29200 | 8005-64-9 |
| Direct Violet 1 | C.I. 22570 | 25188-44-7 2586-60-9 |
| Direct Violet 12 | C.I. 22550 | 2429-75-6 |
| Direct Violet 21 | C.I. 23520 | 25188-48-1 6470-45-7 |
| Direct Violet 22 | C.I. 22480 | 6426-67-1 |
| Direct Blue 1 | C.I. 24410 | 2610-05-1, |
| Direct Blue 2 | C.I. 22590 | 25180-19-2 2429-73-4 |
| Direct Blue 3 | C.I. 23705 | 2429-72-3 |
| Direct Blue 6 | C.I. 22610 | 2602-46-2 |
| Direct Blue 8 | C.I. 24140 | 2429-71-2 |
| Direct Blue 9 | C.I. 24155 | 6428-98-4 |
| Direct Blue 10 | C.I. 24340 | 4198-19-0 |
| Direct Blue 14 | C.I. 23850 | 72-57-1 |
| Direct Blue 15 | C.I. 24400 | 2429-74-5 |
| Direct Blue 22 | C.I. 24280 | 2586-57-4 |
| Direct Blue 25 | C.I. 23790 | 2150-54-1 |
| Direct Blue 35 | C.I. 24145 | 6473-33-2 |
| Direct Blue 53 | C.I. 23860 | 314-13-6 |
| Direct Blue 76 | C.I. 24411 | 16143-79-6 |
| Direct Blue 151 | C.I. 24175 | 110735-25-6 |
| Direct Blue 160 | --- | 12222-02-5 |
| Direct Blue 173 | --- | 12235-72-2 |

| | | | |
|---|---|---|---|
| Direct Blue 192 | --- | 159202-76-3 | |
| Direct Blue 201 | --- | 60800-55-7 | |
| Direct Blue 215 | C.I. 24415 | 6771-80-8 | |
| Direct Blue 295 | C.I. 23820 | 6420-22-0 | |
| Direct Blue 196 | --- | 866557-14-4 | |
| Direct Green 1 | C.I. 30280 | 3626-28-6 | |
| Direct Green 6 | C.I. 30295 | 4335-09-500, | |
| Direct Green 8 | C.I. 30315 | 5422-17-3 | |
| Direct Green 8:1 | --- | 76012-70-9 | |
| Direct Green 85 | C.I. 30387 | 72390-60-4 | |
| Direct Brown 1 | C.I. 30045 | 3811-71-0 | |
| Direct Brown 1:2 | C.I. 30110 | 2586-58-5 | |
| Direct Brown 2 | C.I. 22311 | 2429-82-5 | |
| Direct Brown 6 | C.I. 30140 | 2893-80-3 | |
| Direct Brown 25 | C.I. 36030 | 33363-87-0 | |
| Direct Brown 27 | C.I. 31725 | 6360-29-8 | |
| Direct Brown 31 | C.I. 35660 | 2429-81-4 | |
| Direct Brown 33 | C.I. 35520 | 1324-87-4 | |
| Direct Brown 51 | C.I. 31710 | 25180-43-2 4623-91-0 | |
| Direct Brown 59 | C.I. 22345 | 6247-51-4 3476-90-2 | |
| Direct Brown 79 | C.I. 30050 | 6483-77-8 | |
| Direct Brown 95 | C.I. 30145 | 16071-86-6 | |
| Direct Brown 101 | C.I. 31740 | 3626-29-7 | |
| Direct Brown 154 | C.I. 30120 | 6360-54-9 | |
| Direct Brown 222 | C.I. 30368 | 64743-15-3 | |
| Direct Black 4 | C.I. 30245 | 2429-83-6 | |
| Direct Black 29 | C.I. 22580 | 25180-14-7 3626-23-1 | |
| Direct Black 38 | C.I. 30235 | 1937-37-7 | |
| Direct Black 91 | C.I. 30400 | 6739-62-4 | |
| Direct Black 154 | --- | 54804-85-2 | |
| Disperse Blue 1 | C.I. 64500 | 2475-45-8 | |
| Disperse Yellow 7 | C.I. 26090 | 6300-37-4 | |
| Disperse Yellow 23 | C.I. 26070 | 6250-23-3 | |
| Disperse Yellow 56 | --- | 54077-16-6 | |
| Disperse Red 151 | C.I. 26130 | 6250-23-3 | |
| Disperse Orange 149 | --- | 85136-74-9 | |
| **Other Forbidden Dyes** | | | |
| Acid Red 8 | C.I. 14900 | 4787-93-3 | |
| Acid Red 16 | C.I. 14920 | 5858-66-2 | |
| Acid Red 22 | C.I. 14940 | 5864-85-7 | |
| Acid Red 25:1 | C.I. 16047 | 8004-51-4 | |
| Acid Red 26:1 | C.I. 16151 | 8004-46-4 | |
| Acid Red 26:2 | C.I. 16152 | 8004-47-5 | |
| Acid Red 35 | C.I. 18065 | 6441-93-6 | |
| Acid Red 48 | C.I. 18070 | | |
| Acid Red 104 | C.I. 26420 | 8006-06-2 | |
| Acid Red 107 | C.I. 18025 | 6416-33-7 | |
| Acid Red 119:1 | --- | 90880-75-4 | |
| Acid Red 135 | C.I. 14695 | 5858-37-7 | |
| Acid Red 170 | C.I. 27210 | 6226-81-9 | |
| Acid Red 177 | C.I. 27015 | 8012-09-7 | |
| Acid Red 323 | C.I. 22238 | 6358-34-5 | |
| Acid Red 350 | C.I. 26207 | | |
| Acid Black 28 | C.I. 20500 | 5850-41-9 | |
| Acid Black 66 | C.I. 30275 | 6360-59-4 | |
| Acid Black 70 | C.I. 30355 | 8005-88-7 | |
| Acid Black 232 | C.I. 30334 | | |
| Acid Brown 89 | C.I. 17570 | 6417-27-2 | |
| Acid Green 33 | C.I. 33545 | 6487-06-5 | |
| Acid Orange 3 | C.I. 10385 | 6373-74-6 | |
| Acid Orange 16 | C.I. 16011 | 33340-36-2 | |
| Acid Orange 17 | C.I. 16020 | 52749-23-2 | |
| Acid Orange 24 | C.I. 20170 | 1320-07-6 | |
| Acid Orange 31 | C.I. 15995 | 5858-89-9 | |
| Acid Orange 55 | C.I. 24765 | 6459-66-1 | |
| Azoic diazo component | C.I. 37270 | | |
| Azoic diazo component | C.I. 37115 | | |
| Azoic diazo component /Azoic Brown 29 | C.I. 37077 | | |
| Azoic diazo component 4 | C.I. 37210 | 101-89-3 | |
| Basic Red 9 | C.I. 42500 | 569-61-9 | |
| Basic Red 76 | C.I. 12245 | 68391-30-0 | |
| Basic Red 114 | C.I. 23635 | 6459-94-5 | |
| Basic Violet 14 | C.I. 42510 | 632-99-5 | |
| Basic Brown 2 | C.I. 21030 | 6358-83-4 | |
| Basic Yellow 82 | --- | | |
| Basic Yellow 103 | --- | | |
| Direct Black 11 | C.I. 30240 | | |
| Direct Black 14 | C.I. 30345 | | |
| Direct Black 15 | C.I. 22620 | | |
| Direct Black 20 | C.I. 30395 | | |
| Direct Black 24 | C.I. 31925 | | |
| Direct Black 27 | C.I. 31810 | | |
| Direct Black 30 | C.I. 23675 | | |
| Direct Black 34 | C.I. 35075 | 6473-08-1 | |

| | | | |
|---|---|---|---|
| Direct Black 40 | C.I. 31760 | 6449-81-6 | Usage ban |
| Direct Black 83 | C.I. 31850 | 6837-80-5 | |
| Direct Black 86 | C.I. 24115 | 6449-34-9 | |
| Direct Black 87 | C.I. 24110 | 8015-03-0 | |
| Direct Black 100 | C.I. 35415 | | |
| Direct Black 126 | --- | 12239-25-7 | |
| Direct Black 131 | C.I. 30270 | 6486-54-0 | |
| Direct Blue 4 | C.I. 24380 | 4247-14-7 | |
| Direct Blue 11 | C.I. 30350 | | |
| Direct Blue 12 | C.I. 24170 | | |
| Direct Blue 16 | C.I. 22475 | | |
| Direct Blue 19 | C.I. 22485 | 6426-68-2 | |
| Direct Blue 21 | C.I. 23710 | 6420-09-3 | |
| Direct Blue 23 | C.I. 24405 | | |
| Direct Blue 26 | C.I. 31930 | | |
| Direct Blue 27 | C.I. 23750 | 6420-15-1 | |
| Direct Blue 30 | C.I. 31955 | | |
| Direct Blue 31 | C.I. 23690 | | |
| Direct Blue 36 | C.I. 24150 | 28407-37-6 | |
| Direct Blue 37 | C.I. 24270 | | |
| Direct Blue 38 | C.I. 30090 | 1324-83-0 | |
| Direct Blue 39 | C.I. 30390 | 6360-70-9 | |
| Direct Blue 42 | C.I. 22505 | | |
| Direct Blue 43 | C.I. 30205 | 7273-59-8 | |
| Direct Blue 45 | C.I. 24310 | 6428-87-1 | |
| Direct Blue 48 | C.I. 22565 | 6459-89-8 | |
| Direct Blue 49 | C.I. 22540 | 6426-73-9 | |
| Direct Blue 50 | C.I. 24205 | | |
| Direct Blue 51 | C.I. 30340 | | |
| Direct Blue 58 | C.I. 22490 | | |
| Direct Blue 60 | C.I. 23810 | 13217-73-7 | |
| Direct Blue 63 | C.I. 31910 | 6441-90-3 | |
| Direct Blue 64 | C.I. 22595 | 6426-74-0 | |
| Direct Blue 65 | C.I. 24220 | | |
| Direct Blue 116 | C.I. 27980 | 6227-23-2 | |
| Direct Blue 131 | C.I. 35085 | 6661-39-8 | |
| Direct Blue 136 | C.I. 24065 | 6473-30-9 | |
| Direct Blue 163 | C.I. 33560 | 6548-42-1 | |
| Direct Blue 177 | C.I. 22625 | 6426-76-2 | |
| Direct Blue 183 | C.I. 31951 | 6416-69-9 | |
| Direct Blue 218 | C.I. 24401 | 28407-37-6 | |
| Direct Blue 230 | C.I. 22455 | | |
| Direct Blue 231 | C.I. 23830 | 2609-87-2 | |
| Direct Blue 306 | C.I. 24203 | | |
| Direct Brown 5 | C.I. 30135 | | |
| Direct Brown 7 | C.I. 30035 | | |
| Direct Brown 13 | C.I. 35710 | | |
| Direct Brown 14 | C.I. 35715 | 8002-97-9 | |
| Direct Brown 17 | C.I. 30100 | 6661-48-9 | |
| Direct Brown 20 | C.I. 30060 | 1324-67-0 | |
| Direct Brown 21 | C.I. 30155 | | |
| Direct Brown 24 | C.I. 31700 | | |
| Direct Brown 26 | C.I. 31730 | 8003-55-2 | |
| Direct Brown 39 | C.I. 35060 | 6473-06-9 | |
| Direct Brown 43 | C.I. 35700 | | |
| Direct Brown 46 | C.I. 31785 | | |
| Direct Brown 52 | C.I. 31885 | 6505-12-0 | |
| Direct Brown 54 | C.I. 31735 | | |
| Direct Brown 56 | C.I. 22040 | | |
| Direct Brown 57 | C.I. 31705 | 6360-28-7 | |
| Direct Brown 58 | C.I. 22340 | 6426-59-1 | |
| Direct Brown 60 | C.I. 22325 | | |
| Direct Brown 61 | C.I. 30055 | | |
| Direct Brown 62 | C.I. 31720 | 8003-56-3 | |
| Direct Brown 68 | C.I. 30125 | | |
| Direct Brown 70 | C.I. 35530 | | |
| Direct Brown 73 | C.I. 35535 | | |
| Direct Brown 74 | C.I. 36300 | 8014-91-3 | |
| Direct Brown 75 | C.I. 30325 | | |
| Direct Brown 86 | C.I. 22030 | | |
| Direct Brown 127 | C.I. 35210 | 6473-10-5 | |
| Direct Brown 147 | C.I. 23360 | 8003-80-3 | |
| Direct Brown 151 | C.I. 31685 | 10130-38-8 | |
| Direct Brown 158 | C.I. 30070 | | |
| Direct Brown 159 | C.I. 31755 | | |
| Direct Brown 171 | C.I. 30040 | | |
| Direct Brown 173 | C.I. 30165 | 6826-64-8 | |
| Direct Brown 175 | C.I. 30150 | 6528-58-1 | |
| Direct Brown 190 | C.I. 31750 | | |
| Direct Brown 215 | C.I. 35720 | 83606-72-8 | |
| Direct Green 7 | C.I. 30330 | | |
| Direct Green 9 | C.I. 30310 | | |
| Direct Green 10 | C.I. 30285 | | |
| Direct Green 12 | C.I. 30290 | | |

| | | |
|---|---|---|
| Direct Green 19 | C.I. 30305 | 6486-58-4 |
| Direct Green 20 | C.I. 30380 | |
| Direct Green 21 | C.I. 31790 | 8003-52-9 |
| Direct Green 21:1 | C.I. 22322 | |
| Direct Green 22 | C.I. 31775 | |
| Direct Green 39 | C.I. 30220 | |
| Direct Green 57 | C.I. 24130 | |
| Direct Green 58 | C.I. 30225 | 110735-26-7 |
| Direct Green 60 | C.I. 22315 | 6426-56-8 |
| Direct Brown 223 | --- | 76930-14-8 |
| Direct Orange 1 | C.I. 22375 | 54579-28-1 |
| Direct Orange 2 | C.I. 22380 | 8005-97-8 |
| Direct Orange 13 | C.I. 23605 | 6470-22-0 |
| Direct Orange 25 | C.I. 22135 | 6486-43-7 |
| Direct Orange 30 | C.I. 22385 | 6420-04-8 |
| Direct Orange 31 | C.I. 23655 | 6420-03-7 |
| Direct Orange 33 | C.I. 22385 | |
| Direct Orange 101 | C.I. 22190 | 6528-39-8 |
| Direct Red 14 | C.I. 29170 | 6420-42-4 |
| Direct Red 15 | C.I. 23510 | |
| Direct Red 18 | C.I. 22280 | 6548-26-1 |
| Direct Red 29 | C.I. 22305 | 6426-54-6 |
| Direct Red 33 | C.I. 22306 | |
| Direct Red 34 | C.I. 23570 | |
| Direct Red 42 | C.I. 22180 | 6548-39-6 |
| Direct Red 43 | C.I. 22205 | 6486-50-6 |
| Direct Red 52 | C.I. 22290 | |
| Direct Red 53 | C.I. 22405 | 6375-58-2 |
| Direct Red 55 | C.I. 27780 | |
| Direct Red 56 | C.I. 23600 | 6406-05-9 |
| Direct Red 59 | C.I. 22420 | 6655-94-3 |
| Direct Red 60 | C.I. 22200 | 6486-49-3 |
| Direct Red 61 | C.I. 23040 | 6470-31-1 |
| Direct Red 64 | C.I. 17875 | 6417-30-7 |
| Direct Red 65 | C.I. 17870 | 6369-37-5 |
| Direct Red 68 | C.I. 23515 | 6405-98-7 |
| Direct Red 73 | C.I. 29180 | 6406-01-1 |
| Direct Red 74 | C.I. 22170 | 8003-75-6 |
| Direct Red 119 | C.I. 19590 | 6404-55-3 |
| Direct Red 123 | C.I. 17820 | 6470-23-1 |
| Direct Red 126 | C.I. 17785 | 6369-36-4 |
| Direct Red 142 | C.I. 19500 | 6826-61-5 |
| Direct Red 168 | C.I. 19575 | 6404-53-1 |
| Direct Red 216 | C.I. 17815 | 8004-49-7 |
| Direct Red 264 | C.I. 29187 | |
| Direct Violet 3 | C.I. 22445 | 6507-83-1 |
| Direct Violet 4 | C.I. 22555 | 6472-95-3 |
| Direct Violet 5 | C.I. 27660 | 6227-01-6 |
| Direct Violet 13 | C.I. 24080 | 13478-92-7 |
| Direct Violet 14 | C.I. 29105 | 6420-38-8 |
| Direct Violet 17 | C.I. 22465 | 6426-65-9 |
| Direct Violet 27 | C.I. 22460 | 6426-64-8 |
| Direct Violet 28 | C.I. 23685 | 6420-06-0 |
| Direct Violet 32 | C.I. 24105 | |
| Direct Violet 36 | C.I. 22470 | |
| Direct Violet 37 | C.I. 24370 | 6473-24-1 |
| Direct Violet 38 | C.I. 22630 | 6426-77-3 |
| Direct Violet 39 | C.I. 23680 | 6059-43-3 |
| Direct Violet 42 | C.I. 22450 | 6459-88-7 |
| Direct Violet 43 | C.I. 22440 | 6426-63-7 |
| Direct Violet 45 | C.I. 22510 | 6426-72-8 |
| Direct Violet 85 | C.I. 22520 | 6507-84-2 |
| Direct Red 88 | C.I. 22360 | |
| Direct Yellow 2 | C.I. 23640 | 6459-95-6 |
| Direct Yellow 20 | C.I. 22410 | |
| Disperse Black 6 | C.I. 37235 | 119-90-4 |
| Disperse Orange 11 | --- | 82-28-0 |
| Disperse Orange 60 | --- | 12270-44-9 |
| Disperse Red 220 | C.I. 12476 | 65907-69-9 |
| Disperse Red 221 | --- | 64426-35-3 |
| Disperse Yellow 3 | --- | 2832-40-8 |
| Disperse Yellow 218 | --- | 83929-90-2 |
| Solvent Red 1 | C.I. 12150 | 1229-55-6 |
| Solvent Red 2 | C.I. 12005 | 5098-94-2 |
| Solvent Red 19 | C.I. 26050 | 6368-72-5 |
| Solvent Red 23 | C.I. 26100 | 85-86-9 |
| Solvent Red 24 | C.I. 26105 | 85-83-6 |
| Solvent Red 26 | C.I. 26120 | 4477-79-6 |
| Solvent Red 27 | C.I. 26125 | 1320-06-5 |
| Solvent Red 31 | C.I. 27306 | 6226-90-0 |
| Solvent Red 32 | C.I. 26766 | 6406-53-7 |
| Solvent Red 68 | --- | 61813-90-9 68555-82-8 |
| Solvent Red 69 | C.I. 27290 | 5413-75-2 |
| Solvent Red 80 | C.I. 12156 | 6358-53-8 |

| | | | |
|---|---|---|---|
| Solvent Red 110 | C.I. 27305 | 12217-00-4 | |
| Solvent Red 164 | --- | 92257-31-3 | |
| Solvent Red 215 | --- | 85203-90-3 | |
| Solvent Orange 2 | C.I. 12100 | 2646-17-5 | |
| Solvent Orange 7 | C.I. 12140 | 3118-97-6 | |
| Solvent Orange 8 | C.I. 12175 | 2653-66-9 | |
| Solvent Orange 13 | C.I. 26075 | 6300-42-1 | |
| Solvent Orange 14 | C.I. 26020 | 6368-70-3 | |
| Solvent Orange 30 | C.I. 20020 | 5863-44-5 | |
| Solvent Yellow 1 | C.I. 11000 | 60-09-3 | |
| Solvent Yellow 2 | C.I. 11020 | 60-11-7 | |
| Solvent Yellow 3 | C.I. 11160 | 97-56-3 | |
| Solvent Yellow 6 | C.I. 11390 | 131-79-3 | |
| Solvent Yellow 12 | C.I. 11860 | 6370-43-0 | |
| Solvent Yellow 16 | C.I. 12700 | 4314-14-1 | |
| Solvent Yellow 20 | C.I. 14070 | 6408-41-9 | |
| Solvent Yellow 72 | --- | 61813-98-7 | |
| Solvent Yellow 107 | C.I. 21140 | 67990-27-6 | |
| p-Phenylendiamine | --- | 106-50-3 | |
| Pigment Orange 5 | C.I. 12075 | 3468-63-1 | |
| Pigment Red 3 | C.I. 12120 | 2425-85-6 | |
| Pigment Red 53 | C.I. 15585 | 2092-56-0 | |
| Pigment Red 104 | C.I. 77605 | 12656-85-8 | |
| Pigment Yellow 34 | C.I. 77603 | 1344-37-2 | |
| Acid Dye | C.I. 16155 | | |
| Acid Dye | C.I. 14810 | | |
| Acid Dye | C.I. 15000 | | |
| Acid Dye | C.I. 16010 | | |
| Acid Dye | C.I. 19610 | | |
| Acid Dye | C.I: 22255 | | |
| Acid Dye | C.I. 22285 | | |
| Acid Dye | C.I. 22400 | | |
| Acid Dye | C.I. 23070 | | |
| Acid Dye | C.I. 25110 | | |
| Acid Dye | C.I. 25115 | | |
| Basic Dye | C.I. 11280 | | |
| Direct Dye | C.I. 21060 | | |
| Direct Dye | C.I. 29205 | | |
| Leather Dye | C.I. 30255 | | |
| Mordant Dye | C.I. 14085 | | |
| Mordant Dye | C.I. 22270 | | |
| Mordant Dye | C.I. 22275 | | |
| Mordant Red 57 | C.I. 22310 | 2429-84-7 | |
| Mordant Yellow | C.I. 14135 | | |
| Mordant Yellow 16 | C.I. 25100 | 8003-87-0 | |
| Blue Colourant (as described in European Directive 1907/2006/EC: Appendix 9, Point 43, Page 277) | | 118685-33-9 | |
| **Organotin Compounds** | | | |
| Dibutyltin (DBT) | | 1002-53-5 | Usage ban |
| Tributyltin (TBT) | | 56573-85-4 | |
| Triphenyltin (TPhT) | | 668-34-8 | |
| **Chlorobenzenes** | | | |
| 1,2-Dichlorobenzene | | 95-50-1 | Usage ban // Restrictions according with the RSL and with the Discharge Quality Standard |
| 1,2,3-Trichlorobenzene | | 87-61-6 | |
| 1,2,3,4-Tetrachlorobenzene | | 634-66-2 | |
| Pentachlorobenzene | | 608-93-5 | |
| Hexachlorobenzene | | 118-74-1 | |
| **Chlorinated Solvents** | | | |
| Trichloroethylene | | 79-01-6 | Usage ban |
| Methylene Chloride | | 75-09-2 | |
| Tetrachloroethylene | | 127-18-4 | |
| **Chlorophenols** | | | |
| Pentachlorophenol | | 87-86-5 | Usage ban |
| 2,3,5,6-Tetrachlorophenol | | 935-95-5 | |
| **Short Chain Chlorinated Paraffins (SCCPs) (C10 – C13)** | | | |
| Short Chain Chlorinated Paraffins (SCCPs) | | 85535-84-8 | Usage ban |
| **Metals** | | | |
| Cadmium | | | Restrictions according with the RSL and with the Discharge Quality Standard |
| Lead | | | |
| Mercury | | | |
| Nickel | | | |
| Chromium VI | | | |
| **Perfluorinated Chemicals (PFCs)** | | | |
| Perfluorooctanoic acid (PFOA) | | 335-67-1 | Usage ban |
| Perfluorooctane sulphonates (PFOS) | | 1763-23-1 | |
| Other C8 PFCs | | Various | |
| PFHXS | | 355-46-4 | |
| PFHXA | | 307-24-4 | |
| Other C6 PFCs | | Various | |
| Perfluorobutane Sulfonate (PFBS) | | 375-73-5 & 29420-49-3 | |
| Perfluorobutane Acid (PFBA) | | 375-22-4 | |
| Other C4 PFCs | | Varios | |

## Annex II: Product Restricted Substances List (RSL)

See CTW standard on http://www.inditex.com/en/sustainability/product/health_quality_standards

# Annex III: Chemicals and parameters to be tested on the water sample

| Name of Chemical | CAS-No. | Detection Limit (ppm)* | Test Method |
|---|---|---|---|
| **Phthalates** | | | |
| Butyl benzyl phthalate (BBP) | 85-68-7 | 0,001 | With reference to U. S. EPA 8270D. |
| Dibutyl phthalate (DBP) | 84-74-2 | 0,001 | |
| Di-2-ethylhexyl phthalate (DEHP) | 117-81-7 | 0,001 | |
| Di-n-octyl phthalate (DNOP) | 117-84-0 | 0,001 | |
| Di-iso-nonyl phthalate (DINP) | 28553-12-0 & 68515-48-0 | 0,001 | |
| Di-iso-decyl phthalate (DIDP) | 26761-40-0 & 68515-49-1 | 0,001 | |
| Dimethyl phthalate (DMP) | 131-11-3 | 0,001 | |
| Diethyl phthalate (DEP) | 84-66-2 | 0,001 | |
| Di-n-propyl phthalate (DPRP) | 131-16-8 | 0,001 | |
| Di-iso-butyl phthalate (DIBP) | 84-69-5 | 0,001 | |
| Di-cyclohexyl phthalate (DCHP) | 84-61-7 | 0,001 | |
| Di-n-hexyl phthalate (DnHP) | 84-75-3 | 0,001 | |
| Dinonyl phthalate (DNP) | 84-76-4 | 0,001 | |
| Di-iso-octyl phthalate (DIOP) | 27554-26-3 | 0,001 | |
| Dimethoxyethyl phthalate (DMEP) | 117-82-8 | 0,001 | |
| **Brominated Flame Retardants** | | | |
| Polybromobiphenyls (PBBs) | Various | 0,00005 | With reference to U. S. EPA 527 and with reference to U.S. EPA 8321B. |
| Tris(2,3-dibromopropyl) phosphate (TRIS) | 126-72-7 | 0,0005 | |
| Polybromodiphenyl ethers (PBDEs) | Various | 0,00005 | |
| Tetrabromobisphenol A (TBBPA) | 79-94-7 | 0,0005 | |
| Bis(2,3-dibromopropyl) phosphate | 5412-25-9 | 0,025 | |
| Hexabromocyclododecane (HBCDD) | 3194-55-6 | 0,0005 | |
| 2,2-Bis(bromomethyl)-1,3-propanediol (BBMP) | 3296-90-0 | 0,025 | |
| **Chlorinated Flame Retardants** | | | |
| Tris(2-chloroethyl) phosphate (TCEP) | 115-96-8 | 0,00005 | With reference to U. S. EPA 527 and with reference to U.S. EPA 8321B. |
| Tris(1,3-dichloro-isopropyl) phosphate (TDCP) | 13674-87-8 | 0,0005 | |
| **Azo Dyes** | | | |
| 4-Aminodiphenyl | 92-67-1 | 0,0001 | With reference to German Standard DIN 38407-16, with reference to European Standard EN 14362-1 incorporating Corrigendum and with reference to European Standard EN 14362-3. |
| Benzidine | 92-87-5 | 0,0001 | |
| 4-Chloro-o-toluidine | 95-69-2 | 0,0001 | |
| 2-Naphthylamine | 91-59-8 | 0,0001 | |
| o-Aminoazotoluene | 97-56-3 | 0,0001 | |
| 5-nitro-o-toluidine | 99-55-8 | 0,0001 | |
| 4-Chloroaniline | 106-47-8 | 0,0001 | |
| 4-Methoxy-m-phenylenediamine | 615-05-4 | 0,0001 | |
| 4,4`-Diaminodiphenylmethane | 101-77-9 | 0,0001 | |
| 3,3`-Dichlorobenzidine | 91-94-1 | 0,0001 | |
| 3,3`-Dimethoxybenzidine | 119-90-4 | 0,0001 | |
| 3,3`-Dimethylbenzidine | 119-93-7 | 0,0001 | |
| 4,4`-Methylenedi-o-toluidine | 838-88-0 | 0,0001 | |
| p-Cresidine | 120-71-8 | 0,0001 | |
| 4,4`-Methylene-bis-(2-chloraniline) | 101-14-4 | 0,0001 | |
| 4,4`-Oxydianiline | 101-80-4 | 0,0001 | |
| 4,4`-Thiodianiline | 139-65-1 | 0,0001 | |
| o-Toluidine | 95-53-4 | 0,0001 | |
| 4-Methyl-m-phenylenediamine | 95-80-7 | 0,0001 | |
| 2,4,5-Trimethylaniline | 137-17-7 | 0,0001 | |
| o-Anisidine | 90-04-0 | 0,0001 | |
| 4-Aminoazobenzene | 60-09-3 | 0,0001 | |
| 2,4-Xylidine | 95-68-1 | 0,0001 | |
| 2,6-Xylidine | 87-62-7 | 0,0001 | |
| Aniline | 62-53-3 | 0,0001 | |
| **Organotin Compounds** | | | |
| Mono butyltin compounds (MBT) | Various | 0,00001 | With reference to European Standard EN ISO 17353. |
| Dibutyltin (DBT) | Various | 0,00001 | |
| Dioctyltin (DOT) | Various | 0,00001 | |
| Tributyltin (TBT) | Various | 0,00001 | |
| Triphenyltin (TPhT) | Various | 0,00001 | |
| Tricyclohexyltin (TCyHT) | Various | 0,00001 | |
| Trioctyltin (TOT) | Various | 0,00001 | |
| Tripropyltin (TPT) | Various | 0,00001 | |
| **Chlorobenzenes** | | | |
| Chlorobenzene | 108-90-7 | 0,00002 | With reference to U. S. EPA 8260B and with reference to U. S. EPA 8270D. |
| 1,2-Dichlorobenzene | 95-50-1 | 0,00002 | |
| 1,3-Dichlorobenzene, 1,4-Dichlorobenzene | 541-73-1, 106-46-7 | 0,00002 | |
| 1,2,3-Trichlorobenzene | 87-61-6 | 0,00002 | |
| 1,2,4-Trichlorobenzene | 120-82-1 | 0,00002 | |
| 1,3,5-Trichlorobenzene | 108-70-3 | 0,00002 | |
| 1,2,3,4-Tetrachlorobenzene | 634-66-2 | 0,00002 | |
| 1,2,3,5-Tetrachlorobenzene, 1,2,4,5-Tetrachlorobenzene | 634-90-2, 95-94-3 | 0,00002 | |
| Pentachlorobenzene | 608-93-5 | 0,00002 | |
| Hexachlorobenzene | 118-74-1 | 0,00002 | |
| **Chlorinated Solvents** | | | |
| 1,2-Dichloroethane | 107-06-2 | 0,1 | With reference to U. S. EPA 8260B. |
| 1,1-Dichloroethylene | 75-35-4 | 0,1 | |
| Methylene Chloride | 75-09-2 | 0,1 | |
| cis-1,2-Dichloroethylene | 156-59-2 | 0,1 | |
| trans-1,2-Dichloroethylene | 156-60-5 | 0,1 | |
| Chloroform | 67-66-3 | 0,1 | |
| 1,1,1-Trichloroethane | 71-55-6 | 0,1 | |
| Carbon Tetrachloride | 56-23-5 | 0,1 | |
| Trichloroethylene | 79-01-6 | 0,1 | |
| 1,1,2-Trichloroethane | 79-00-5 | 0,1 | |
| 1,1,1,2-Tetrachloroethane | 630-20-6 | 0,1 | |
| Tetrachloroethylene | 127-18-4 | 0,1 | |
| **Chlorophenols** | | | |
| Pentachlorophenol | 87-86-5 | 0,0005 | |
| 2,3,4,5-Tetrachlorophenol | 4901-51-3 | 0,0005 | |

| | | | |
|---|---|---|---|
| 2,3,4,6-Tetrachlorophenol | 58-90-2 | 0,0005 | With reference to U. S. EPA 8270D. |
| 2,3,5,6-Tetrachlorophenol | 935-95-5 | 0,0005 | |
| 2,4,6-Trichlorophenol | 88-06-2 | 0,0005 | |
| 2,4,5-Trichlorophenol | 95-95-4 | 0,0005 | |
| 2,3,4-Trichlorophenol | 15950-66-0 | 0,0005 | |
| 2,3,5-Trichlorophenol | 933-78-8 | 0,0005 | |
| 3,4,5-Trichlorophenol | 609-19-8 | 0,0005 | |
| 2,4-Dichlorophenol | 120-83-2 | 0,0005 | |
| 2,6-Dichlorophenol | 87-65-0 | 0,0005 | |
| 3,5-Dichlorophenol | 591-35-5 | 0,0005 | |
| 2,3-Dichlorophenol | 576-24-9 | 0,0005 | |
| 3,4-Dichlorophenol | 95-77-2 | 0,0005 | |
| 2,5-Dichlorophenol | 583-78-8 | 0,0005 | |
| 2-Chlorophenol | 95-57-8 | 0,0005 | |
| 3-Chlorophenol | 108-43-0 | 0,0005 | |
| 4-Chlorophenol | 106-48-9 | 0,0005 | |
| **Short Chain Chlorinated Paraffins (SCCPs) (C10 – C13)** | | | |
| Short Chain Chlorinated Paraffins (SCCPs) | 85535-84-8 | 0,0004 | With reference to International Standard ISO 12010 |
| **Total Heavy Metals** | | | |
| Total Arsenic (As) | Various | 0,001 | With reference to U. S. EPA 3015A and with reference to U. S. EPA 6020A./ With reference to U. S. EPA 7196A./ With reference to APHA 4500 CN- C:2012 & APHA 4500 CN- E:2012 |
| Total Cadmium (Cd) | Various | 0,0001 | |
| Total Mercury (Hg) | Various | 0,00005 | |
| Total Lead (Pb) | Various | 0,001 | |
| Total Antimony (Sb) | Various | 0,001 | |
| Total Cobalt (Co) | Various | 0,001 | |
| Total Nickel (Ni) | Various | 0,001 | |
| Total Copper (Cu) | Various | 0,001 | |
| Total Zinc (Zn) | Various | 0,001 | |
| Total Cromium (Cr) | Various | 0,001 | |
| Manganese (Mn) | Various | 0,001 | |
| Cyanide (CN) | Various | 0,02 | |
| Chromium VI | Various | 0,001 | |
| **Alkylphenols (APs) & Alkylphenol Ethoxylates (APEOs)** | | | |
| Octylphenol (OP) | Various | 0,001 | With reference to ASTM International Standard ASTM D7065. |
| Nonylphenol (NP) | Various | 0,001 | |
| Octylphenolethoxylates (OPEOs) | Various | 0,005 | |
| Nonylphenolethoxylates (NPEOs) | Various | 0,005 | |
| **Perfluorinated Chemicals (PFCs)** | | | |
| Perfluorooctanoic acid (PFOA) | 335-67-1 | 0,00001 | In house method and analysis by Liquid Chromatograph Mass Spectrometer (LC-MS). |
| Perfluorooctane sulphonates (PFOS) | 2795-39-3 | 0,00001 | |
| Perfluoro-n-hexanoic acid (PFHxA) | 307-24-4 | 0,00001 | |
| Perfluorohexane sulphonates (PFHxS) | 3871-99-6 | 0,00001 | |
| Perfluorobutanoic acid (PFBA) | 375-22-4 | 0,00001 | |
| Perfluorobutane sulphonates (PFBS) | 29420-49-3 | 0,00001 | |
| Perfluoro-n-pentanoic acid(PFPeA) | 2706-90-3 | to be confirmed | to be confirmed |
| Perfluoroheptanoic acid (PFHpA) | 375-85-9 | to be confirmed | |
| Perfluorononanoic acid (PFNA) | 375-95-1 | to be confirmed | |
| Perfluorodecanoic acid (PFDA) | 335-76-2 | to be confirmed | |
| Perfluoroundecanoic acid (PFUnA) | 2058-94-8 | to be confirmed | |
| Perfluorododecanoic acid(PFDoA) | 307-55-1 | to be confirmed | |
| Perfluorotridecanoic acid (PFTrA) | 72629-94-8 | to be confirmed | |
| Perfluorotetradecanoic acid (PFTeA) | 376-06-7 | to be confirmed | |
| Perfluoroheptane sulfonate (PFHpS) | 375-92-8 | to be confirmed | |
| Perfluorodecane sulfonate (PFDS) | 335-77-3 | to be confirmed | |
| **Fluorotelomer alcohols and fluorotelomer acrylates** | | | |
| 1H,1H,2H,2H-Perfluoro-1-oktanol (6:2 FTOH) | 647-42-7 | to be confirmed | to be confirmed |
| 1H,1H,2H,2H-Perfluoro-1-decanol (8:2 FTOH) | 678-39-7 | to be confirmed | |
| 1H,1H,2H,2H-Perfluoro -1-dodecanol (10:2 FTOH) | 865-86-1 | to be confirmed | |
| 1H,1H,2H,2H-Perfluorooctylacrylate (6:2 FTA) | 17527-29-6 | to be confirmed | |
| 1H,1H,2H,2H-Perfluorodecylacrylate (8:2 FTA) | 27905-45-9 | to be confirmed | |
| 1H,1H,2H,2H-Perfluorododecylacrylate (10:2 FTA) | 17741-60-5 | to be confirmed | |
| **Other parameters** | | | |
| BOD (in mg/L) | NA | to be confirmed | With reference to "Standard Methods for the Examination of Water and Wastewater" (22th edition, #5210B and 5210D), International Standard ISO 5815:1989, European Standard EN 1899-2, 1998, U.S. EPA #405.1, HJ 505-2009 Code of China. |
| COD (in mg/L) | NA | to be confirmed | With reference to the "Standard Methods for the Examination of Water and Wastewater" (22ª Ed.; 2012, method #2540C and method #2540D), International Standard ISO 6060:1989, International Standard ISO 15705:2002, U.S. EPA #410.4 and GB/T 11914-1989 Code of China |
| pH (in units) | NA | to be confirmed | With reference to "Standard Methods for the Examination of Water and Wastewater" (22th edition, #4500 H+), International Standard ISO 10523:2008, U.S. EPA #150.1, GB/T 6920-1986 Code of China |
| Suspended Solids (in mg/L) | NA | to be confirmed | With reference to the "Standard Methods for the Examination of Water and Wastewater" (22th edition, #2540D), International Standard ISO 11923:1997, U.S. EPA 160.2., European Standard EN 872 2005 and GB/T 11901-1989 Code of China |
| Conductivity (in uS/cm) | NA | to be confirmed | With reference to "Standard Methods for the Examination of Water and Wastewater" (22th edition, #2510B), European Standard EN 27888: 1993, International Standard ISO 7888:1985, U.S. EPA #120.1. |

(*) The detection limit will be continually updated to always reflect the best current technical detection limit that can be achieved at the time for the sample in question with enough reasonable cientific evidences

INDITEX
www.inditex.com