



**Daffodil**  
*International*  
**University**

**Faculty of Engineering**  
**Department of Textile Engineering**

**Study on Water Treatment Plant**

Course Code: TE 417 Course Title: Project (Thesis)

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A thesis submitted in partial fulfillment of the requirement for the **Degree of Bachelor of Science in Textile Engineering**

Advance in Textile Wet Processing

December, 2014

## Acknowledgement

At first our gratefulness goes to Almighty Allah to give us strength and ability to complete the industrial training and this report. May your name be exalted, honored and glorified.

Thesis is an academic function of the Daffodil International University that emphasizes on the development of analysis and research capabilities of students which surely going to help them to face any difficulties and solve them with ease . Thus thesis course aims to make students skilled enough to stand out successfully in today's competitive job market. This course will also enable them to find out the drawbacks and additional scope of different projects and gain most out of it by capitalizing all the resources available. We are highly delighted to express our regards & gratitude to honorable Head Prof. Dr. Mahbulul Haque for providing his best support to us.

Special thanks to our supervising teacher, Tanvir Ahmed Chowdhury to whom we are extremely indebted for his tremendous support and guidance throughout my training period, without whose help it would not have been possible to complete the training successfully.

Finally, we would like to acknowledge that we remain responsible for the inadequacies & errors, which doubtless remain in the following report.

## DECLARATION

We hereby declare that the work which is being presented in this thesis entitled, “**Study On Water Treatment Plant**” is original work of our own, has not been presented for a degree of any other university and all the resource of materials uses for this project have been duly acknowledged.

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This is to certify that the above declaration made by the candidates is correct to the best of my knowledge.

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Date

## **ABSTRACT**

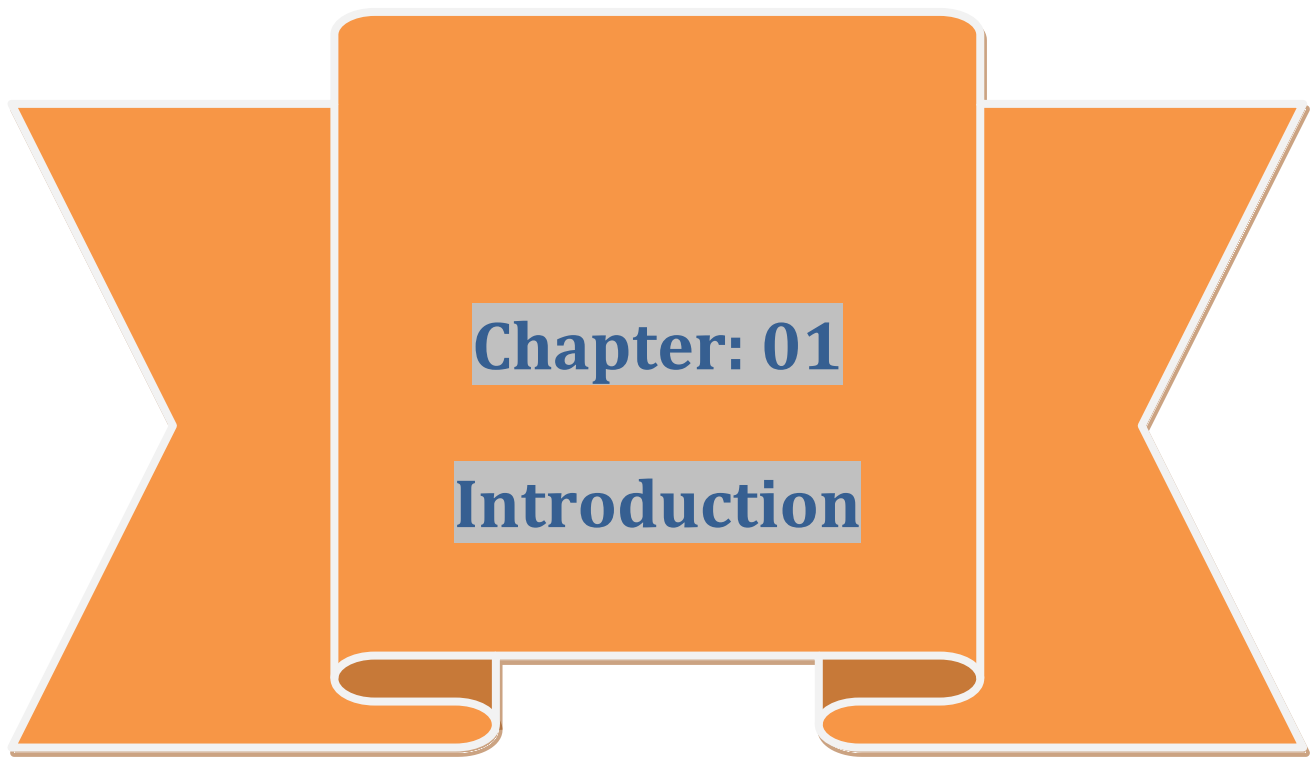
The study makes an assessment on water treatment plant that gives us knowledge about water treatment plant, temporary and permanent hardness of water, effect of hardness on fabric. To conduct this project work, we have examined three water treatment plants of three different industries. At first examine the total water treatment plant, then we examine initial hardness and after hardness of WTP. We examine that three industries use ion exchange process for removing their water hardness. Limit of soft water is 0 PPM to 50 PPM. Soft water increases the efficiency of easily exaction and fixation of dye.

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# Chapter: 01

## Introduction

## 1. Introduction :

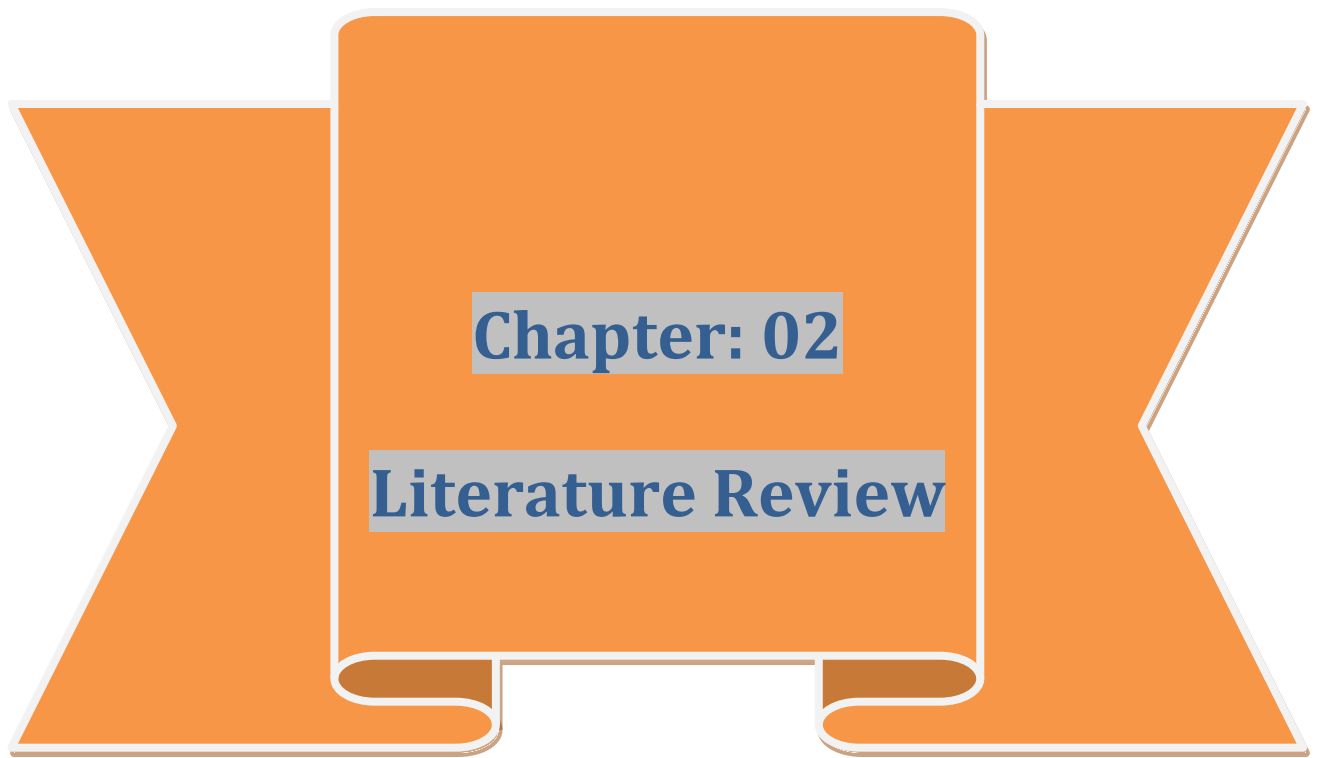
Water is a vital element of our environment. It is widely considered as the main force that keeps creatures alive in the earth. It is a must for any living thing. According to definition Water is a transparent fluid which forms the world's stream, lakes, oceans and rain, and is the major constituent of the fluids of living things. Water is also extensively used in manufacturing plants and different industries as the major resource. In textile wet processing water is the main resource for all the operation. But naturally this water contains many unwanted things popularly termed as impurities. Water contains many impurities among them most attention drawers are hardness, microorganisms, bacteria, virus, sediments, dissolved gases, dissolved salts, suspended solids , odor, arsenic , iron , copper , turbidity etc. Among these impurities hardness is our main headache as it directly effect on dyeing and finishing result. Hardness is an impurity by the virtue of which water contains metal ions which later react with dye, chemicals used in pre treatment, dyeing and finishing and alter predefined result. Thus hardness attributes to faulty dyeing, variation of dyeing shade, improper pretreatment, and insufficient pre treatment. For example hard water forms scale inside boiler and pipeline. Boilers used to generate steam in textile industries tend to be very expensive. If hard water is used in boiler it will significantly reduce its heat efficiency and lifetime. Sometimes it may also causes serious accident like boiler explosion. Hard water reduces solubility of sizing agent causing poor sizing of textile material. Hard water also cause problems in pretreatment as it hampers the action of enzyme in de-sizing resulting in low degradation of sizing material causing poor de-sizing . Hard water decomposes bleaching agents. In mercerization hard water forms insoluble metal oxide and reduce absorbency and luster. In dyeing hard water react with dyes and change the shade. In washing hard water cause yellowing by re decomposition of dirt and insoluble soap on fabric. In some cases finishing chemicals are found to be incompatible with hard water. Therefore we need water treatment plant where hard water is softened through various techniques to make it suitable for pretreatment, dyeing and finishing. Treatment of water to make it soft is termed as water softening. Water softening also improves overall quality control by ensuring better product quality. Therefore water treatment plant is a must to have in modern dyeing industries. There are many processes used for water softening. Most commonly methods are discussed in this report. Most widely used processes are ion-exchange method, soda-lime process, demineralization. These techniques are based on the removal of metal ions present in water to make water soft which is to be used in manufacturing process. So we must choose best treatment plant depending on cost, duration of operation, durability, capacity and overall efficiency. Then water treatment plant will help us getting good quality soft water for dyeing and finishing processes.



## **1.1. Significance :**

As water treatment plant is a vital element of dyeing industries anyone studying in textile engineering must know the basic procedure and mechanism of a water treatment plant. For ensuring best possible water quality it is essential to know the parameter used in water treatment plant and possible faults and remedies. As Bangladesh is emerging as a developing country and now we own a large share in world textile business it is high time we take some serious action to develop our manufacturing system with highly efficient manufacturing plant to survive the increasing tough competition from other developing countries. As a part of highly efficient manufacturing system water treatment plant plays a major role in determining product quality in textile wet processing. Therefore we had chosen “study on water treatment plant” as our topic for thesis. To make this thesis report successful we have visited several industries and observed the techniques and procedure used to make water softened. We also closely observed the quality of water, parameter used and techniques used to ensure best possible quality. Thus we have gained a detailed knowledge about the water softening processes and their best possible implementation techniques in textile wet processing industries. This report covers the major water softening processes, hardness removal techniques, quality control, hardness measurement, survey result and comparison among different softening processes. We wish this report will help everyone to understand the basic mechanism of water treatment plant of textile industries and make it possible to find out new techniques or at least further improve already existed ones.

We hope by the proper implementation of water treatment plant our country will be able to set a benchmark in ensuring best product quality with a highly efficient modern manufacturing system and maintain its stronghold in global textile business.



**Chapter: 02**

**Literature Review**

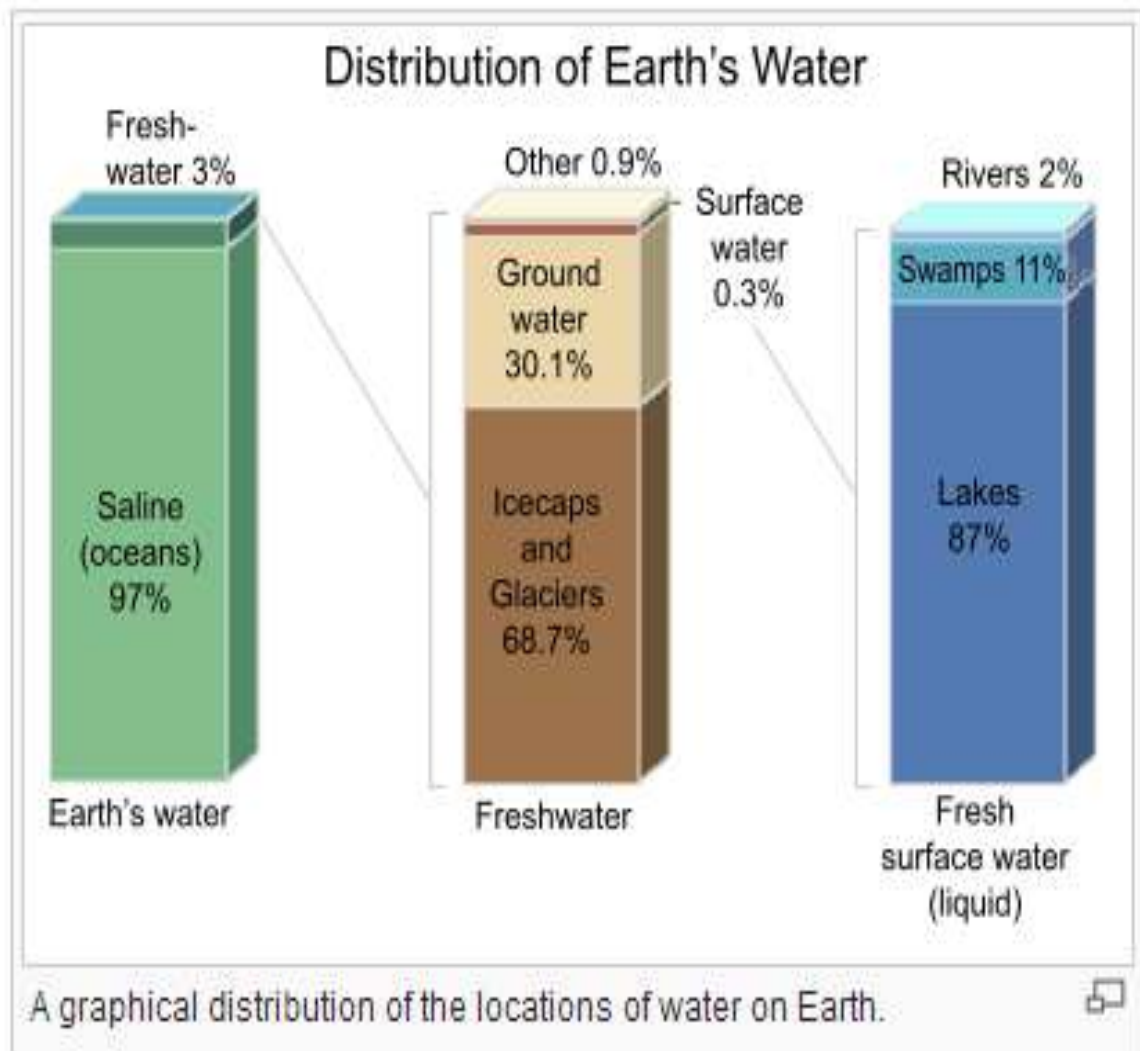
## 2. Literature Review

### 2.1. Water

Water is the chemical substance with chemical formula  $H_2O$ : one molecule of water has two hydrogen atoms covalently bonded to a single oxygen atom. Water appears in nature in all three common states of matter (solid, liquid, and gas) and may take many different forms on Earth: water vapor and clouds in the sky, seawater in the oceans, icebergs in the polar oceans, glaciers in the mountains, fresh and salt water lakes, rivers, and aquifers in the ground. It is an incredibly important aspect of our daily lives. Every day we drink water, cook with water, bathe in water, and participate in many other activities involving water. In industries the daily requirement of water is about 2000000-3000000 gallons.

Molar mass:	18.01528 g/mol
Density:	999.97 kg/m <sup>3</sup>
Boiling point:	99.98 °C
Melting point:	0 °C
Formula:	H <sub>2</sub> O
Triple point temperature:	0.01 °C
IUPAC ID:	Water, Oxidane

## 2.2. Sources of water:



### 2.2.1. Surface water:

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation and sub-surface seepage.

Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the

watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss.

Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing stream flow.

The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need.

Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed.

### **2.2.2. Under river flow:**

Throughout the course of a river, the total volume of water transported downstream will often be a combination of the visible free water flow together with a substantial contribution flowing through sub-surface rocks and gravels that underlie the river and its floodplain called the hypohetic zone. For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. The hypohetic zone often forms a dynamic interface between surface water and true ground-water receiving water from the ground water when aquifers are fully charged and contributing water to ground-water when ground waters are depleted. This is especially significant in karsts areas where pot-holes and underground rivers are common.

### **2.2.3. Ground water:**

Sub-surface water, or groundwater, is fresh water located in the pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between sub-surface water that is closely associated with surface water and deep sub-surface water in an aquifer (sometimes called "fossil water").

Sub-surface water can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, sub-surface water storage is generally much larger compared to inputs than it is for surface water. This difference makes it easy for humans to use sub-surface water unsustainably for a long time without severe consequences. Nevertheless, over the long

term the average rate of seepage above a sub-surface water source is the upper bound for average consumption of water from that source.

The natural input to sub-surface water is seepage from surface water. The natural outputs from sub-surface water are springs and seepage to the oceans.

If the surface water source is also subject to substantial evaporation, a sub-surface water source may become saline. This situation can occur naturally under endorheic bodies of water, or artificially under irrigated farmland. In coastal areas, human use of a sub-surface water source may cause the direction of seepage to ocean to reverse which can also cause soil Salinization. Humans can also cause sub-surface water to be "lost" (i.e. become unusable) through pollution. Humans can increase the input to a sub-surface water source by building reservoirs or detention ponds.

### 2.2.4. Frozen water:

Several schemes have been proposed to make use of icebergs as a water source, however to date this has only been done for novelty purposes. Glacier runoff is considered to be surface water.

The Himalayas, which are often called "The Roof of the World", contain some of the most extensive and rough high altitude areas on Earth as well as the greatest area of glaciers and permafrost outside of the poles. Ten of Asia's largest rivers flow from there, and more than a billion people's livelihoods depend on them. To complicate matters, temperatures are rising more rapidly here than the global average. In Nepal the temperature has risen with 0.6 degree over the last decade, whereas the global warming, has been around 0.7 over the last hundred years.

### 2.3. Water Is considered as the life line of the wet processing

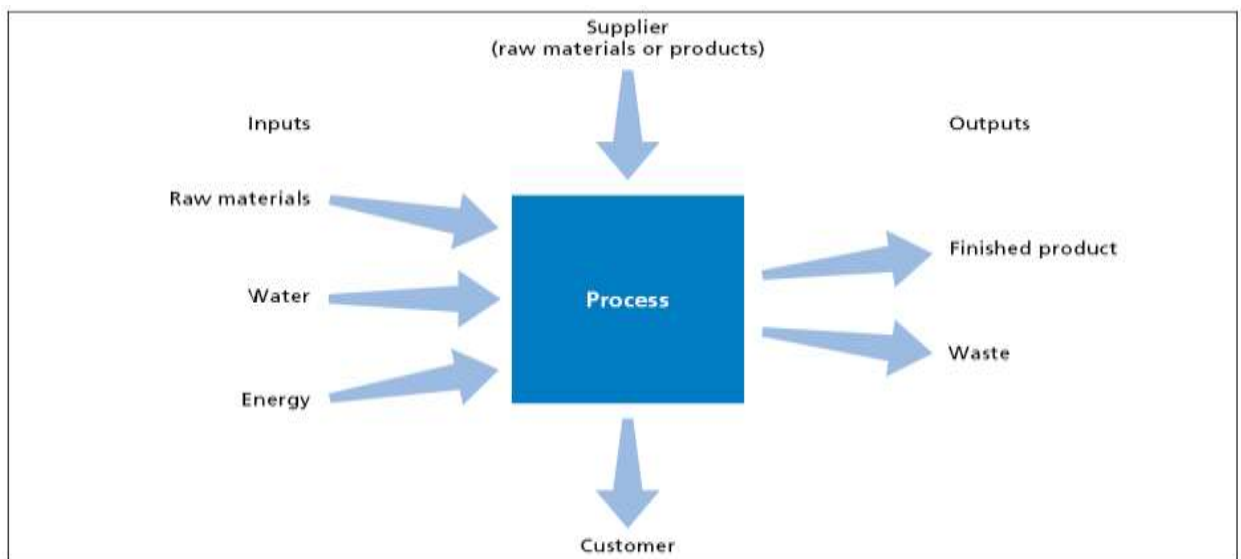
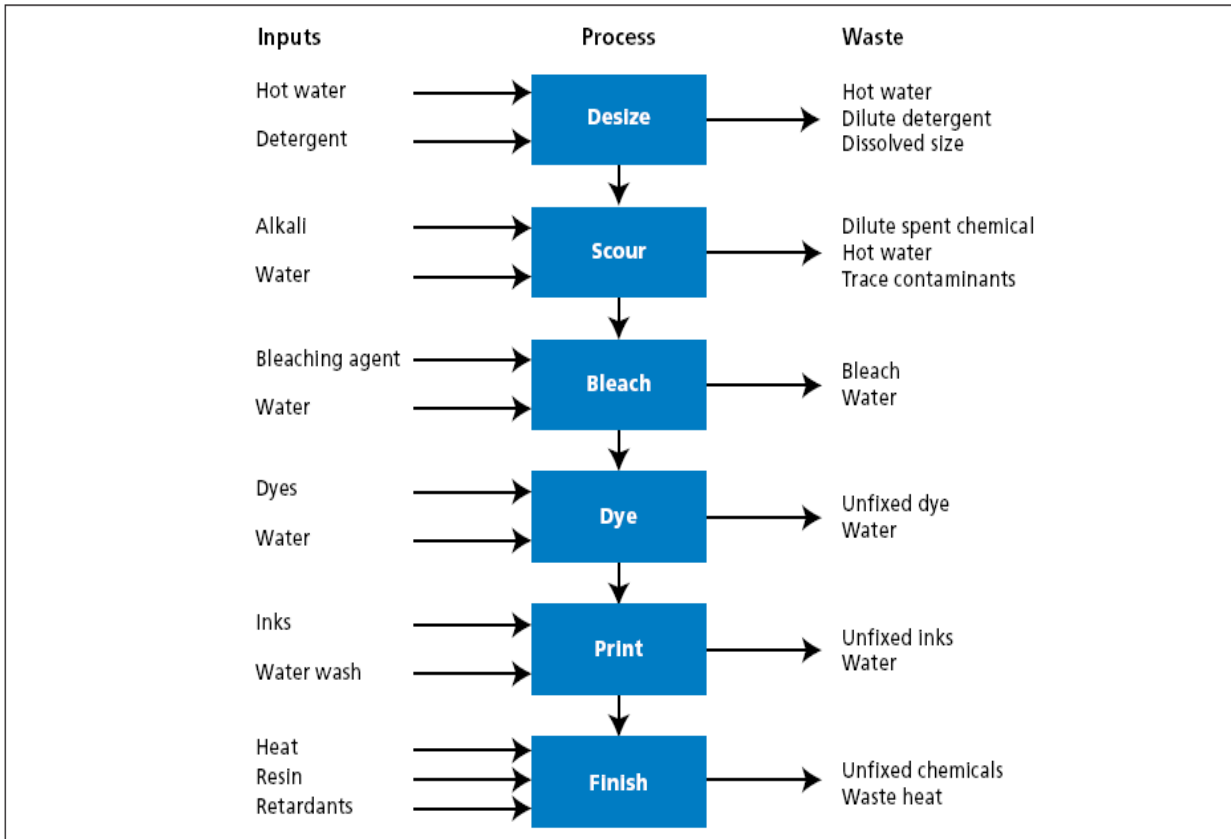


Fig 1 General process flow diagram



*Fig 2 Woven fabric finishing*

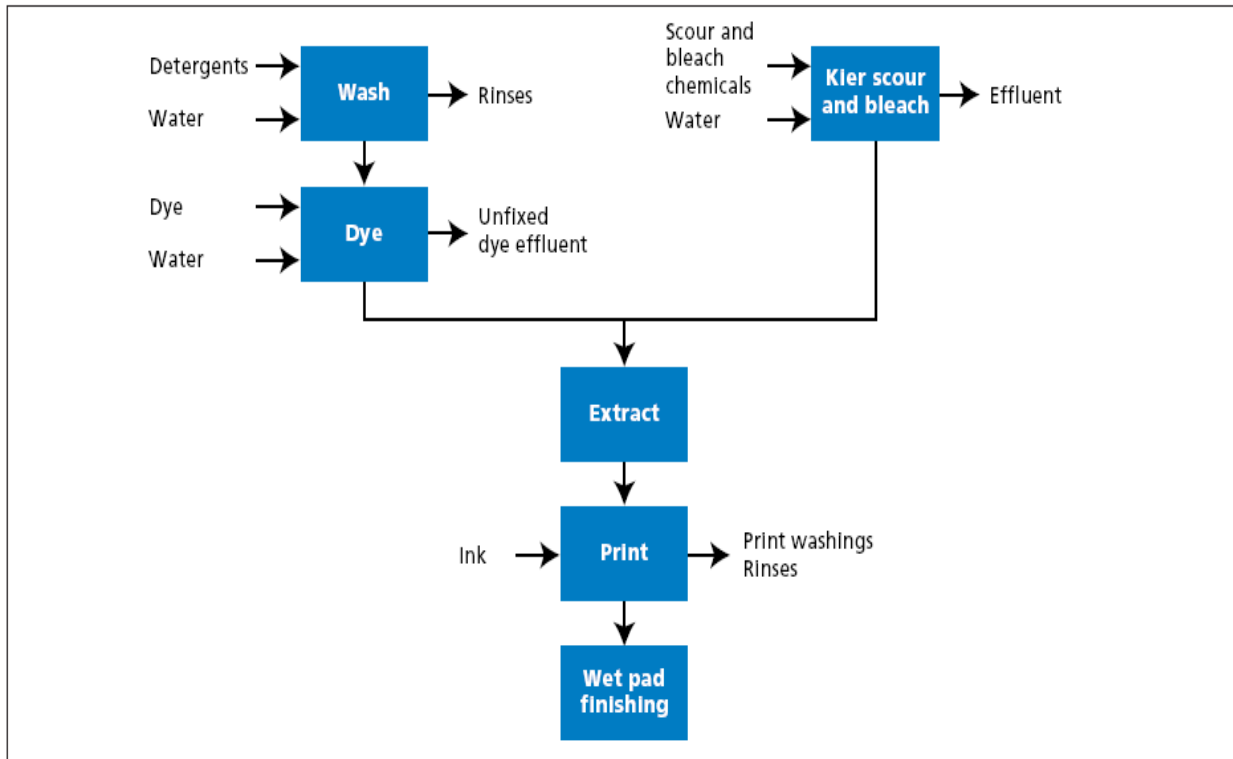


Fig 3 Knit fabric finishing

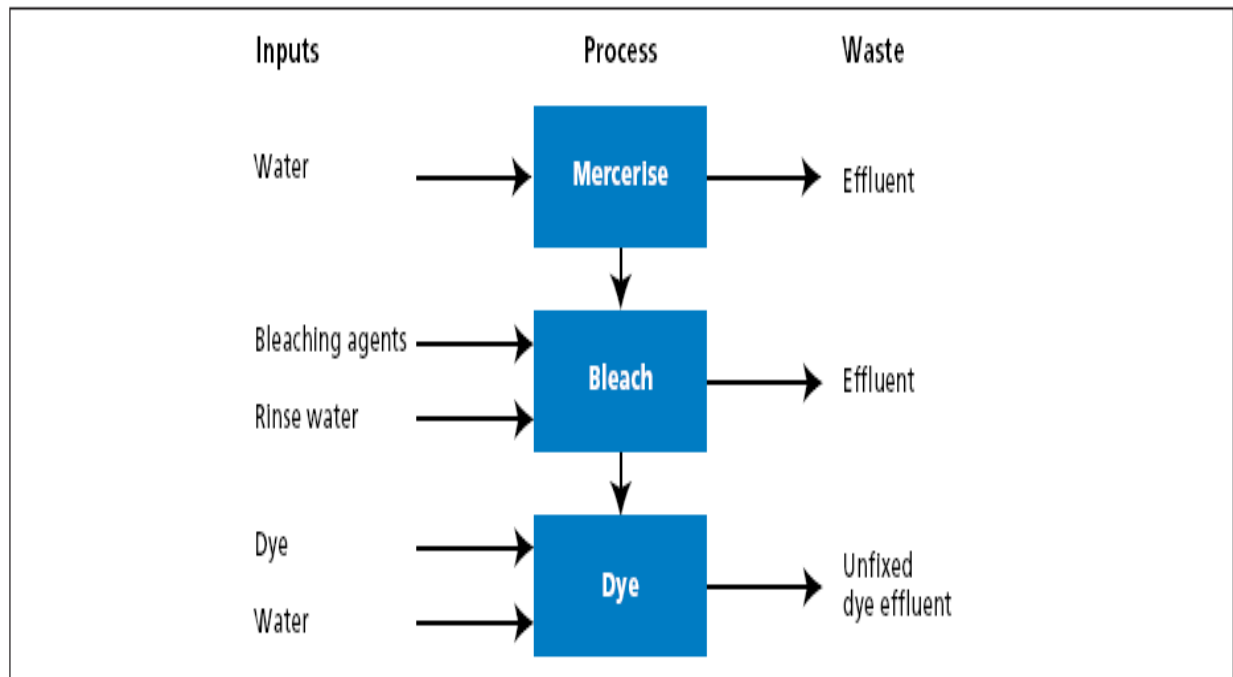


Fig 4 Stock and yarn dyeing and finishing



## **2.4. Water treatment:**

Water treatment in textile finishing, water consumption is far greater than the amounts of fibres processed. It is the ubiquitous solvent for the solutions of chemicals used. Rinsing and washing operations alone consume enormous amounts of water. Steam is still the major heat-transfer medium for many processes and the quality of water fed to boilers is often critical. The volume of aqueous effluent leaving a textile finishing plant is very close to the total input for the many different wet processes. The effluent consists of a relatively dilute solution of a considerable number of chemicals, including acids, alkalis, salts, dyes and other organic chemicals. Any presentation of textile dyeing would be incomplete without some discussion of the quality of water required for textile wet processing, and of the treatment of waste water so that it can be discarded with minimum environmental impact. Important topics for water treatment- Water treatment in the textile, Water treatment in the leather, Reprocessed water using in the dyeing, Total amount of water required in knit dyeing, Procedure of water treatment, The result of water treatment in dyeing.

## **2.5. Water hardness:**

Hard water is water that has high mineral content (in contrast with "soft water"). Hard water is formed when water percolates through deposits of calcium and magnesium-containing minerals such as limestone, chalk and dolomite.

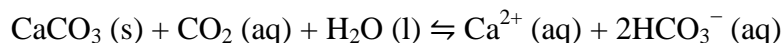
Hard drinking water is generally not harmful to one's health,<sup>[1]</sup> but can pose serious problems in industrial settings, where water hardness is monitored to avoid costly breakdowns in boilers, cooling towers, and other equipment that handles water. In domestic settings, hard water is often indicated by a lack of suds formation when soap is agitated in water, and by the formation of limescale in kettles and water heaters. Wherever water hardness is a concern, water softening is commonly used to reduce hard water's adverse effects.

## **2.6. Sources of hardness:**

Water's hardness is determined by the concentration of multivalent cations in the water. Multivalent cations are cations (positively charged metal complexes) with a charge greater than 1+. Usually, the cations have the charge of 2+. Common cations found in hard water include  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ . These ions enter a water supply by leaching from minerals within an aquifer.

Common calcium-containing minerals are calcite and gypsum. A common magnesium mineral is dolomite (which also contains calcium). Rainwater and distilled water are soft, because they contain few ions.

The following equilibrium reaction describes the dissolving and formation of calcium carbonate :



The reaction can go in either direction. Rain containing dissolved carbon dioxide can react with calcium carbonate and carry calcium ions away with it. The calcium carbonate may be re-deposited as calcite as the carbon dioxide is lost to atmosphere, sometimes forming stalactites and stalagmites.

Calcium and magnesium ions can sometimes be removed by water softeners.<sup>[3]</sup>

### **2.6.1. Temporary hardness:**

Temporary hardness is a type of water hardness caused by the presence of dissolved bicarbonate minerals (calcium bicarbonate and magnesium bicarbonate). When dissolved these minerals yield calcium and magnesium cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ) and carbonate and bicarbonate anions ( $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ ). The presence of the metal cations makes the water hard. However, unlike the permanent hardness caused by sulfate and chloride compounds, this "temporary" hardness can be reduced either by boiling the water, or by the addition of lime (calcium hydroxide) through the softening process of lime softening.<sup>[4]</sup> Boiling promotes the formation of carbonate from the bicarbonate and precipitates calcium carbonate out of solution, leaving water that is softer upon cooling.

### **2.6.2. Permanent hardness**

Permanent hardness is hardness (mineral content) that cannot be removed by boiling. When this is the case, it is usually caused by the presence of calcium sulfate and/or magnesium sulfates in the water, which do not precipitate out as the temperature increases. Ions causing permanent hardness of water can be removed using a water softener, or ion exchange column.

Total Permanent Hardness = Calcium Hardness + Magnesium Hardness

The calcium and magnesium hardness is the concentration of calcium and magnesium ions expressed as equivalent of calcium carbonate.

Total permanent water hardness expressed as equivalent of CaCO<sub>3</sub> can be calculated with the following formula: Total Permanent Hardness

$$(\text{CaCO}_3) = 2.5(\text{Ca}^{2+}) + 4.1(\text{Mg}^{2+}).$$

### Carbonate and non-carbonate hardness:

Carbonate hardness is primarily caused by the carbonate and bicarbonate salts of calcium and magnesium. Non-carbonate hardness is a measure of calcium and magnesium salts other than carbonate and bicarbonate salts, such as calcium sulfate, CaSO<sub>4</sub>, or magnesium chloride, MgCl<sub>2</sub>. Total hardness is expressed as the sum of the carbonate hardness and non-carbonate hardness.

$$\begin{array}{l} \text{Total hardness} = \text{Carbonate hardness} + \text{Non-carbonate hardness} \\ (\text{mg/L as CaCO}_3) \quad (\text{mg/L as CaCO}_3) \quad (\text{mg/L as CaCO}_3) \end{array}$$

The amount of carbonate and non-carbonate hardness depends on the alkalinity of the water.

When a laboratory reports a value for total hardness of, for instance, 150 mg/l as CaCO<sub>3</sub>, this indicates that the combined effect of the different hardness causing agents is the same as if the water contained exactly 150 mg/l of CaCO<sub>3</sub>.

### Calcium and magnesium hardness:

Hardness caused by calcium is called calcium hardness, regardless of the salts associated with it. Likewise, hardness caused by magnesium is called magnesium hardness. Since calcium and magnesium are normally the only significant minerals that cause hardness, it is generally assumed that:

$$\begin{array}{l} \text{Total Hardness} = \text{Calcium Hardness} + \text{Magnesium Hardness} \\ (\text{mg/L as CaCO}_3) \quad (\text{mg/L as CaCO}_3) \quad (\text{mg/L as CaCO}_3) \\ = 2.50 \times \text{Calcium concentration} + 4.12 \times \text{Magnesium concentration} \\ \quad (\text{mg/L as Ca}^{2+}) \quad \quad (\text{mg/L as Mg}^{2+}) \end{array}$$

## 2.7. HARDNESS MEASUREMENTS:

Water hardness is unfortunately, expressed in several different units and it is often necessary to convert from one unit to another when making calculations. Most commonly used units include grains per gallon (gpg), parts per million (ppm), and milligrams per liter (mg/L).

Grains per gallon is based on the old English system of weights and measures, and is based on the average weight of a dry kernel of grain (or wheat). Parts per million is a weight to weight ratio, where one ppm of calcium means 1 pound of calcium in 1 million pounds of water (or 1 gram of calcium in 1 million grams of water). Milligrams per liter (mg/L) are the same as ppm in the dilute solutions present in most raw and treated water (since pure water weighs 1000 grams per liter).

### 2.7.1. Determination of water hardness:

The hardness of a water sample can be determined by direct titration of a known volume with a standardized solution of a soap such as potassium oleate. Initially, this soap will precipitate, and the calcium and magnesium salts and the water will not produce any foam on shaking. Gradual addition of the potassium oleate solution is continued until the agitation of the solution produces a reasonably permanent foam. From Scheme 8.4,  $2R^- K^+ (aq) + Ca^{2+} (aq) = R_2Ca(s) + 2K^+ (aq)$  R= Oleate radical is equivalent to 0.01 mmol  $Ca^{2+}$ . Thus, if a 100.0 ml sample of water is titrated with 0.02 M potassium oleate solution to just give a permanent foam after addition of V ml of soap, equivalent to V 0.01 mmol  $Ca^{2+}$ , the hardness will be V 10 ppm  $CaCO_3$ . Despite the simplicity of this method, it is not always possible to detect precisely the point at which a layer of foam persists. Hardness is therefore more usually determined by titration with a standardized solution of the disodium salt of ethylene diamine tetra-acetic acid (EDTA). EDTA forms very stable, soluble complexes with calcium and magnesium ions (Figure 8.1). EDTA is a tetraprotic acid and the various acid-base forms are usually abbreviated by  $H_4Y$ ,  $H_3Y^-$ ,  $H_2Y^{2-}$ ,  $HY^{3-}$ , and  $Y^{4-}$ , as the degree of dissociation progresses. Scheme 8.5 illustrates complex formation with calcium and magnesium ions. The equilibrium constants are large and ensure quantitative formation of the colourless complexes on addition of EDTA to a solution containing calcium and magnesium ions. The titration involves gradual addition of standardized EDTA solution ( $Na_2H_2Y$ ) to the water sample, buffered at pH 10 with an ammonia-ammonium chloride solution. The indicator is a dye that changes colour on complexing with calcium or

magnesium, such as Eriochrome Black T (CI Mordant Black 11). At the beginning of the titration, the large concentrations of calcium and magnesium ions ensure that all the dye indicator is in the form of the red complexes with these metals (Ca–Dye–, Scheme 8.6). Very close to the equivalence point, the free  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ion concentrations become so low that the added EDTA begins to remove the metals from their red complexes with the dye. This liberates the blue dye ion. The colour of the solution therefore changes from red (dye–metal complex) to blue (free dye anion) at the end-point.

In the titration of calcium ions alone at pH 10, the red calcium–dye complex (Ca–Dye–) is not sufficiently stable and the calcium transfers to EDTA liberating the blue dye anion (H–Dye<sup>2–</sup>) slightly before the true equivalence point. For titrations of magnesium ion, the magnesium–dye complex is more stable than that of calcium and the blue colour does not occur until all the  $\text{Mg}^{2+}$  ions in solution have reacted with the EDTA. Thus, the red-to-blue colour change occurs at the true equivalence point. Towards the end of the titration of hard water, as long as calcium ion is present, it will liberate magnesium ion from the magnesium–EDTA complex because the calcium–EDTA complex is more stable. The liberated magnesium thus ensures that the more stable magnesium–dye complex is always present, until all the calcium has been complexes with EDTA. The last addition of this reagent then removes the magnesium from the red magnesium–dye complex and the solution becomes blue. To ensure that a water sample contains a sufficient quantity of magnesium, it is common to add a little to the EDTA solution before standardization with a known calcium ion solution.

### 2.7.2. Degree of Hardness:

The degree of hardness consumers consider objectionable will vary, depending both on the water and the degree of hardness to which consumers have become accustomed. The following table shows a classification of water hardness:

Hardness	mg/L as $\text{CaCO}_3$
Soft	0 to 75
Moderate	75 to 150
Hard	150 to 300
Very Hard	Above 300

The degree of hardness acceptable for a finished water varies with the consumer or industry served. In 1968, the American Water Works Association (AWWA) established a water quality goal for total hardness of 80 to 100 mg/l as calcium carbonate.

It has often been proposed that ideally water should have a total hardness of 75 to 85 mg/l (as CaCO<sub>3</sub>) and a magnesium hardness of not more than 40 mg/L as CaCO<sub>3</sub> to minimize magnesium hydroxide scaling at elevated temperatures, although the actual magnesium concentration that can be present before precipitation of magnesium salt is a function of the pH of the finished water.

In recent years, many cities have allowed the hardness in finished water to approach 110 to 150 mg/L to reduce chemical costs and sludge production. The general use of synthetic detergents has reduced the importance of hardness for soap consumption; however, industrial requirements for a higher-quality feed water for high pressure boilers and cooling towers have generally increased. As industrial waste treatment costs increase, the demand for higher quality water has increased dramatically. Industries purchasing water from municipal supplies have generally been faced with additional water treatment costs, dependent upon the quality of the municipal supply and the intended plant or process use. The degree of water treatment provided, is therefore determined to some degree by the user's requirements.

### 2.7.3. Conversion table for water hardness units of measure:

According to definition, water hardness is a value characteristic of the dissolved salts found in water (calcium and magnesium hydrogen-carbonate, °dH = 0.357 meq/l).

Unit	mekv/l	°dH (°dH)	°e	°f (°tH)	mg/l CaCO <sub>3</sub>	gpg CaCO <sub>3</sub>
1 mekv/l	1	2.805	3.51	5	50	2.924
1 °dH (°dH)	0.3536	1	1.25	1.78	17.8	1.042
1 °e	0.2852	0.8	1	1.43	14.3	0.833

1 °f (°tH)	0.2	0.561	0.702	1	10	0.585
1 mg/l CaCO <sub>3</sub>	0.02	0.0561	0.0702	0.1	1	0.0585
1 gpg CaCO <sub>3</sub>	0.342	0.9593	1.2004	1.71	17.1	1

1 °dH (°dH) German hardness: Ca and/or Mg salt, which is equivalent to 1 °dH=17.85 mg/l calcium carbonate (CaCO<sub>3</sub>) or 1 °dH=10 mg/l calcium oxide (CaO), is dissolved in 1 litre of water.

1 meq/l of hardness means that 1 litre of water contains 1 meq, that is 1 mg equivalent weight of dissolved hardness minerals (Ca and/or Mg).

1 °e that is 1 English degree of hardness means that 0.8 litres of water contains dissolved hardness minerals (Ca and/or Mg) equivalent to 10 mg CaO. (another definition: 1 English degrees of hardness (Clark°) means that 1 gallon (i.e. imperial U.K. gallon, 4.546 litres) of water contains dissolved hardness minerals (Ca and/or Mg) equivalent to 1 grain (i.e. 0.0648 gramm) CaCO<sub>3</sub>.

1 °f (°tH) that is 1 French degree of hardness means that 1 litre of water contains dissolved hardness minerals (Ca and/or Mg) equivalent to 10 mg CaCO<sub>3</sub>.

1 ppm CaCO<sub>3</sub> hardness means that 1 litre of water contains dissolved hardness minerals (Ca and/or Mg) equivalent to 1 mg CaCO<sub>3</sub>.

1 gpg CaCO<sub>3</sub> that is 1 grain/gallon of hardness means that 1 gallon (i.e. U.S. gallon, 3.785 litres) of water contains dissolved hardness minerals (Ca and/or Mg) equivalent to 1 grain (i.e. 0.0648 gram) CaCO<sub>3</sub>.

## 2.8. Water Quality For Dye House:

During the Industrial Revolution, the textile industry invariably grew in regions having an abundant supply of soft water such as in West Yorkshire. Such water is relatively free from calcium and magnesium salts. It does not precipitate soap or other chemicals during washing, or form a scale on the boiler walls when generating steam. Water for a textile plant may come from

various sources. These include surface water from rivers and lakes, and subterranean water from wells. The water may be obtained directly from the source or from the local municipality. Natural and pretreated water may contain a variety of chemical species that can influence textile wet processing in general, and dyeing in particular. The various salts present in water depend on the geological formations through which the water has flowed. These salts are mainly the carbonates ( $\text{CO}_3^{2-}$ ), hydrogen carbonates ( $\text{HCO}_3^-$ , more commonly named bicarbonates), sulphates ( $\text{SO}_4^{2-}$ ) and chlorides ( $\text{Cl}^-$ ) of calcium ( $\text{Ca}^{2+}$ ), magnesium ( $\text{Mg}^{2+}$ ) and sodium ( $\text{Na}^+$ ). Although calcium and magnesium carbonates in limestone are relatively insoluble, the action of dissolved carbon dioxide in rain water can leach them out in the form of the more soluble bicarbonates (Scheme 8.1). Hard water contains calcium and magnesium ions and gives an immediate precipitate with soap. Soap is a water-soluble sodium salt of a high molecular weight carboxylic acid, such as stearic acid. Its calcium and magnesium salts are much less soluble and give a gummy precipitate with a soap solution in hard water (Scheme 8.2). When this happens, the cleaning efficiency of the soap decreases dramatically. The dirt in suspension, as well as the precipitated calcium and magnesium soaps, can deposit back onto the material being washed. This gives a dingy fabric with a poor handle that will be difficult to dye in a level shade.

$\text{CaCO}_3(\text{s}) + \text{CO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) = \text{Ca}(\text{HCO}_3)_2(\text{aq})$  Scheme 8.1  
 $2\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2\text{Na}^+(\text{aq}) + \text{Ca}^{2+}(\text{aq}) = (\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2)_2\text{Ca}(\text{s}) + 2\text{Na}^+(\text{aq})$  Scheme 8.2

Besides dissolved salts of natural origin, water may contain a variety of other salts from human or industrial activity. These include nitrates ( $\text{NO}_3^-$ ), phosphates ( $\text{HPO}_4^{2-}$  and  $\text{H}_2\text{PO}_4^-$ ) and various metal ions. The ions of certain transition metals, such as those of iron, copper and manganese, can precipitate dyes, or form complexes with them, dulling or even changing their shade. In addition, many of these ions catalyse the decomposition of hydrogen peroxide in bleaching baths. It is not uncommon for a particle of iron rust on the surface of a cotton fabric to generate such rapid peroxide decomposition that the cellulose is totally oxidized and a hole results. These transition metal ions may be present in the natural or municipal water, or, in the case of iron, come from corrosion within pipelines. Both dissolved and colloidal silica in boiler feed water can lead to the formation of a hard resistant scale on the boiler's internal surfaces, considerably decreasing heat transfer efficiency. Organic compounds from the decomposition of vegetable matter in the water, or from sources of pollution, can be very varied. They can have such high concentrations that the water is colored. Table 8.1 illustrates the quality of water usually considered acceptable for textile processing and steam generation. Water entering a textile dyeing or finishing plant usually passes through a grill to eliminate floating debris. Small particles in suspension must also be removed.



Parameter	Permissible Concentration
Color	Color Less
Smell	No Bad Smell
Water Hardness	<5 ppm
pH	7-8 (Neutral)
Dissolved solid	< 1 ppm
Inorganic salt	< 500 ppm
Iron (Fe)	<0.1 ppm
Manganese (Mn)	<0.01 ppm
Copper (Cu)	<0 .005 ppm
Nitrate (NO <sub>3</sub> )	< 50 ppm
Nitrate (NO <sub>2</sub> )	< 5 ppm

## 2.9. WATER SOFTENING:

Soft water is a desirable prerequisite for all textile wet processes, except for bleaching with solutions of hydrogen peroxide stabilized by sodium silicate. Modern synthetic detergents do not form precipitates in hard water containing calcium and magnesium ions so a certain degree of hardness is tolerable provided that other dyes and chemicals are not seriously affected by this. In general, however, if a mill is in a region where the water is hard, a softening pretreatment is essential for at least part of the water used. The objective of this is simply to reduce the concentration of the alkaline earth metals to a level at which the water has the desired quality. In many cases, the softening process may reduce the calcium and magnesium ion concentrations to zero.

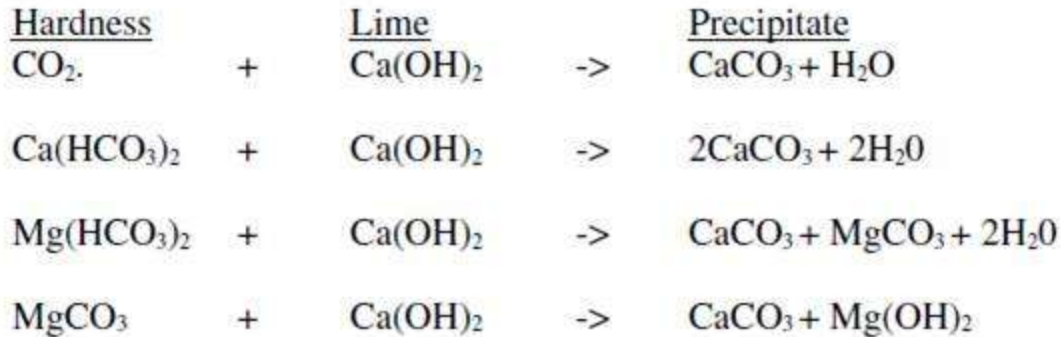
### 2.9.1. Soda- Lime Process:

Chemical precipitation is one of the more common methods used to soften water. Chemicals normally used are lime (calcium hydroxide,  $\text{Ca(OH)}_2$ ) and soda ash (sodium carbonate,  $\text{Na}_2\text{CO}_3$ ). Lime is used to remove chemicals that cause carbonate hardness. Soda ash is used to remove chemicals that cause non-carbonate hardness.

When lime and soda ash are added, hardness-causing minerals form nearly insoluble precipitates. Calcium hardness is precipitated as calcium carbonate ( $\text{CaCO}_3$ ). Magnesium hardness is precipitated as magnesium hydroxide ( $\text{Mg(OH)}_2$ ). These precipitates are then removed by

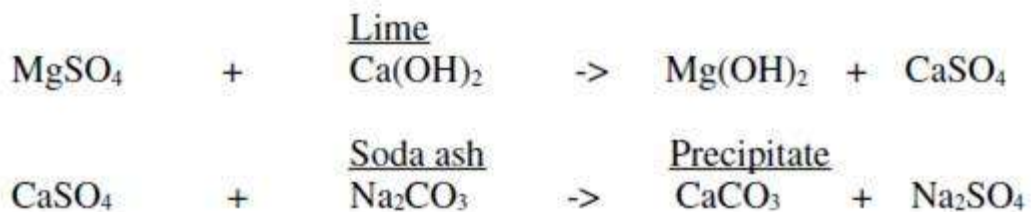
conventional processes of coagulation/flocculation, sedimentation, and filtration. Because precipitates are very slightly soluble, some hardness remains in the water--usually about 50 to 85 mg/l (as CaCO<sub>3</sub>). This hardness level is desirable to prevent corrosion problems associated with water being too soft and having little or no hardness.

### LIME ADDITION



CO<sub>2</sub> does not contribute to the hardness, but it reacts with the lime, and therefore uses up some lime before the lime can start removing the hardness.

### LIME AND SODA ASH ADDITION



CO<sub>2</sub> = carbon dioxide, Ca(OH)<sub>2</sub> = calcium hydroxide or hydrated lime, CaCO<sub>3</sub> = calcium carbonate, Ca(HCO<sub>3</sub>)<sub>2</sub> = calcium bicarbonate, Mg(HCO<sub>3</sub>)<sub>2</sub> = magnesium bicarbonate, MgCO<sub>3</sub> = magnesium carbonate, Mg(OH)<sub>2</sub> = magnesium hydroxide, MgSO<sub>4</sub> = magnesium sulfate, CaSO<sub>4</sub> = calcium sulfate, H<sub>2</sub>O = water. Na<sub>2</sub>CO<sub>3</sub> = sodium carbonate or soda ash

For each molecule of calcium bicarbonate hardness removed, one molecule of lime is used. For each molecule of magnesium bicarbonate hardness removed, two molecules of lime are used. For each molecule of non-carbonate calcium hardness removed, one molecule of soda ash is used.

For each molecule of non-carbonate magnesium hardness removed one molecule of lime plus one molecule of soda ash is used.

### **2.9.1.1. CONVENTIONAL LIME-SODA ASH TREATMENT:**

When water has minimal magnesium hardness, only calcium needs to be removed. Only enough lime and soda ash are added to water to raise pH to between 10.3 and 10.6, and calcium hardness will be removed from the water (but minimal magnesium hardness will be removed).

### **2.9.1.2. EXCESS LIME TREATMENT:**

When magnesium hardness is more than about 40 mg/l as  $\text{CaCO}_3$ , magnesium hydroxide scale deposits in household hot-water heaters operated at normal temperatures of 140 to 150° F. To reduce magnesium hardness, more lime must be added to the water. Extra lime will raise pH above 10.6 to help magnesium hydroxide precipitate out of the water.

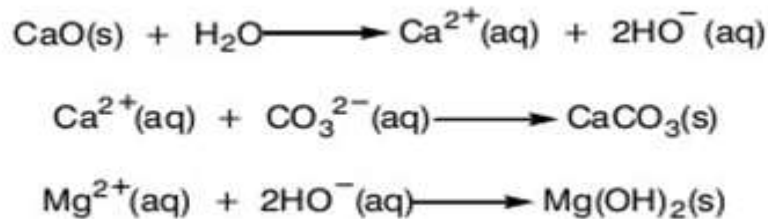
### **2.9.1.3. SPLIT TREATMENT:**

When water contains high amounts of magnesium hardness, split treatment may be used. Approximately 80 percent of the water is treated with excess lime to remove magnesium at a pH above 11, after which it is blended with 20 percent of the source water. Split treatment can reduce the amount of carbon dioxide required to re-carbonate the water as well as offer a savings in lime feed.

Since the fraction of the water that is treated contains an excess lime dose, magnesium is almost completely removed from this portion. When this water is mixed with the water that does not undergo softening, the carbon dioxide and bicarbonate in that water re-carbonates the final blend. Split treatment reduces the amount of chemical needed to remove hardness from water by 20 to 25 percent (a significant savings).

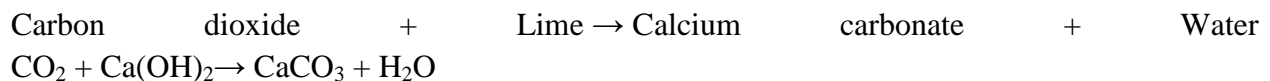
## 2.9.2. Details of Water Softening with Soda- Lime process:

The old lime-soda process is now obsolete but was very useful for the treatment of large volumes of hard water. Addition of lime (CaO) and soda (Na<sub>2</sub>CO<sub>3</sub>) to the hard water precipitates calcium as the carbonate, and magnesium as its hydroxide. The amounts of the two chemicals required are easily calculated from the analysis of the water and stoichiometry of the reactions (Scheme 8.9). Since calcium carbonate and magnesium hydroxide are not completely insoluble, the water obtained has a residual hardness of not less than 20 ppm CaCO<sub>3</sub>. A major problem of this type of process is the disposal of the sludge of precipitated calcium carbonate and magnesium hydroxide.



### 2.9.2.1. Carbon Dioxide Demand:

The first step in lime softening is the addition of lime to water using a typical dry feeder, either volumetric or gravimetric. As in the chlorination process, lime reacts with substances in the water before it can begin softening the water. Carbon dioxide is the primary compound which creates the initial demand for lime. The following reaction occurs, using up carbon dioxide and lime and creating calcium carbonate and water:

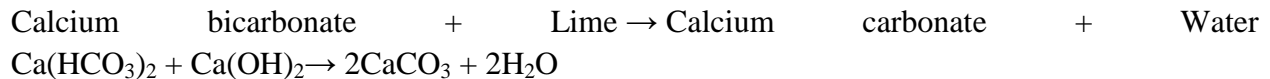


The resulting calcium carbonate precipitates out of solution. When water, especially groundwater, has a high carbon dioxide concentration, the water is often pretreated with aeration before softening begins. Aeration removes the excess carbon dioxide and lowers the lime requirements.

### 2.9.3. Removal of Hardness:

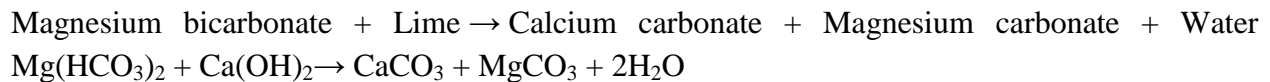
#### 2.9.3.1. Removal of Carbonated hardness:

Once the carbon dioxide demand has been met, the lime is free to react with and remove carbonate hardness from the water. Calcium compounds react with lime in the reaction shown below.

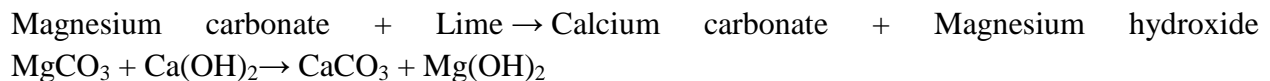


We have focused on calcium bicarbonate since it is the most common calcium compound in water, but other calcium-based hardness compounds have similar reactions. In any case, the calcium carbonate produced is able to precipitate out of solution.

Magnesium compounds have a slightly different reaction. First, magnesium bicarbonate reacts with lime and produces calcium carbonate (which precipitates out of solution) and magnesium carbonate.



Then the magnesium carbonate reacts with lime and creates more calcium carbonate and magnesium hydroxide. Both of these compounds are able to precipitate out of water.



#### 2.9.3.2. Removal of Non-carbonate Hardness:

In many cases, only the carbonate hardness needs to be removed, requiring only the addition of lime. However, if noncarbonate hardness also needs to be removed from water, then soda ash must be added to the water along with lime.

Each noncarbonate hardness compound will have a slightly different reaction. Here, we will consider the reactions of magnesium sulfate. The lime first reacts with the magnesium sulfate, as shown below:

Magnesium sulfate + Lime → Magnesium hydroxide + Calcium sulfate  
 $MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaSO_4$

The resulting compounds are magnesium hydroxide, which will precipitate out of solution, and calcium sulfate. The calcium sulfate then reacts with soda ash:

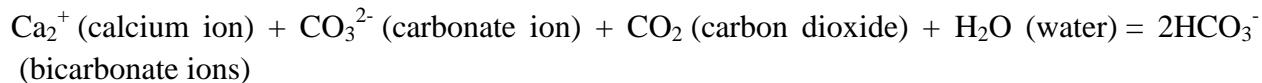
Calcium sulfate + Soda Ash → Calcium carbonate + Sodium sulfate  
 $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$

The calcium carbonate resulting from this reaction will settle out of the water. The sodium sulfate is not a hardness-causing compound, so it can remain in the water without causing problems.

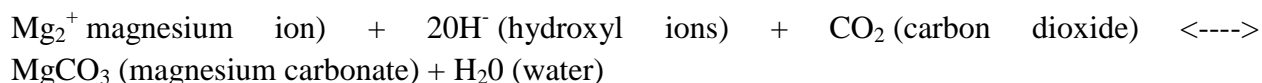
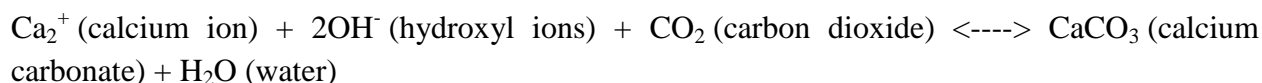
#### **2.9.4. Re-carbonation:**

After adding lime and/or soda ash, treated water will generally have a pH greater than 10. It is necessary to lower the pH to stabilize the water and prevent deposition of carbonate scale on filter sand and distribution piping. Recarbonation is the most common process used to reduce pH. This procedure adds carbon dioxide to water after softening. Generally, enough carbon dioxide is added to reduce the pH of the water to less than 8.7. The amount of carbon dioxide added is determined using a saturation index. The Langelier Index (LI) is the most common stabilization index used, but some plants instead use the Rizner Index, (reciprocal of the Langelier Index). The Langelier Index is expressed as pH of stabilization (pH<sub>s</sub>) minus actual pH measured (pH<sub>a</sub> - pH). When the Langelier Index is positive, pipes tend to become coated with scale. When it is negative, the water tends to be corrosive.

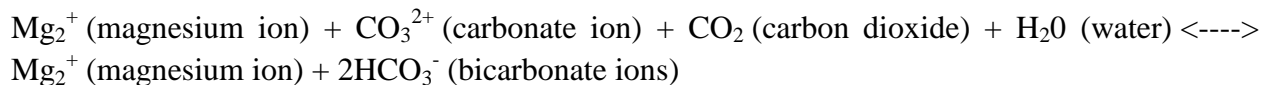
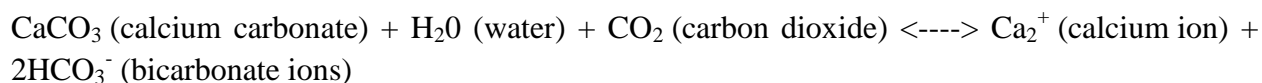
When low magnesium water is softened, no excess lime needs to be added. After softening, water becomes supersaturated with calcium carbonate and has a pH between 10.0 and 10.6. When carbon dioxide is added, the excess calcium carbonate is converted back to permanent hardness or calcium bicarbonate by the following formula:



When high magnesium water is softened, excess lime needs to be added to raise the pH above 11, and magnesium hydroxide precipitates out. After treatment, enough carbon dioxide must be added to neutralize the excess hydroxide ions, as well as convert carbonate ions to bicarbonate ions. The first stage of this reaction reduces the pH to between 10.0 and 10.5. In this range, calcium carbonate is formed and magnesium hydroxide that did not precipitate, or did not settle out, is converted to magnesium carbonate.



Additional carbon dioxide needs to be added to lower the pH to between 8.4 and 8.6. The previously formed calcium carbonate re-dissolves and carbonate ions are converted to bicarbonate ions as shown below:



For treatment of low magnesium water (where excess-lime addition is not required) single-stage re-carbonation is used. The water is mixed with lime or soda ash in the rapid-mix basin, resulting in a pH of 10.2 to 10.5. If non-carbonate hardness removal is required, soda ash will also be added at this step. After rapid mixing, the resulting slurry is mixed gently for a period of 30 to 50 minutes to allow the solids to flocculate. After flocculation, the water is allowed to flow into a sedimentation basin where the solids will be removed by sedimentation. Following sedimentation the clear water flows to the recarbonation basin where carbon dioxide is added to

reduce the pH to between 8.3 and 8.6. Any particles remaining in suspension after recarbonation are removed by filtration.

#### **2.9.4.1. Two-Stage Softening:**

Two-stage softening is sometimes used for treatment of high magnesium water (where excess lime is required). Excess lime is added in the first stage to raise pH to 11.0 or higher for magnesium removal. Following first stage treatment, carbon dioxide is added to reduce the pH to between 10.0 and 10.5, the best value for removal of calcium carbonate. If non-carbonate hardness removal is needed, soda ash will be added at this point. After second stage treatment, the water flows to a secondary recarbonation tank, where pH is reduced to between 8.3 and 8.6.

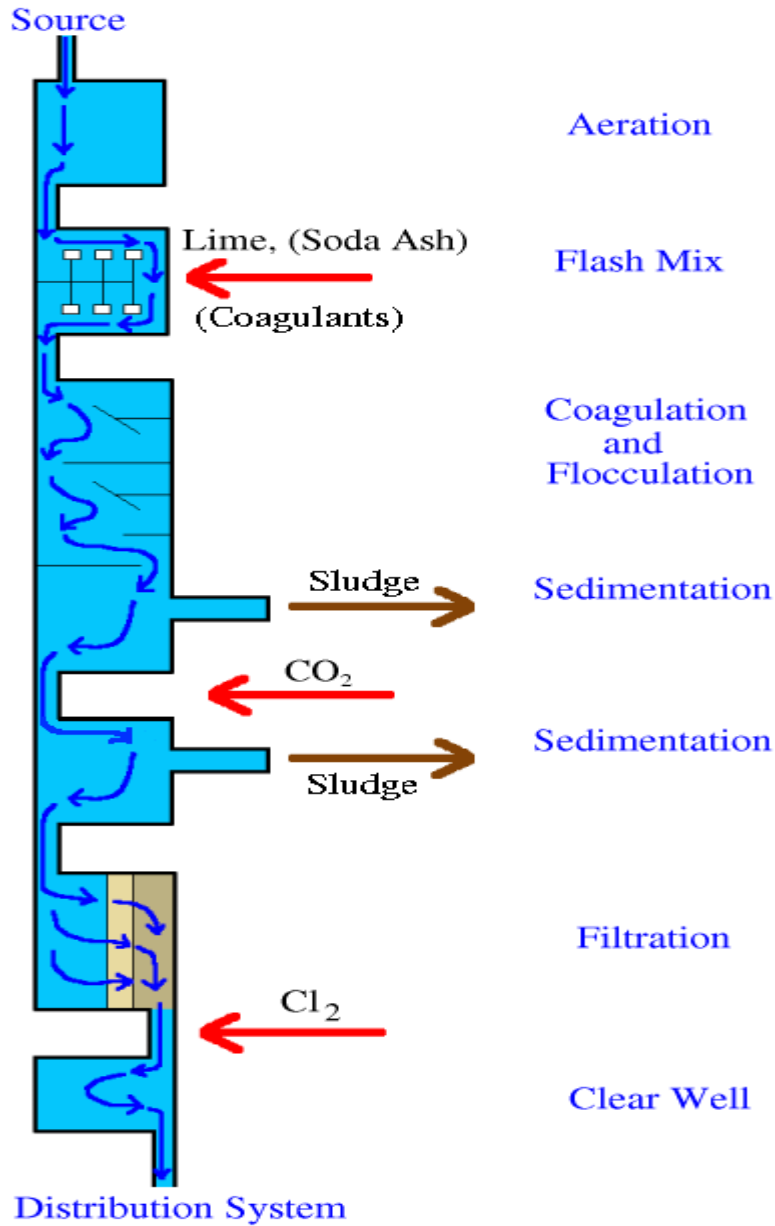
#### **2.9.4.2. Single-Stage Softening:**

Single-stage recarbonation is the one most commonly practiced (Because of the high capital cost for building this type of two-stage treatment train). There are some benefits to using the two-stage method, including reduced operating cost since less carbon dioxide is needed. Better finished water quality is usually obtained through the two-stage process.

#### **In The Treatment Process Equipment Used**

Lime softening uses the equipment already found in most treatment plants for turbidity removal. An overview of the lime treatment process is shown below.





### 2.9.5. Sludge

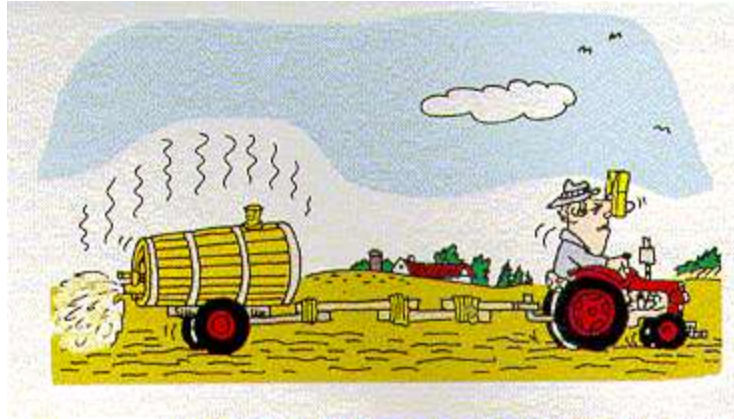
Lime softening produces large quantities of sludge. In fact, for every pound of lime used, about two pounds of sludge are formed.



*Lime sludge*

The softening process usually requires two sedimentation basins, each with a detention time of 1.5 to 3 hours, to deal with the large quantities of sludge. One sedimentation basin handles the sludge resulting from lime and soda ash softening and the other sedimentation basin deals with the sludge resulting from recarbonation.

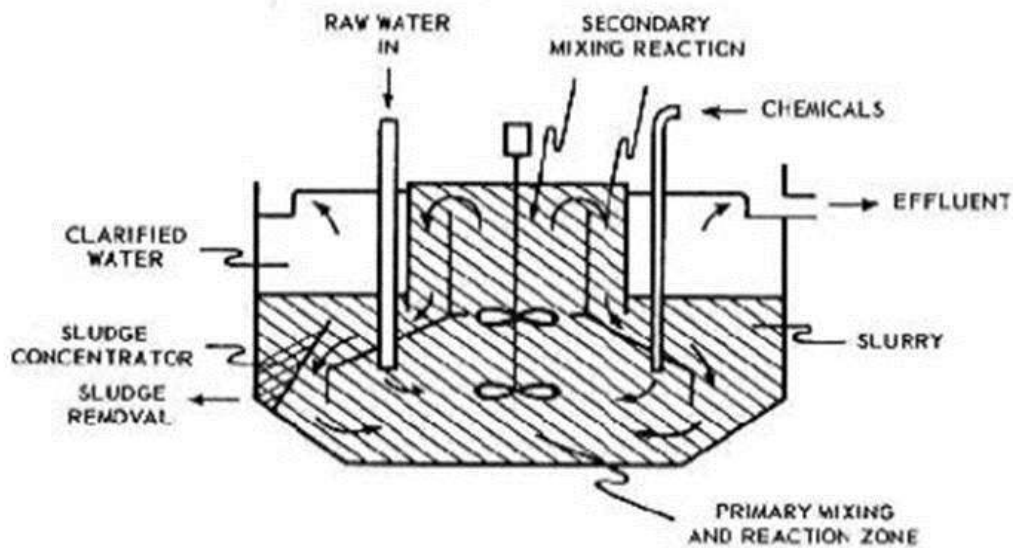
Disposal of lime sludge is the same as for sedimentation basin sludge. Landfill disposal is the most common method, although sludge may sometimes be sent to sanitary sewers. Lime sludge has a high pH and has increasingly been disposed of by applying it to agricultural land to increase the pH of acidic soils.



### **2.9.6. Sludge Removal:**

Residue created from lime-soda ash softening is normally very high in calcium carbonate or a mixture of calcium carbonate, and magnesium hydroxide. Calcium carbonate sludges are normally dense, stable inert, and dewater readily. Solids content in the sludge range from 5 to 30 total solids with a pH greater than 10.5.

Lime-soda ash sludges may be treated with lagooning, vacuum filtration, centrifugation, pressure filtration, recalcination, or land application. The most common method is storage of sludge in lagoons and application to farmland or landfills disposal.



**FUNCTIONAL DRAWING OF  
SOLIDS CONTACT UNIT  
USED FOR WATER SOFTENING**

### 2.9.7. Calculations:

There are two methods for calculating lime and soda ash dosages (conventional dosage method and conversion factor method). The conventional method, although much longer, is helpful in understanding the chemical and mathematical relationships involved in softening. The conversion factor method is simpler, quicker, and more practical for daily operations.

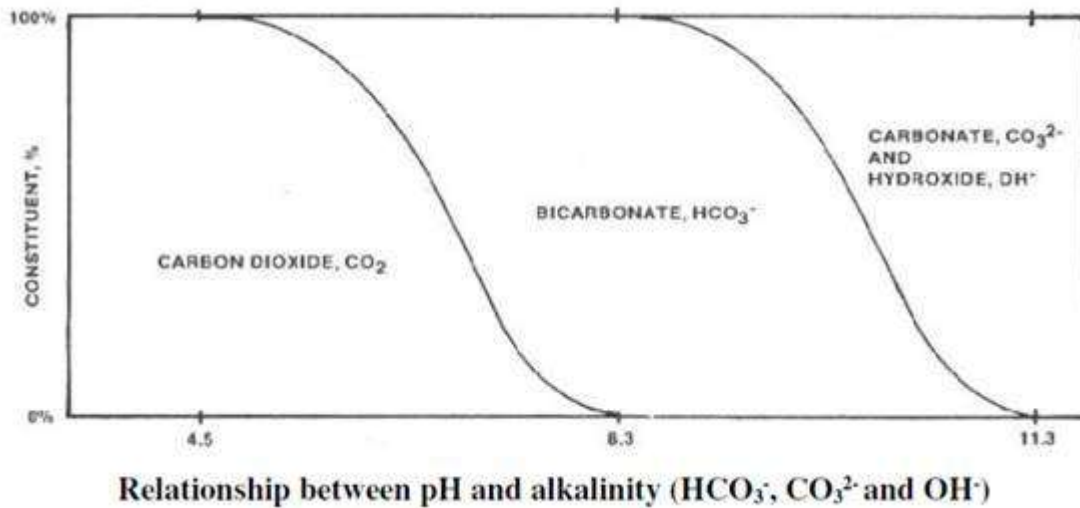
In both calculation methods, lime and soda ash dosages depends on carbonate and non-carbonate hardness in the water. Lime is used to remove carbonate hardness, and both lime and soda ash are used to remove non-carbonate hardness. If total hardness is less than or equal to total alkalinity, there is no non-carbonate hardness (only carbonate hardness). If total hardness is greater than total alkalinity, non-carbonate hardness equals the difference between total hardness and total alkalinity (and carbonate hardness equals total alkalinity).

If total hardness is equal to or less than total alkalinity, then:

Lime Dosage = the carbon dioxide concentration  $[CO_2]$  + the total hardness concentration

$[Total\ Hardness]$  + the magnesium concentration  $[Mg]$  +  $[Excess]$

Optimum chemical dosages can be evaluated with a jar test.



Alkalinity (mg/l as  $CaCO_3$ ) is the capacity of water to neutralize acids. This is determined by the content of carbonate, bicarbonate and hydroxide. Alkalinity is a measure of how much acid can be added to a liquid without causing any significant change in pH.

When pH is less than 8.3, all alkalinity is in the bicarbonate form and is commonly referred to as natural alkalinity. When pH is above 8.3, alkalinity may consist of bicarbonate, carbonate, and hydroxide. As pH increases the alkalinity progressively shifts to carbonate and hydroxide forms.

Total alkalinity is the sum of bicarbonate, carbonate, and hydroxide alkalinity. Various chemicals effect water differently:

**Lowers Alkalinity:**

Aluminum sulfate  
Carbon dioxide  
Chlorine gas  
Ferric Chloride  
Ferric Sulfate  
Sulfuric acid

**Increases Alkalinity:**

Calcium hypochlorite  
Caustic soda  
Hydrate lime  
Soda ash  
Sodium Aluminate

The following table gives molecular weights for common chemicals:

Quicklime (CaO).....	56
Hydrate Lime (CaOH).....	74
Magnesium (Mg).....	24.3
Carbon Dioxide (CO <sub>2</sub> ).....	44
Magnesium Hydroxide (Mg(OH) <sub>2</sub> )...	58.3
Soda Ash (NaCO <sub>3</sub> ).....	106
Alkalinity (as CaCO <sub>3</sub> ).....	100
Hardness (as CaCO <sub>3</sub> ).....	100

Quicklime dosage can be calculated with the following formula:

$$\text{Quicklime (CaO) mg/l} = \frac{(A + B + C + D) + \% \text{ EXCESS}}{\text{purity of lime as a decimal}}$$

$$\begin{aligned} A &= \text{Carbon Dioxide in source water} \\ &= \text{mg/l CO}_2 \times (\text{CaO/CO}_2) \\ &= \text{mg/l CO}_2 \times 56/44 \\ &= \text{mg/l CO}_2 \times 1.27 \end{aligned}$$

$$\begin{aligned} B &= \text{Bicarbonate alkalinity removed} \\ &= \text{mg/l as CaCO}_3 \times (\text{CaO/CaCO}_3) \\ &= \text{mg/l} \times 56/100 \\ &= \text{mg/l alkalinity} \times .56 \end{aligned}$$

$$\begin{aligned} C &= \text{Hydroxide alkalinity in softener effluent} \\ &= \text{mg/l hydroxide alkalinity} \times (\text{CaO/CaCO}_3) \\ &= \text{mg/l hydroxide alkalinity} \times 56/100 \\ &= \text{mg/l hydroxide alkalinity} \times .56 \end{aligned}$$

$$\begin{aligned} D &= \text{Magnesium removed in softening} \\ &= \text{Mg/l as Mg}^{2+} \times (\text{CaO/Mg(OH)}_2) \\ &= \text{Mg/l as Mg}^{2+} \times 56/24.3 \\ &= \text{Mg/l as Mg}^{2+} \times 2.30 \end{aligned}$$

If hydrated lime (CaOH) is used in place of quicklime, the molecular weight of quicklime of 56 should be replaced with the weight of hydrated lime (74).

When treating water that contains non-carbonate hardness, soda ash is required. The amount of soda ash can be estimated by using the following formula:

$$\text{Soda Ash (NaCO}_3\text{) mg/l} = \text{mg/l Non Carbonate Hardness as CaCO}_3 \times \text{Na}_2\text{CO}_3 / \text{CaCO}_3$$

$$= \text{mg/l Non-Carbonate Hardness as CaCO}_3 \times 106/100$$

$$= \text{mg/l Non-Carbonate Hardness as CaCO}_3 \times 1.06$$

After softening, pH of the water is generally above 10. If left at this pH, water will plate filter sand and cause problems in the distribution system. Carbon dioxide (through re-carbonation), is added to lower the pH. The amount of carbon dioxide (CO<sub>2</sub>) required can be estimated:

$$\text{Total CO}_2 (\text{mg/l}) = \text{Ca(OH)}_2 (\text{mg/l}) \times \frac{\text{CO}_2}{\text{Ca(OH)}_2} + \text{Mg(OH)}_2 \text{residual} \times \frac{\text{CO}_2}{\text{Mg(OH)}_2}$$

$$\text{Total CO}_2 = \text{Ca(OH)}_2 \text{mg/l} \times 44/74 + \text{Mg(OH)}_2 \text{residual} \times 44/58.3$$

$$\text{Total CO}_2 = \text{Ca(OH)}_2 \text{mg/l} \times .59 + \text{Mg(OH)}_2 \text{residual} \times .75$$

### 2.9.8. Conversion Method:

Equivalent weight conversions required in the conventional method have been combined into single factors shown in the table below. These factors, multiplied by the concentration of the corresponding material, will give the lime or soda ash dosage needed to remove material in units of milligrams per liter or pounds per million gallons. The total dosage is the sum of all material removed from the water, such as the carbon dioxide, bicarbonate alkalinity, and the magnesium, plus the amount of excess that is required to reduce the hardness in the water. The total soda-ash dosage is found in the same manner by finding the sum of the amounts needed to remove the non-carbonate material from the water. An additional calculation is needed to adjust for the purity of the lime or soda-ash used.



	Converting to:			
	Lime (CaO)		Soda Ash	
	mg/l	lb/MG	mg/l	lb/MG
Carbon Dioxide (mg/l as CaCO <sub>3</sub> )	1.27	10.63	---	---
Bicarbonate Alkalinity (mg/l as CaCO <sub>3</sub> )	0.56	4.67	---	---
Magnesium as Mg (mg/l as CaCO <sub>3</sub> )	2.31	19.24	---	---
Excess as CaCO <sub>3</sub> (mg/l as CaCO <sub>3</sub> )	0.56	4.67	---	---
Non-carbonate Hardness (mg/l as CaCO <sub>3</sub> )	---	---	1.06	8.83
Excess Soda ash (mg/l as CaCO <sub>3</sub> )	---	---	1.06	8.83

*Example:*

The following test results were provided by the laboratory:

CO <sub>2</sub> concentration	25 mg/l as CO <sub>2</sub>
HCO <sub>3</sub> (bicarbonate) concentration	205 mg/l as CaCO <sub>3</sub>
Mg (magnesium) concentration	9 mg/l as Mg
non-carbonate hardness concentration	95 mg/l as CaCO <sub>3</sub>

Assuming no excess lime is added, find correct dosages for lime (containing 90% pure CaO) and soda ash (containing 99% pure Na<sub>2</sub>CO<sub>3</sub>) required to remove all hardness.

CO <sub>2</sub>	25 mg/l x 1.27	=	31.75 mg/l as CaO
HCO <sub>3</sub>	205 mg/l x 0.56	=	114.80 mg/l as CaO
Mg	9 mg/l x 2.31	=	20.79 mg/l as CaO
TOTAL		=	167.34 mg/l as CaO

Then adjust lime dosage for purity:

$$\text{Actual Lime Dose} = \frac{167.34 \text{ mg/l}}{.90} = 185.93 \text{ mg/l}$$

Next, find soda ash dosage:

$$\text{Soda Ash Dosage} = 95 \text{ mg/l} \times 1.0 = 100.7 \text{ mg/l as Na}_2\text{CO}_3$$

$$\text{Actual Dosage} = \frac{100.7 \text{ mg/l}}{.99} = 101.7 \text{ mg/l as Na}_2\text{CO}_3$$

## **2.9.9. Monitoring:**

If softening problems are discovered, the cause usually lies in either chemical feeder malfunctions or source water quality changes. A variety of water characteristics can influence lime-soda ash softening:

Water hardness will determine the quantity of chemicals which must be added to soften the water.

pH influences the chemical reactions in the softening process. A higher pH makes the process more efficient.

Alkalinity determines whether the hardness in the water is carbonate or noncarbonate hardness.

Temperature influences the rate of the reaction and the amount of hardness which the water will hold.

These four water characteristics should be monitored carefully when softening water using lime. In addition, coagulants used to remove turbidity can influence the alkalinity or pH of the water, thus affecting the softening process. After softening, the Langelier Index of the water should be tested to ensure that the water is not corrosive. We will study the Langelier index and corrosive water in more depth in the next lesson.

Softening is especially well-suited to treating groundwater since groundwater characteristics tend to remain relatively constant. Changing water conditions require a great deal of manipulating the softening process to keep it efficient. In addition, the high turbidity found in surface water sometimes requires pre-sedimentation prior to softening.

## **2.9.10. Chemicals Used in Lime Softening:**

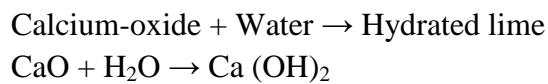
### **2.9.10.1. Types of Lime:**

The lime used for softening comes in two forms - hydrated lime and quicklime. Both types of lime soften water in the same way, but the equipment required for the two types of lime is different.

Hydrated lime ( $\text{Ca}(\text{OH})_2$ ) is also known as calcium hydroxide or slaked lime. Hydrated lime can be added to water as it is without requiring any special equipment, so it is a popular choice for small water treatment plants.

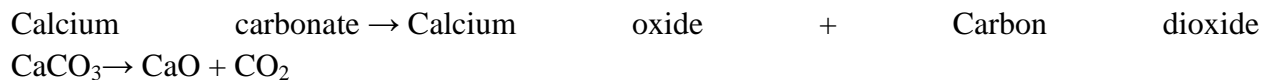
In contrast, quicklime ( $\text{CaO}$ ), also known as calcium oxide or unslaked lime, must be slaked

before it is used. Slaking is the process of converting quicklime to hydrated lime by adding water, as shown below:



Slaking requires specialized equipment. The cost of equipment and the operator time required to run the equipment usually make quicklime use uneconomical in small plants. However, since the chemical cost of quicklime is less than the cost of hydrated lime, quicklime is often used in large plants.

The slaking process can also allow a large plant to reuse a large quantity of the lime sludge produced in the softening process. First, the sludge is heated, and the calcium carbonate in the sludge produces calcium oxide:



Then the calcium oxide can be slaked and reused in the plant. Reusing lime sludge cuts down on both chemical purchase and sludge disposal costs.

### **2.9.11. Lime Handling and Storage:**

Operators should observe safety procedures while handling both hydrated lime and quicklime. Lime dust can be harmful when it comes in contact with the eyes, nose, or mouth, and skin contact can cause burns. As a result, operators should wear goggles and dust masks as well as protective clothing.

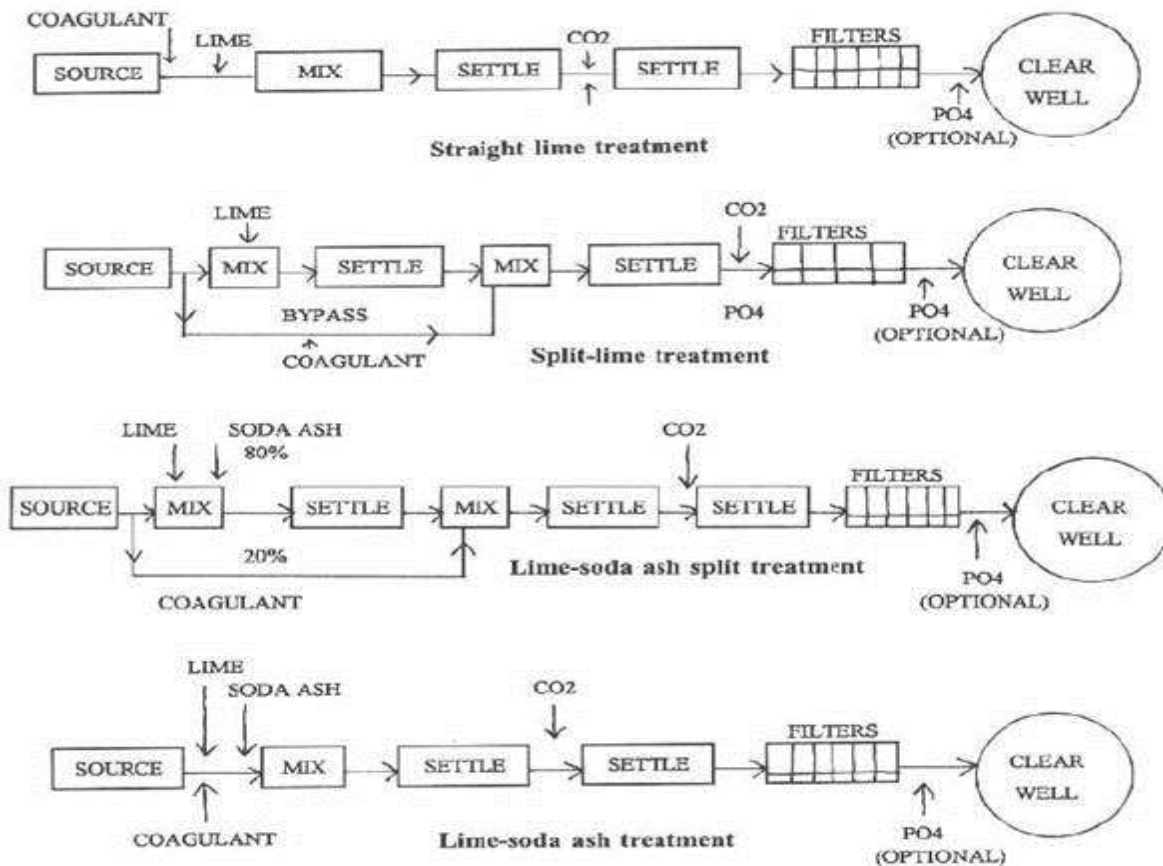
Both hydrated lime and quicklime can deteriorate in quality over time while in storage. In addition, storing quicklime can cause safety problems. If quicklime comes in contact with water, it begins to slake, a process which produces a great deal of heat and can cause explosions when uncontrolled. Quicklime should never be stored with alum since the quicklime will absorb water away from the alum and cause an explosion.

## 2.9.12. Soda Ash:

Soda ash ( $\text{Na}_2\text{CO}_3$ ) comes in only one form and does not require any treatment before it is added to the water. Safety issues resemble those for lime handling. Soda ash dust irritates the eyes and mucous membranes of the nose, so the operator should wear protective clothing, goggles, and a dust mask. In addition, areas in which soda ash is used should be equipped with a ventilation system to deal with the dust.

### 2.10. DESIGN CONSIDERATIONS:

In lime soda-ash softening plants, the softening process may be carried out by a sequence of rapid mix, flocculation, and sedimentation or in a solids contactor. In the solids contactor the rapid mix, flocculation, and sedimentation occur in a single unit. The process begins with the mixing of the chemicals into the water, followed by violent agitation, termed rapid mixing. This allows chemicals to react with, and precipitate calcium or magnesium hardness in the water.



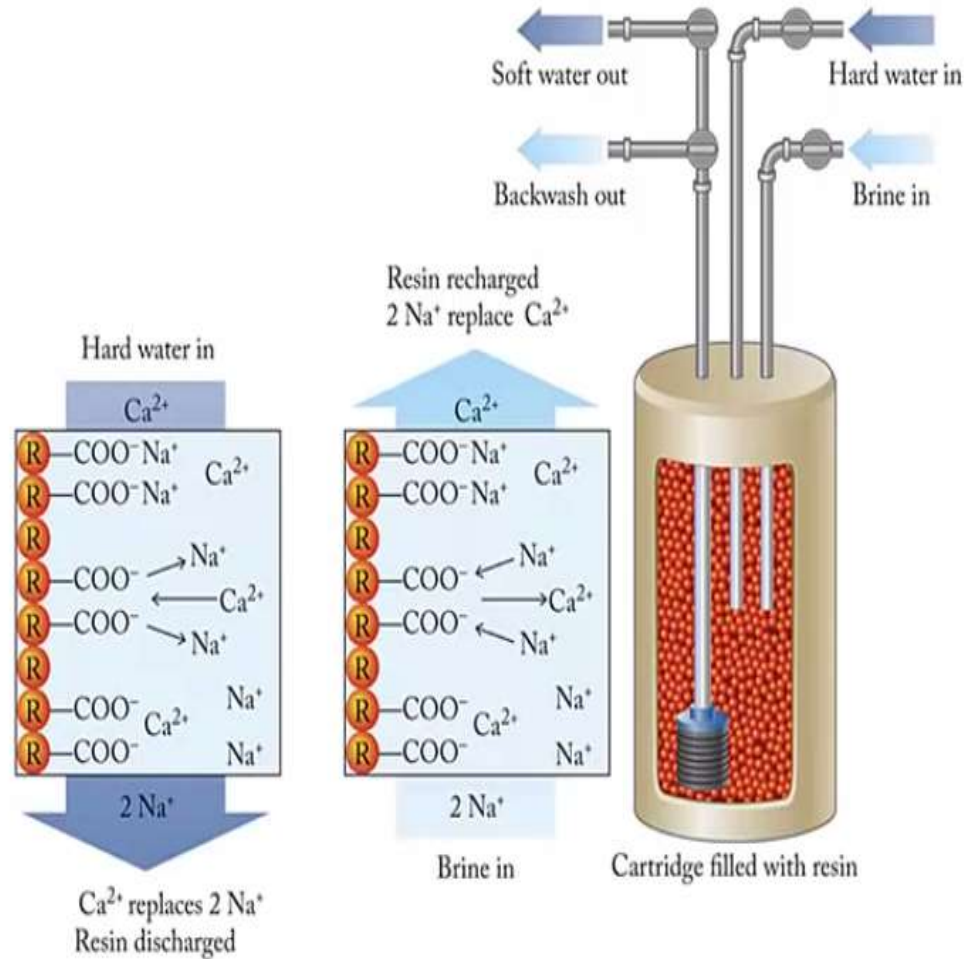
## 2.11. Water softening with Ion exchange methods:

Ion exchange is a treatment process in which a solid phase pre-saturant ion is exchanged for an unwanted ion in the untreated water. The process is used for water softening (removal of calcium and magnesium), removal of some radionuclides (e.g. radium and barium) and removal of various other contaminants (e.g. nitrate, arsenate, chromate, selenate and dissolved organic carbon). The effectiveness of the process depends on the background water quality, and the levels of other competing ions and total dissolved solids. Although some ion exchange systems can be effective for adsorbing viruses and bacteria (Semmens, 1977), such systems are not generally considered a microbial treatment barrier, because the organisms can be released from the resin by competing ions. Also, ion exchange resins may become colonized by bacteria, which can then contaminate treated effluents (Flemming, 1987; Parsons, 2000). Backflushing and other rinsing procedures, even regeneration, will not remove all of the attached microbes. Impregnation of the resin with silver suppresses bacterial growth initially, but eventually a silver-tolerant population develops. Disinfection of ion exchange resins using 0.01% peracetic acid (1 hour contact time) has been suggested (Flemming, 1987).

A zeolite is a naturally occurring insoluble mineral of the sodium aluminosilicate type. When hard water passes through a bed of small particles of such a mineral, an ion exchange reaction takes place (Scheme 8.10). As more and more alkaline earth metal ions are retained by the zeolite, its exchange capacity gradually decreases. Regeneration of the sodium salt of the zeolite involves passing a concentrated solution of NaCl through the zeolite. The calcium and magnesium ions are displaced and leave with the solution (the reverse of Scheme 8.10). After rinsing with water to eliminate the excess salt, the zeolite is ready for another cycle of softening.

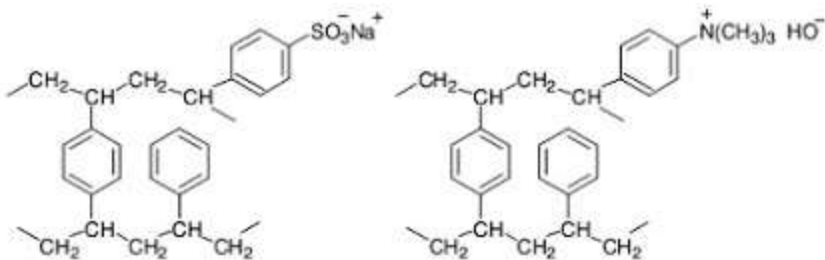


# Ion Exchange to Soften Water

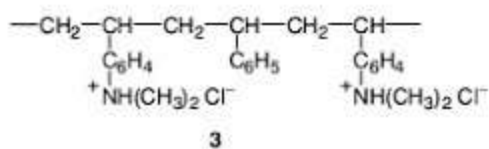
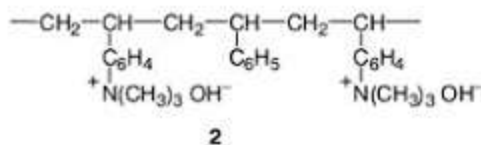
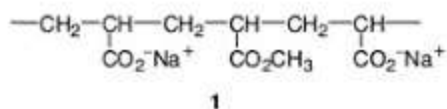


Many zeolites occur in nature but they can also be manufactured. The removal of the alkaline earth metal ions is more effective the greater the surface area of the zeolite particles in contact with the water. For this reason, softening involves percolation of the water down a packed column of the finely ground zeolite, followed by periodic regeneration. Although the calcium and magnesium ions in the water are replaced by sodium ions, these are relatively harmless in textile processing. The chemical structures of aluminosilicates are based on the structure of silica. This consists of a three dimensional network of  $\text{SiO}_4$  units, in which the oxygen atoms have a tetrahedral arrangement around the central silicon atom. These tetrahedra may have common corners or faces. In an aluminosilicate, a number of aluminium atoms replace silicon atoms in the silica structure. The aluminium atoms are bonded to four tetrahedral oxygen atoms but because their atomic number is one less than silicon, each aluminium atom introduced has a negative charge, balanced by incorporation of a cation such as  $\text{Na}^+$  or  $\text{K}^+$ . It is these cations that

are available for exchange. The newer synthetic polymer ion exchangers are much more versatile than the zeolites and are widely used for water softening and demineralisation. They are often called ion exchange resins. Many are based on polystyrene that has been partly cross-linked by incorporation of a small amount of di-vinyl benzene (2 – 10%). Suspension polymerization of the styrene and di-vinyl benzene produces the cross-linked polymer in the form of small beads. These have the appearance of a fine white sand. Sulphonation of some of the benzene rings, mainly on the bead surfaces, provides anionic sites suitable for cation exchange (Figure 8.2). Since a sulphonic acid is comparable in strength to a mineral acid, these are called strong acid exchangers. They may absorb cations and release hydrogen ions, or, in the form of their sodium salts, exchange sodium ions for other cations in the water



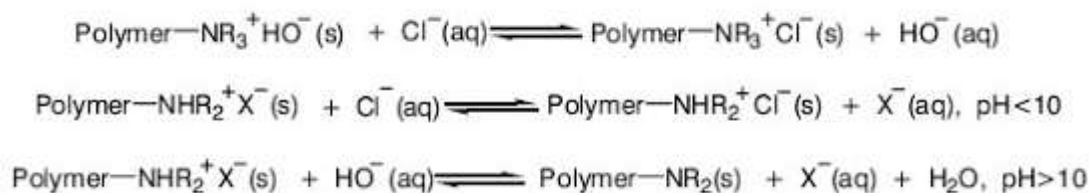
**Figure 8.2** Chemical structures of cation and anion exchangers based on cross-linked polystyrene



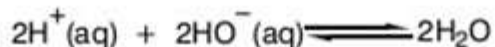
Weak acid cation exchanger, containing acrylic acid (ethenoic acid) units ( 1 ); strong basic anion exchange resin, containing quaternary ammonium hydroxide groups ( 2 ); weakly basic anion exchange resin with protonated secondary amino groups ( 3 ) The so-called weak acid cation exchangers are usually polymers containing carboxylic acid groups, such as vinyl polymers containing acrylic acid (ethenoic acid) units (1, in Figure 8.3). These are used in the form of their sodium salts. They do not exchange hydrogen ions for cations below pH 5 since the free carboxylic acid groups are barely dissociated at low pH values (Scheme 8.12). Other types



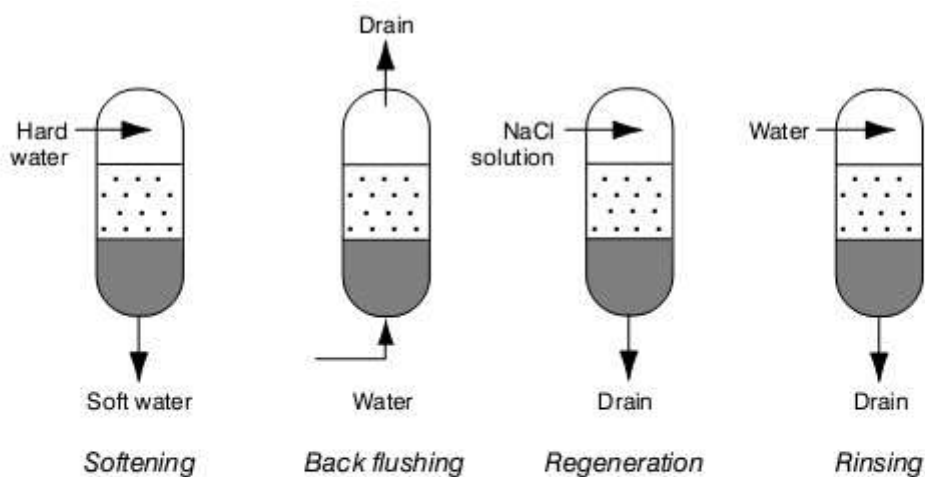
of ion exchange resins are available for an ion exchange. These may be of the strong basic type, containing quaternary ammonium hydroxide groups (see Figure 8.2, and 2 in Figure 8.3), or weakly basic with protonated secondary amino groups (3, in Figure 8.3). Either type will have associated counter anions that exchange with anions in the solution in contact with the resin. The weakly basic types have ammonium ion groups that can lose a proton in contact with an alkaline solution and therefore are ineffective above pH 10 (Scheme 8.13). The ion exchange processes are again reversible so resin regeneration simply involves treatment with a concentrated solution of a salt containing the appropriate anion.



Therefore, a strongly basic quaternary ammonium ion resin is regenerated using NaOH solution, and a secondary amine type with NaCl or HCl solution. The two most important properties of an ion exchanger are its capacity and its selectivity. The capacity is the number of ions that a given mass of resin is capable of binding by exchange, normally expressed in milliequivalents per gram of dry or of wet resin. For example, 1.0 mmol of Na<sup>+</sup> is the same as 1.0 mequiv, but 1.0 mmol of Ca<sup>2+</sup> is 2.0 mequiv. Therefore, a resin with a capacity of 15.0 mequiv g<sup>-1</sup> would be capable of binding 15.0 mmol g<sup>-1</sup> Na<sup>+</sup> or 7.5 mmol g<sup>-1</sup> Ca<sup>2+</sup>. The selectivity of the resin determines how strongly it binds a given ion and therefore its ease of exchange. Clearly, for water softening a cation exchange resin should have a higher selectivity for Ca<sup>2+</sup> and Mg<sup>2+</sup> than for H<sup>+</sup> or Na<sup>+</sup>. Fortunately, the selectivity is often greater for ions of higher ionic charge. Besides these two properties, the degree of swelling of the resin in contact with the water must be limited. The higher the degree of cross-linking, for example from incorporation of more di vinylbenzene in the polystyrene, the lower the extent of swelling. It is also important that the resin particles have a large surface area and that water is able to penetrate into the surface pores. Water can be totally demineralised by firstly exchanging all cations using a strongly acid form of a cation exchanger. Thus, a solution of salts M<sup>+</sup>X<sup>-</sup> becomes a solution of acid H<sup>+</sup>X<sup>-</sup>, the M<sup>+</sup> ions being retained by the resin. Subsequent percolation through a packing of a strongly basic form of an anion exchanger absorbs the X<sup>-</sup> ions and liberates HO<sup>-</sup> ions into the water. These then neutralise the H<sup>+</sup> ions from the first step. The result is retention of all anions and cations and the neutralisation of H<sup>+</sup> and HO<sup>-</sup> to form water.



Thus, the water has been demineralised. It may, however, still contain organic material and dissolved carbon dioxide from the reaction of carbonate and bicarbonate with the acid from the resin. A thorough aeration eliminates the carbon dioxide. Demineralisation is important for water fed to very high pressure boilers. The use of ion exchange resins for water treatment is relatively simple. The resin is packed into a column containing water and treatment simply involves flowing water up or down the column. The capacity of the resin and the ionic content of the water determine when regeneration will be required. One problem with beds of ion exchangers is the retention in the column of suspended matter and living organisms in the water. Countercurrent rinsing and occasional treatment with a bactericide minimise these problems. For removal of both cations and anions (demineralisation), two columns in series are used, the first for strong acid exchange and the second for strong base exchange. It is even possible to mix anion and cation exchangers in the same bed. If the different types of particles have different densities, they can be separated by sedimentation in a counter flow of water, regenerated separately, and then re-mixed. Figure 8.4 shows a typical series of processes for water softening.



**Figure 8.4** Processes for water softening and regeneration using a cation exchanger

- pretreatment — broadly defined as any process to modify microbial water quality before, or at the entry to, a treatment plant;
- coagulation, flocculation and sedimentation — by which small particles interact to form larger particles and settle out by gravity;
- ion exchange — used for removal of calcium, magnesium and some radionuclides;
- granular filtration — in which water passes through a bed of granular materials after coagulation pretreatment;
- slow sand filtration — in which water is passed slowly through a sand

filter by gravity, without the use of coagulation pretreatment. Lime softening Precipitative lime softening is a process in which the pH of the water is increased (usually through the addition of lime or soda ash) to precipitate high concentrations of calcium and magnesium. Typically, calcium can be reduced at pH 9.5–10.5, although magnesium requires pH 10.5–11.5. This distinction is important because the pH of lime softening can inactivate many microbes at the higher end (e.g. pH 10–11), but may have less impact at more moderate levels (e.g. pH 9.5). In precipitative lime softening, the calcium carbonate and magnesium hydroxide precipitates are removed in a clarifier before the water is filtered. The microbial impact of lime softening can, therefore, be a combination of inactivation by elevated pH and removal by settling. Logsdon et al. (1994) evaluated the effects of lime softening on the removal and disinfection efficiency of *Giardia*, viruses and coliform bacteria. Coliform bacteria in river water (spiked with raw sewage) were inactivated by 0.1 log at pH 9.5, 1.0 log at pH 10.5 and 0.8–3.0 logs at pH 11.5 for 6 hours at 2–8°C. Bacteriophage MS2 was sensitive to lime softening conditions, demonstrating more than 4-log inactivation in the pH range of 11–11.5 within 2 hours. Hepatitis A virus was reduced by 99.8% when exposed to pH 10.5 for 6 hours. Poliovirus was the most resistant virus tested, requiring exposure to a pH level of 11 for 6 hours to achieve a 2.5-log inactivation. Reductions were less than 1 log when exposed for 6 hours to a pH of less than 11. The viability of *Giardia muris* cysts (measured by excystation) was not significantly affected by exposure to pH 11.5 for 6 hours. *Cryptosporidium* viability (measured using dye exclusion) was not affected by exposure to pH 9 for 5 hours (Robert, Campbell & Smith, 1992). Jar tests of precipitative lime softening at pH 11.5 resulted in 4-log removal of viruses and bacteria, and 2-log removal of *Giardia* and *Cryptosporidium*, due to combined effects of removal by sedimentation and inactivation through high pH (Bell et al., 2000). Limited full-scale data suggest that 2-log removal can be achieved through sedimentation by precipitative lime softening

## 2.12. Demineralization Softening Process

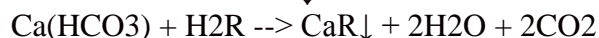
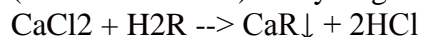
Demineralization process is the modern industrial water softening process. By this process the, It can be possible remove of hardness as well as remove of all dissolve salts i.e.;  $\text{FeCO}_3$ ,  $\text{CaCl}_2$  . We can also say that demineralization or deionization is the process of removing the dissolved ionized solids from water by ion exchange. The major portions of total dissolved solids (TDS) are mineral salts, such as calcium bicarbonate, magnesium sulfate, and sodium chloride. Mineral salts are composed of cations and anions. Since deionization requires the removal of all ions, both the negatively charged anions and the positively charged cations, then materials capable of attracting both are required. These materials are known as cation and anion exchange resins.

Demineralization process of water softening can be brought about in two ways:

1. Hydrogen Cation exchange
2. Anion exchange

### 1. Hydrogen Cation Exchange:

Cation resin can be in Hydrogen ( $\text{R-SO}_3\text{H}$ ) or Sodium form ( $\text{RSO}_3\text{Na}$ ). Sulphonated resin (Cation acid resin) in Hydrogen form is used as cation exchanger for water softening.



### 1. Anion Exchange:

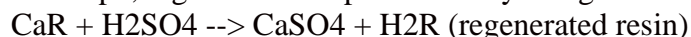
Amino resin (anion base resin) is used and produced HCl is removed.



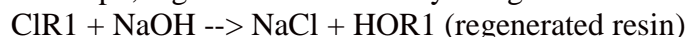
Regeneration:

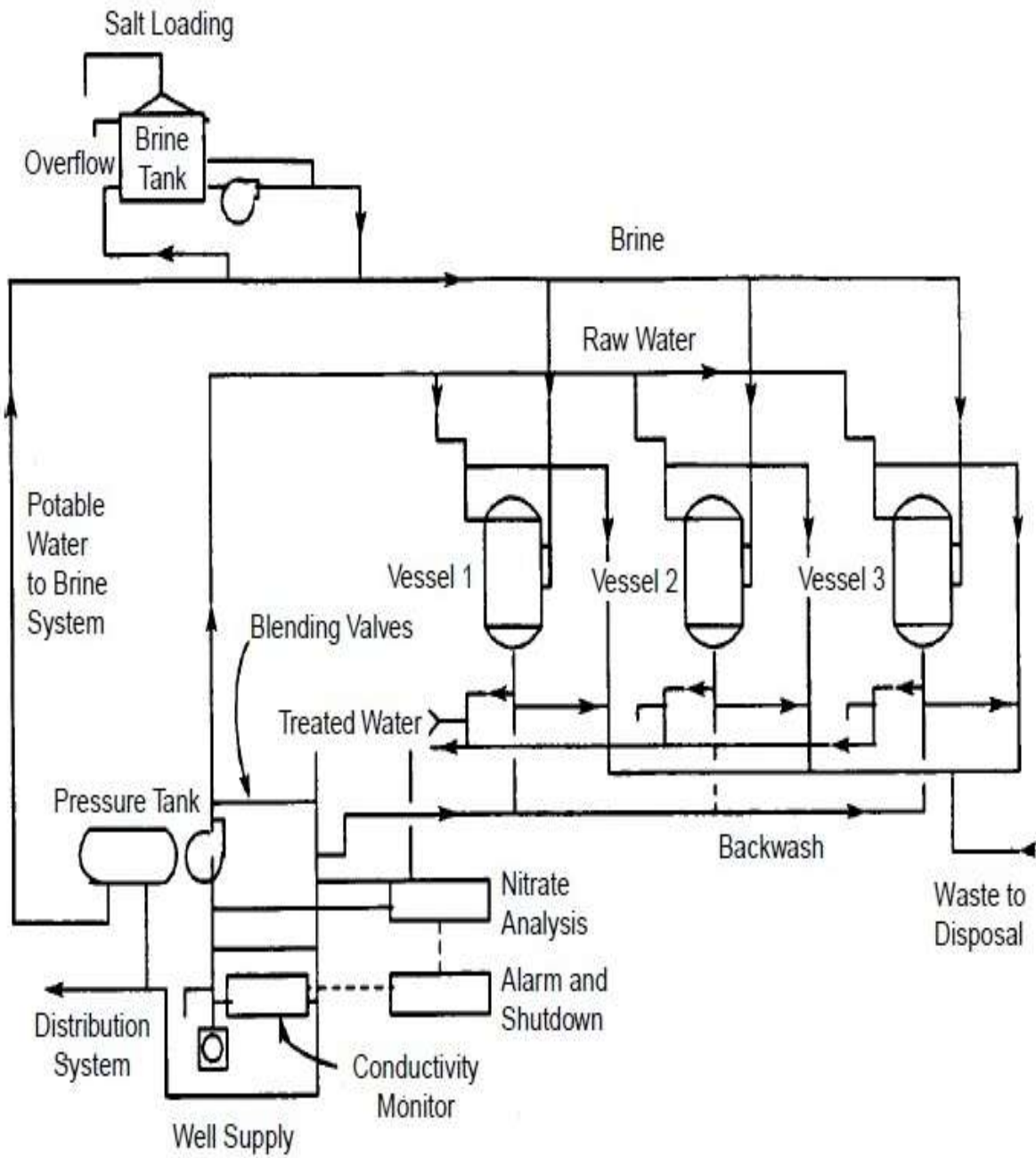
We know, regeneration is done to get back the resins which are used to softening water are exhausted and we have to apply some acid & alkali to regenerate them again.

For step1, regeneration is performed by using acid. Less than 2%  $\text{H}_2\text{SO}_4$  is used.



For step2, regeneration is done by using 1% solution of NaOH.



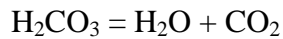


## Mixed Bed Resins

These mixed bed resins are used in Demineralization plant of boiler feed water treatment, to remove the ions (especially  $\text{Na}^+$  and  $\text{SO}_3^{2-}$ ) which may further present in the water after foregoing process of purification.

## Degasser

The function of degasser tower is to remove carbonate ions by forming carbon-di-oxide. In degasser tower stream of water is poured from top & air is blown from bottom to top. In the pressure of air the carbonic acid ( $\text{H}_2\text{CO}_3$ ) present in the water dissociates into  $\text{H}_2\text{O}$  and  $\text{CO}_2$ .



This  $\text{CO}_2$  is free to mix with air.

Benefits of using degasser are:

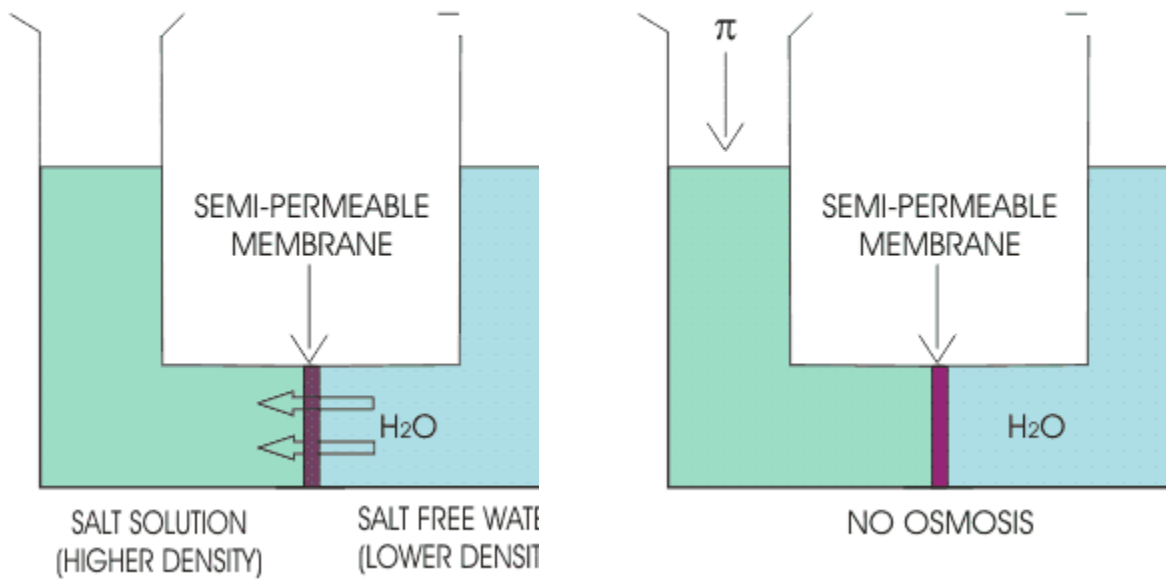
(1) It removes the carbonic acid and other gases mixed with water by simple physical method & thereby reduce the chances of corrosion.

(2) It saves the resins which are very costly chemicals and thereby improves the economy of boiler feed water treatment process.

The  $\text{H}_2\text{CO}_3$  free water is now collected in degasser sump and then pumped to anion exchange resin inlet.

## Reverse Osmosis Plant (RO Plant)

Like demineralization plant there is another stage of water treatment which is known as reverse osmosis plant. RO plant uses the process known as reverse osmosis to produce salt-free water. The theoretical aspect is described below:-



Osmosis is a process in which only the solvent molecules pass through a semi-permeable membrane from higher solvent density to lower solvent density (i.e. from solution of lower density to the solution of higher density).

Osmotic pressure:- It is the minimum pressure that should be applied on the higher density solution so that no osmosis takes place through the semi-permeable membrane is called the osmotic pressure ( $\pi$ ).

$$\pi = iCRT$$

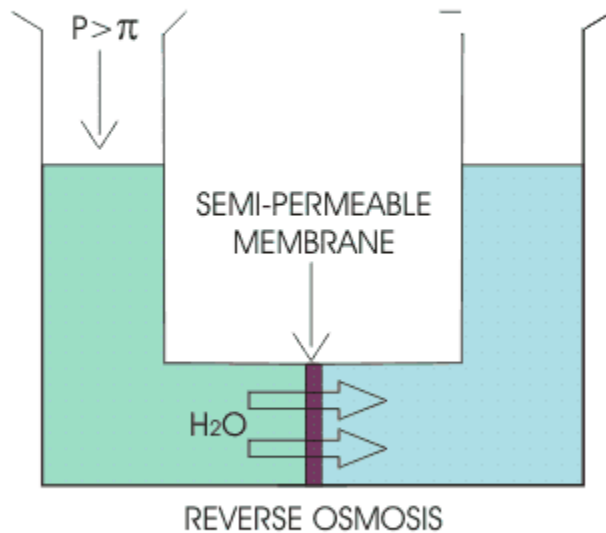
Where,

C is concentration of solution,

R is universal gas constant,

T is temperature in Kelvin scale,

$i$  is van't Hoff's factor, different for different solutions.  $i = 1$  for infinitely dilute solution. Hence osmotic Pressure is a function of temperature.



### Reverse Osmosis

On the higher density solution (lower density solvent) if a pressure ( $P$ ), greater than osmotic pressure ( $\pi$ ) is applied then the solvent molecules pass through the semi-permeable membrane from higher density solution to lower density solution. This phenomenon is called reverse osmosis. This one important stage for boiler feed water treatment process.

## Reverse Osmosis Plant

In RO plant using reverse osmosis phenomenon salt-free water is taken out from raw water after the sand filtration. Purity of the salt-free water depends on effectiveness of the permeable membrane.

The layout of a typical Reverse Osmosis Plant is given below



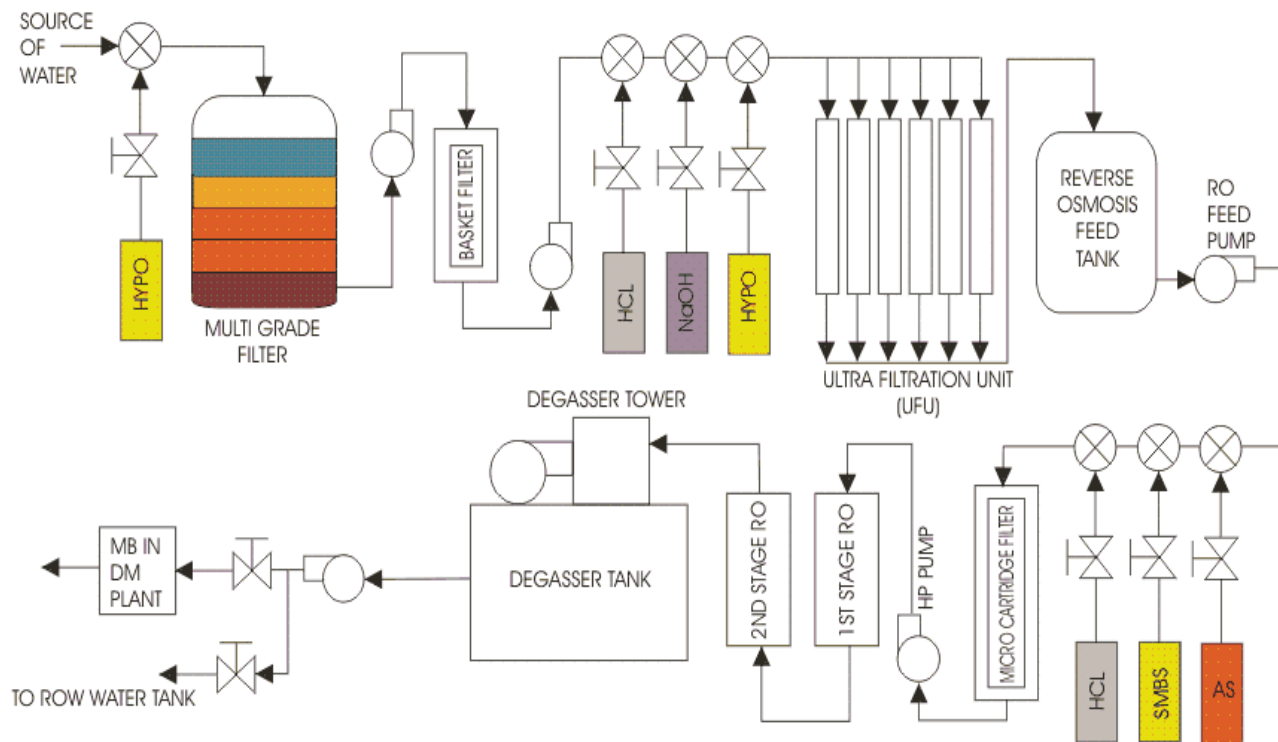


Fig: Reverse Osmosis Plant Layout

Steam air pre-heater require some steam which will reduce the efficiency of the power plant.

The procedure is described below:

- (1) Sodium hypochlorite( $\text{NaOCl}$ ) is injected to raw water to kill the algae or bacteria present in the raw water. Otherwise they may cause harm to the multi grade-filter (MGF).
- (2) The multi-grade filter is the primitive type of filter where sand, stone-chips, stones are used in stacks to remove the large size suspended particles from the raw water.
- (3) The net filter again removes medium-size suspended particles, where the raw water passes through the net minute vents.
- (4) Then by ultra-filtration very small suspended particles are removed. After long usage of ultra-filtration unit, it requires back-wash, and then it is back-washed with water & three chemicals, viz.  $\text{HCl}$ ,  $\text{NaOH}$  &  $\text{NaOCl}$  (Sodium Hypochlorite).  $\text{HCl}$  Removes iron by dissolving it. It also removes the basic salts those are rejected on UFU.  
 $\text{NaOH}$   $\leftarrow$ ; It helps to remove acidic salt.  
 $\text{NaOCl}$   $\leftarrow$ ; To kill algae and bacteria inside the UFU.
- (5) After ultra-filtration the water is stored into RO feed tank & then pumped with RO feed pump of Reverse Osmosis Plant. In the channel the water is mixed with  $\text{HCl}$  (for pH controlling,

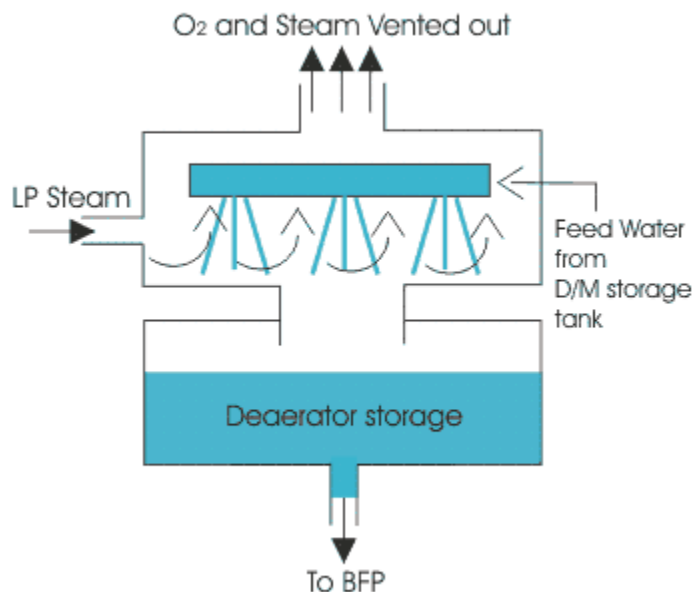
as the water coming from RO plant or RO permeate water should have pH around 6.0) and SMBS (sodium meta bi-sulphate)  $[\text{Na}_2\text{S}_2\text{O}_5]$ . Due to the presence of sodium hypochlorite the water is chlorinated. To remove excess chlorine SMBS is used. If excess chlorine is not removed then the semi-permeable membrane may get damaged. It is also mixed with anti-scaling reagent (AS), which reacts with those chemicals which form scale inside the channel.

(6) Then the water is passed through micro-cartridge filter (MCF) which removes the other suspended particles & the precipitate formed by the reaction of anti-scaling reagent with the scaling chemicals.

(7) In the this stage of boiler feed water treatment the water is fed to RO unit by H/P pump, where after successive filtration by 1<sup>st</sup> & 2<sup>nd</sup> stage RO it is fed to degasser unit.

(8) After degasification the water is passed through D/M plant MB (mixed bed) resin & stored into D/M water storage tank.

## Deaerator



Deaerator is a contact type open heater in which dissolved oxygen in the feed water is removed as much as possible by mechanical means. Gases move from higher partial pressure to lower partial pressure. Partial pressure of oxygen in air is high (as air contains almost 21% oxygen by volume) than the partial pressure of dissolved oxygen in feed water. Hence, by simple mechanical means it is not possible to eliminate the dissolved oxygen from water.

Hence, in deaerator the feed water is heated by LP or VB steam (pressure:  $2.5 - 3.5\text{kg/cm}^2$ , temperature:  $140^\circ\text{C}$ ). Due to heating the partial pressure of dissolved oxygen in feed water increases and solubility decreases to considerable amount. Then by mechanical means dissolved

oxygen is released in air. Hence Deaerator is another very important part of boiler feed water treatment plant.

The mechanical means is same as that of in degasser. But instead of air, LP steam is blown from bottom to top and feed water is poured from top to bottom.

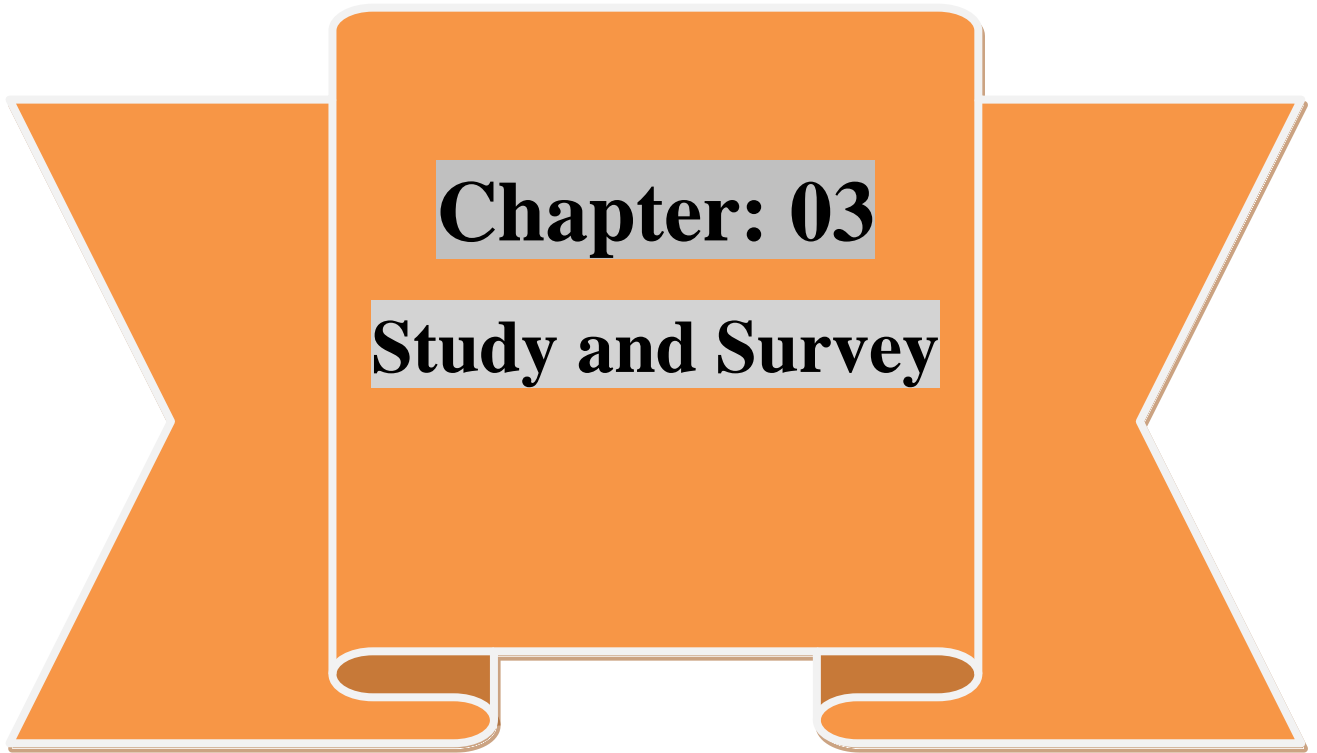
Deaerator also serves as header, to provide a net positive suction head (NPSH) to the boiler feed pumps (BFP) and here by protects the BFPs from any damage due to vapor lock and cavitations.

### Advantages & Disadvantage of demineralization process :

#### Advantages :

1. Very pure water can be obtained .
2. Improved aesthetics and rugged design.
3. User friendly, low maintenance and easy to install.
4. Simpler distribution and collection systems.
5. Quick availability.
6. Very easy to install.
7. Less power consumption
8. Durable
9. Economical
10. High shelf life

Disadvantage: Very expensive

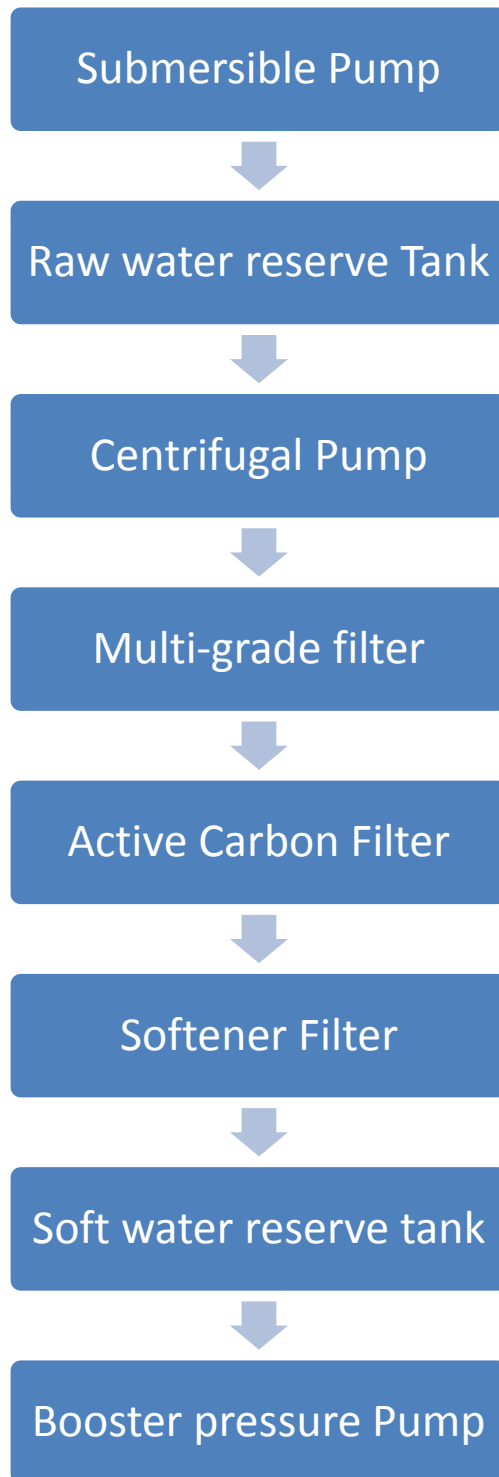


**Chapter: 03**  
**Study and Survey**

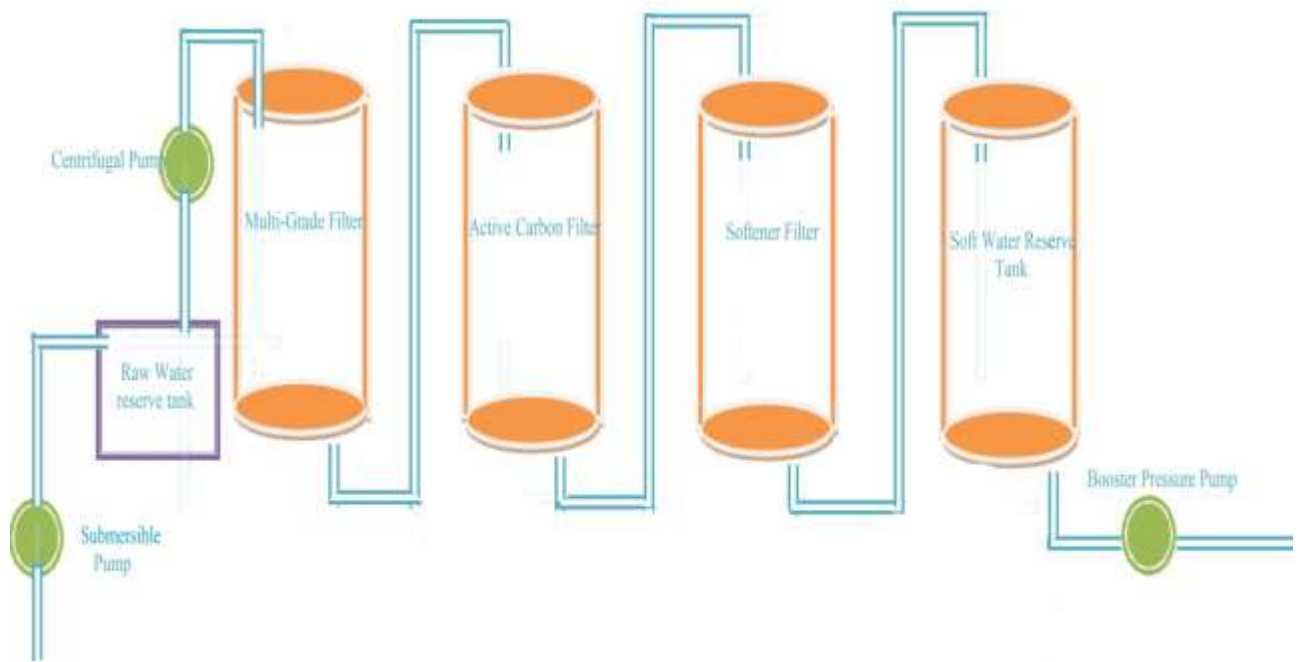
### 3. Study and Survey

#### 3.1. Knit Concern Group:

##### 3.1.1. Water Treatment Flow Chart:



### 3.1.2. Diagram:



### 3.1.3. Parts of Water treatment system:

1. **Submersible Pump:**

This Pump pulls water from underground.

2. **Raw water reserve Tank:**

This tank reserves the raw water which was pulled out by Submersible Pump.

3. **Centrifugal Pump:**

This Pump supplies the raw water from raw water reserve Tank to Multi-grade filter.

#### 4. Multi-grade filter:

This filter vessel consist:

Sand :4600kg

Gables :800kg

Pebbles-II :750kg

Pebbles-I :850kg

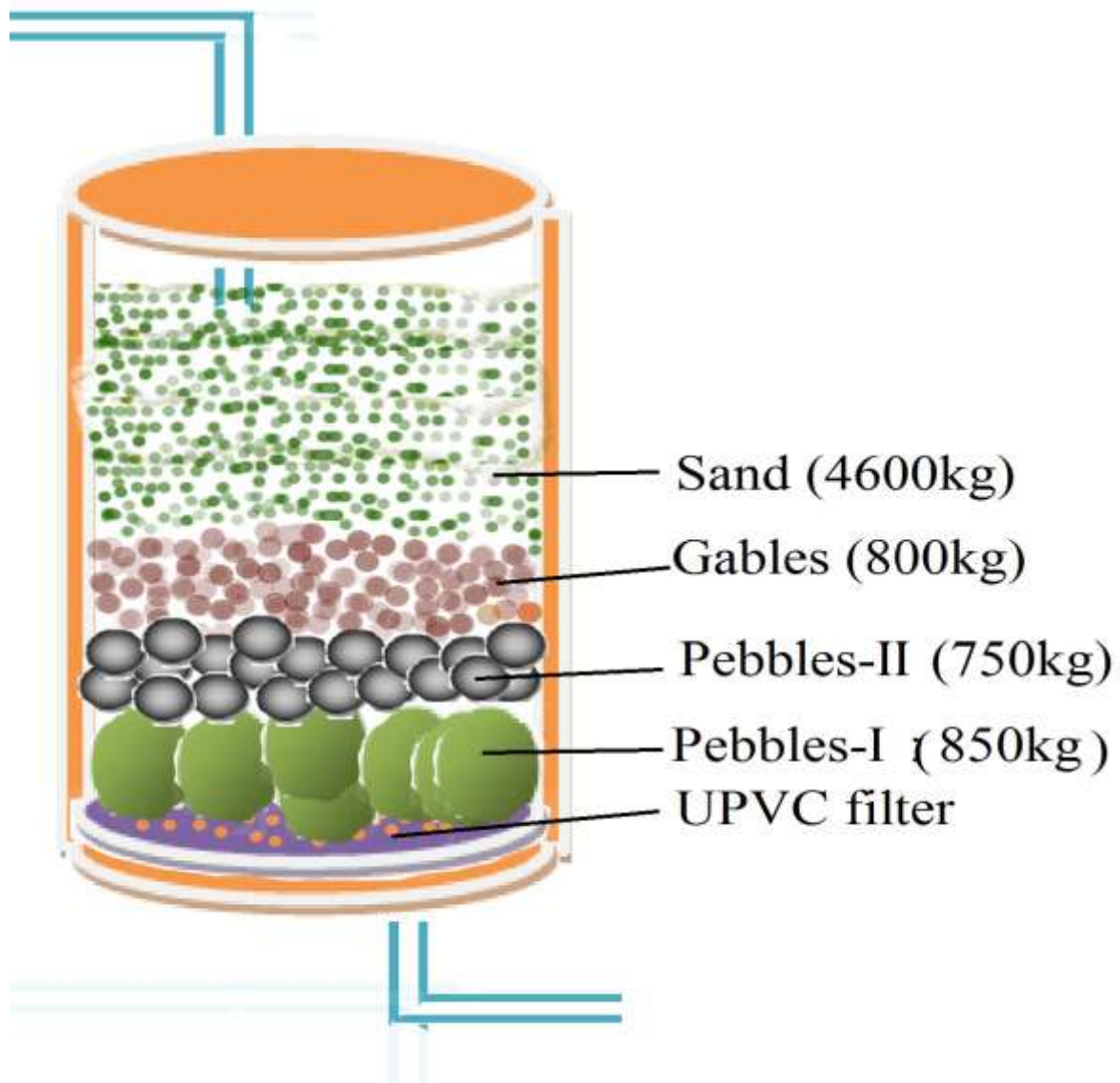


Fig: Multi-grade filter

## 5. Active Carbon Filter:

This filter vessel consist:

Carbon : 1200kg

Sand : 4600kg

Gables : 800kg

Pebbles-II : 750kg

Pebbles-I : 850kg

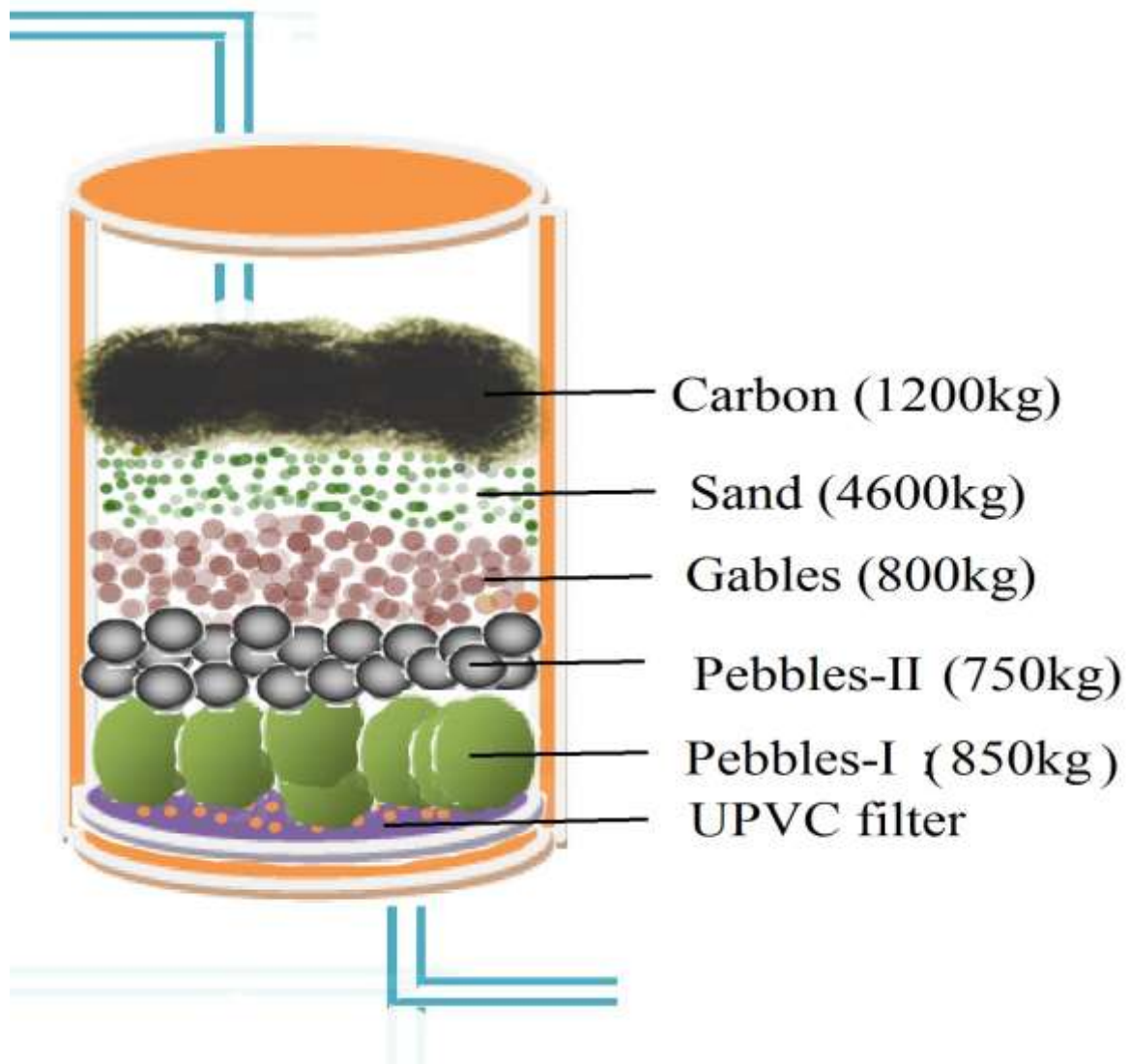


Fig: Active Carbon Filter



#### 6. Softener Filter:

This filter vessel consist sand and 7000kg cat-ion resin.

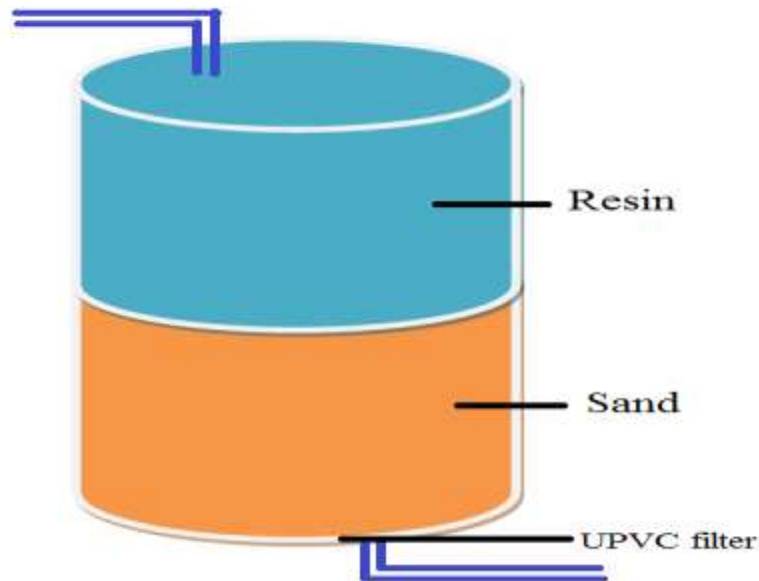
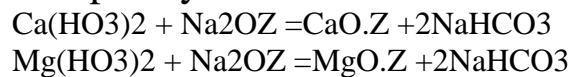


Fig: Softener Filter

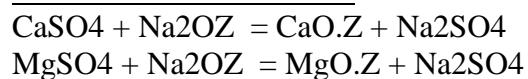
7. **Soft water reserve tank:** This tank stores the soft water.
8. **Booster pressure Pump:** This Pump supplies the soft water from Soft water reserve tank to where needed with pressure.

#### 3.1.4. Chemistry involved:

##### Temporary hardness

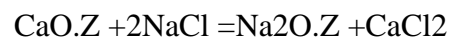


##### Permanent hardness



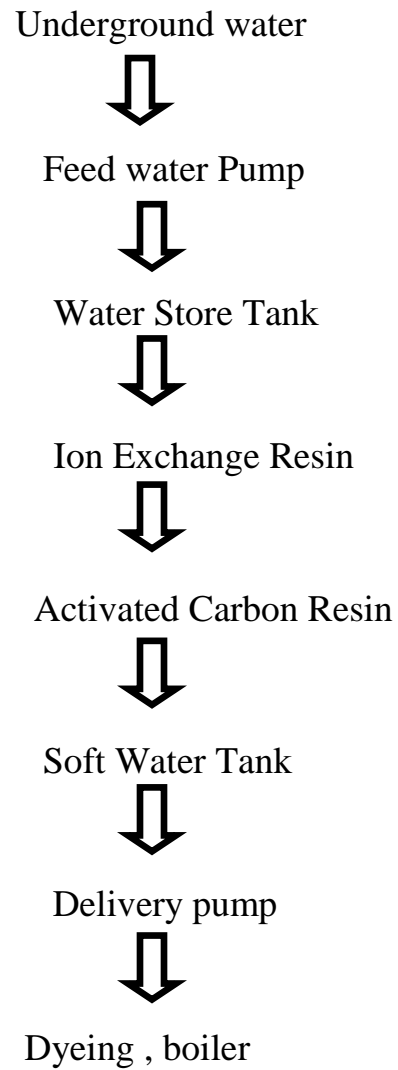
Where Z =  $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$

In this tank after every 15 minutes around 3002kgs of salt is added to regenerate the resin by following reaction

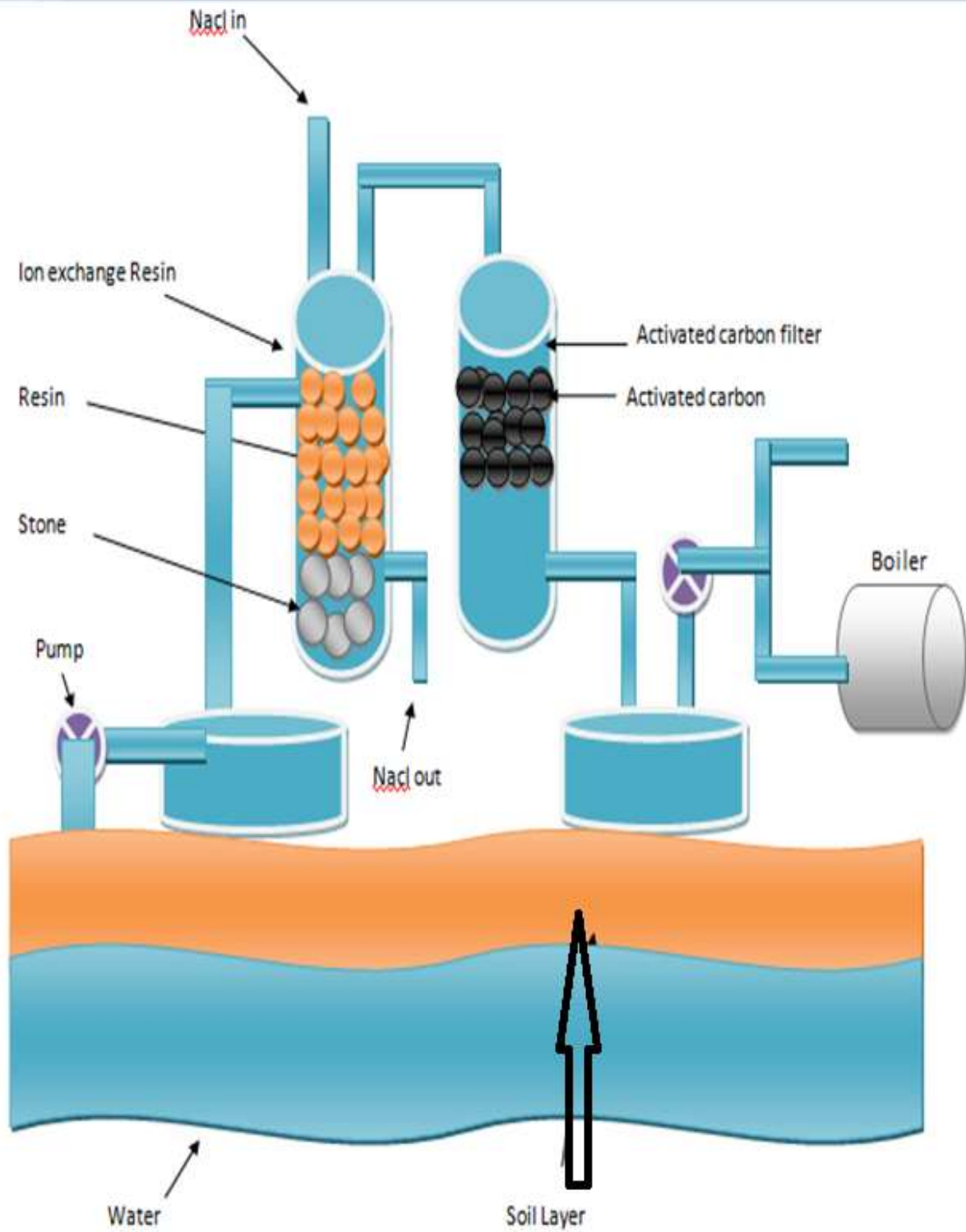


## 3.2. Hamid Fabrics Ltd

### 3.2.1. Flowchart



### 3.2.2. Diagram



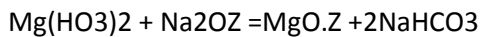
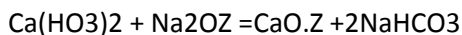
### 3.2.3. Main Functional Parts

1. Suction Pipe ; It penetrates through earth surface and draws water from underground
2. Suction Pump ; It uses motor and air pressure to suck water
3. Hard water tank ; Here hard water is stored for formal use and emergency
4. Ion –exchange Resin; Here main softening is done . Here ions of resin are exchanged with metal ions of hard water and thus water is purified
5. Outlet pipe ; Through this pipe water is exhausted
6. Activated Carbon filter ; Here additional impurities such as dirt is removed
7. Soft Water Tank ; Here soft water is stored and then supplied to boiler and dyeing industry

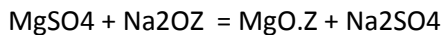
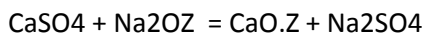
### 3.2.4. Working Procedure

1. At first water is sucked from underground by suction pump
2. Then water is stored in a water tank
3. Then water enters in a sand and stone filter and purified from dirt dust and sediments and un dissolved solid
4. Then water enters in a set of ion exchange resins where hard water is purified by exchanging its metal ions like calcium ions and magnesium ions with sodium ions of ion exchange resin where following reaction occurs

Temporary hardness

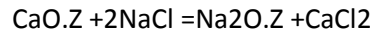


Permanent hardness



Where  $Z = \text{Al}_2\text{O}_3.\text{SiO}_2.\text{H}_2\text{O}$

In this tank after every 15 minutes around 3002kgs of salt is added to regenerate the resin by following reaction



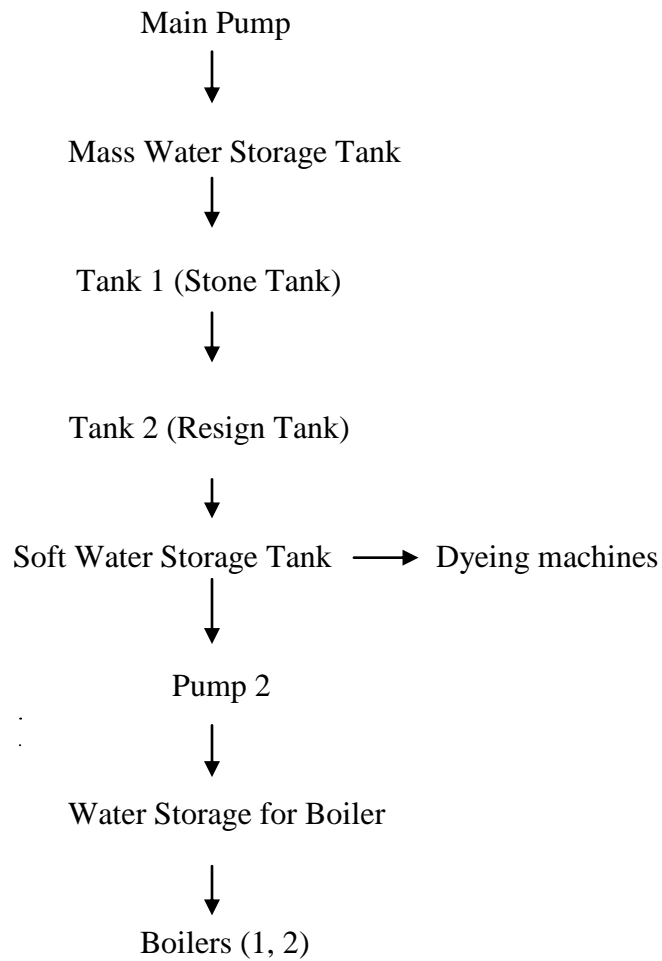
5. Then water enters activated carbon resin where water is further purified
6. Then water is kept on a soft water tank
7. From this soft water tank water is pumped to supply the water to boiler and dye house

### 3.2.5. Water quality

Parameter	before softening	after softening
PH	7.5-8	6.9-7.2
Hardness	200 PPM	5 PPM

### 3.3. R.L. Tex Limited

#### 3.3.1. Flow Chart of Water Treatment Plant (WTP):



### 3.3.2. Description of main Functional Part:

#### Main Pump:

- I. Main pump is used for store the raw water for use in dyeing industry.
- II. Main pump gives continuous flow of water.
- III. Capacity of main pump is 10-11 lack litre.

#### Mass water storage:

- I. It is a house where total water is stored primarily.
- II. It is also a reservoir for continuous flow.
- III. From here water goes through tank 1(Stone Tank) & Tank 2 (Resign Tank) for water softening.

#### Tank 1 (Stone Tank):

- I. This tank contains three layers of stone.
- II. In first layer or in upper layer contains sand and small size of stones.
- III. In second layer medium size of stones are stored.
- IV. In third layer or lower layer large size of stones are stored.
- V. Water passes from the upper layer to lower layer.
- VI. Those three layers primarily remove water impurities.
- VII. Then by using valve water go to second tank.

#### Tank 2 (Resign Tank):

- I. Tank 2 contains resign, Zeolite stone, medium size stone, large size stone.
- II. The water from tank 1 passes through tank 2.
- III. At first water passed through resign, then from Zeolite stone, then from medium and large size stone.

#### Alternative tank (3, 4):

- I. Alternative tank 3 does as same as tank 1.
- II. Alternative tank 4 does as same as tank 2.
- III. Both tank 3, 4 maintains continuous supply of water.

#### Soft water storage tank:

- I. Soft water comes from tank 2, tank 4.
- II. This water storage tank reserves the total soft water.
- III. Soft water storage tank supply water to dyeing machine and boiler.

#### Dyeing machine:

- I. Soft water used for rinsing, scouring, bleaching, dyeing and softening process.



### Soft water storage tank for boiler:

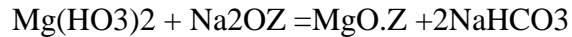
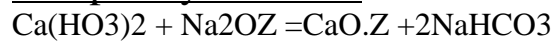
- I. This tank stores water for boiler use.
- II. Soft water supplied by two automatic pumps to boiler 1, 2.

### Boiler (1, 2):

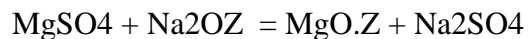
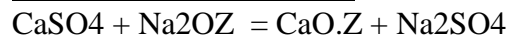
- I. Boiler use water for steam generation.
- II. Soft water is used for low corrosion formation in boiler.

### **3.3.3. Chemistry involved in WTP:**

#### Temporary hardness

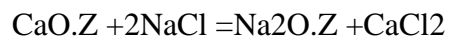


#### Permanent hardness

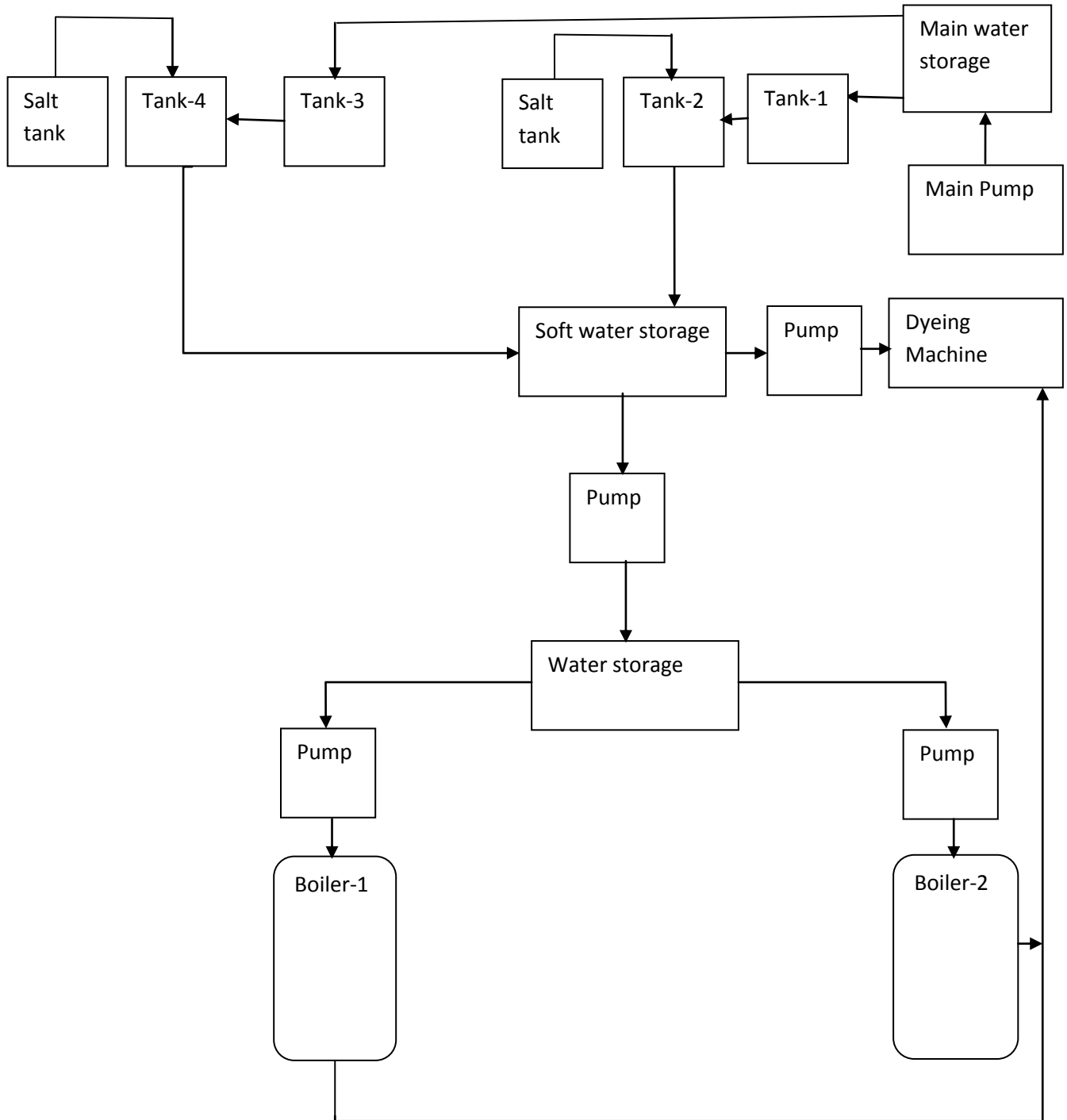


Where Z =  $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$

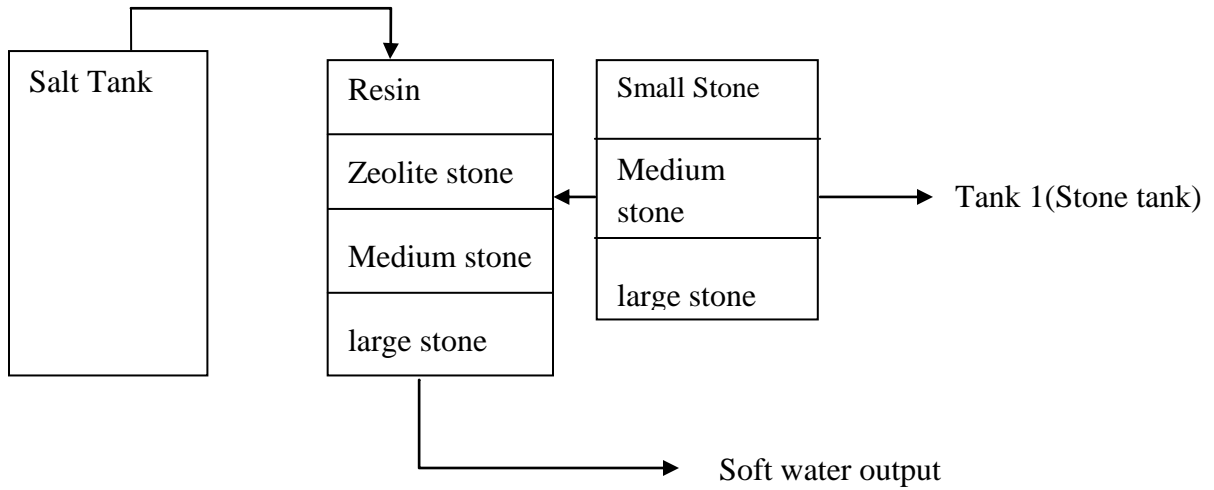
In this tank after every 15 minutes around 3002kgs of salt is added to regenerate the resin by following reaction



**3.3.4. Layout plan of WTP of R.L. Tex Ltd.:**



**3.3.5. Internal structure of tank 1 (stone tank), tank 2 (resin tank):**



### **3.4. Hardness Testing for Three industry:**

#### **Water Hardness Test**

**Name of Hardness Tester:** Water Hardness Test Kit.

#### **Water Hardness Test:**

Required water= 5 ml.

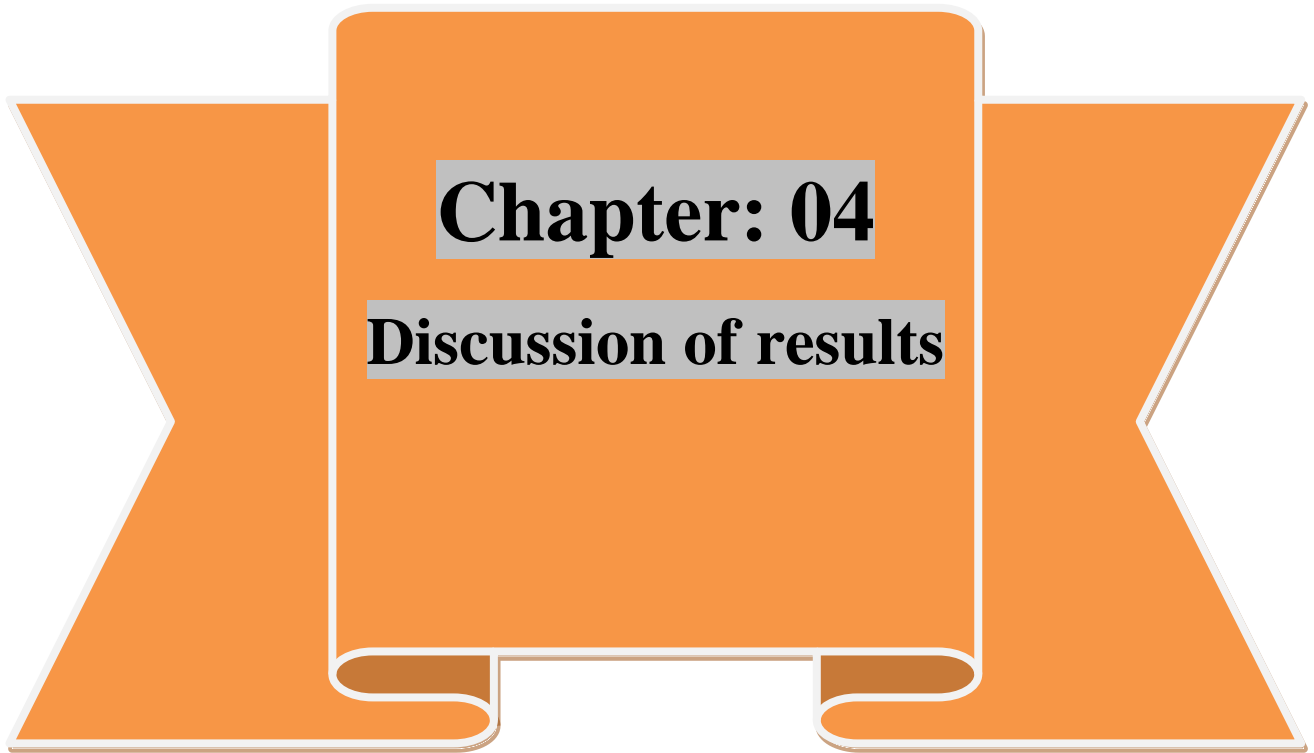
Buffer solution= 5 drops.

Indicator (Red) =1 drop.

EDTA Solution=required drops.

#### **Procedure:**

- I. At first we take 5ml water which needs to be test.
- II. Then we take 5 drops of buffer solution on to the water.
- III. Then we take 1 drop of indicator (red) in water.
- IV. Then the water turned in to red color.
- V. Then we add EDTA solution into water.
- VI. The amount of EDTA required to make the water blue is multiplied by 300.
- VII. The amount will be the hardness.



**Chapter: 04**

**Discussion of results**

#### 4.1. Input & Output Quality of water:

##### a) Knit Concern Group:

Hour	Input water (PPM)	output water (PPM)
1 <sup>st</sup>	350-400	0
2 <sup>nd</sup>	350-400	0
3 <sup>rd</sup>	350-400	0
4 <sup>th</sup>	350-400	0
5 <sup>th</sup>	350-400	5
6 <sup>th</sup>	350-400	20
7 <sup>th</sup>	350-400	45-50

##### b) R.L. Tex Limited:

#### **Initial Hardness:**

In R.L. Tex Limited 170-250 ppm is present.

#### **After Hardness:**

In R.L. Tex Limited 4-5 ppm is present.

##### c) Hamid Fabrics Ltd:

#### **Initial Hardness:**

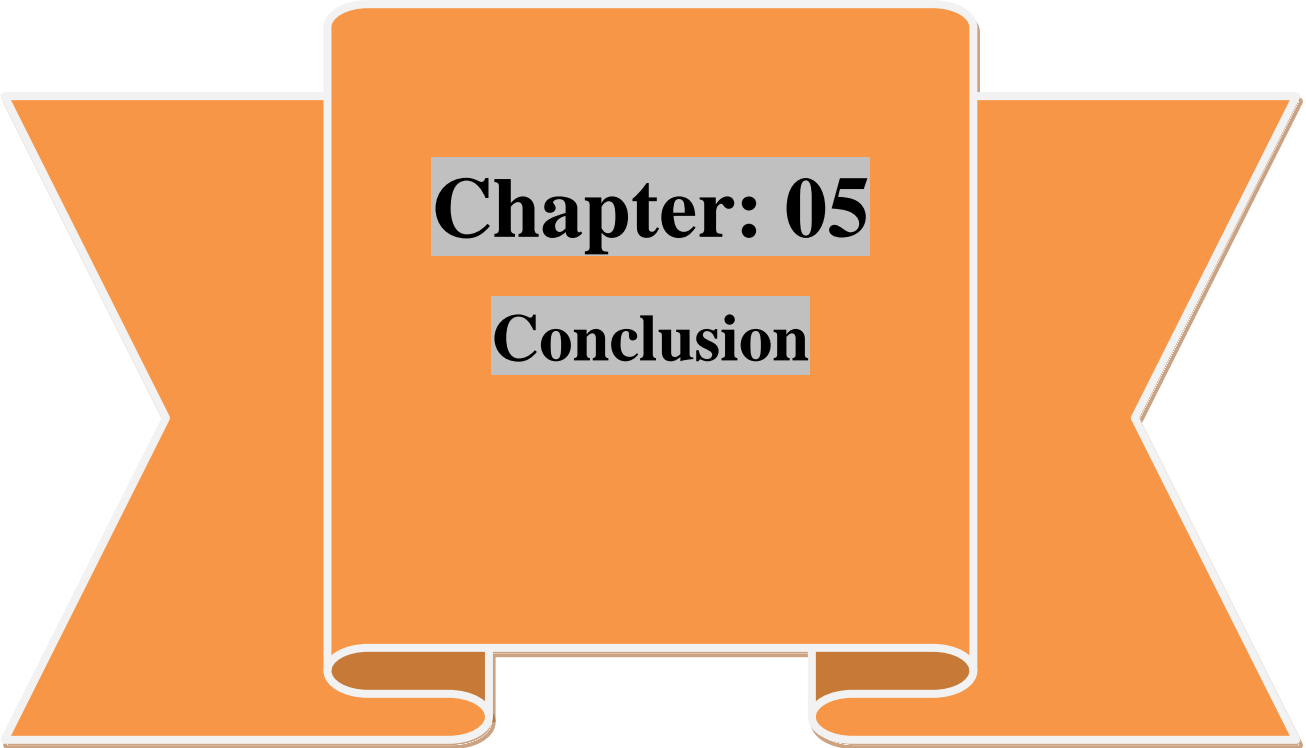
In R.L. Tex Limited 200 ppm is present.

#### **After Hardness:**

In R.L. Tex Limited 5 ppm is present.

## 4.2. Difference

Serial No.	Parameter	Knit Concern	Hamid Fabric Ltd	R.L. Tex Ltd
1	1 <sup>st</sup> vessel consist	Multi-grade filter: This filter vessel consist: Sand :4600kg Gables :800kg Pebbles-II :750kg Pebbles-I :850kg	Sand and Stone Filter sand : 3000 Kgs Gables : 4200 Pebbles I and II : 1550 kgs	1 <sup>st</sup> filter: This filter vessel consist: Sand :3600kg Gables :600kg Pebbles-I :650kg
2	2 <sup>nd</sup> vessel consist	Active Carbon Filter: This filter vessel consist: Carbon : 1200kg Sand : 4600kg Gables : 800kg Pebbles-II : 750kg Pebbles-I : 850kg	Ion Exchange Resin containing zeolites : 1300kgs	2 <sup>nd</sup> Filter: This filter vessel consist: Resin : 800kg Sand : 1200kg Gables : 500kg Pebbles-I : 850kg Zeolite stone : 450 kg
3	3 <sup>rd</sup> vessel consist	Softener Filter: This filter vessel consist sand and 7000kg cat-ion resin.	Activated Carbon filter	N/A
4	Raw water reserve Tank	Yes	Yes	Yes
5	Soft water reserve tank	Yes	Yes	Yes
6	Input hardness	350-400	150-200	170-250
7	Output hardness	Initial: 0ppm Final: 45-50ppm	Intitial ; 5 PPM Increased upto : 40	Initial: 5ppm Final: 35-45ppm
8	Run time	7-8 hour	8 hours	6 hours
9	Softened water amount	0.2 million litre	0.23 million litre	0.13 million litre





In textile wet processing all the process requires water. Without it no process can be carried out. It is estimated that for processing 1kg of textile at least 80-100 liter of water is required. This information is enough to signify the importance of water in textile wet processing. But the problem is the water used in industries originally contains many impurities that hamper its use in different processes. Among all the impurities hardness is most dangerous for textile production. Water treatment plant successfully removes water hardness. Therefore Water treatment plant is one of the most important unit in textile wet processing technology that determines the result next processes. Water quality is a determining factor in textile finishing section. Water treatment plant ensures best water quality and perfect finishing for textile material. As fibres are highly sensitive to the quality of water used during processing it is highly recommended to avoid the use of hard water at any cost. Removal of metal ions results in better pretreated fabric, uniform dyeing, accurate color reproduction and ensure predefined properties after finishing. Thus it helps to gain better dyeing efficiency, less dye waste, proper pre treatment and finishing. It also makes the overall dyeing process economic and thus helps to gain maximum profit. Water treatment plant also preserves better boiler condition even after being used for a long period. Therefore proper attention should be given to get most benefit out of a water treatment plant. In textile dyeing section it is highly recommended to use water of a predefined quality which is free from hardness, odor and other impurities. There is a standard for the quality of dye house water that every industry must maintain if it wants to get desired quality. For getting best result it is required to collect input water from a source with less amount of impurities so that it takes less time and money for purification process. Water treatment plant has to be environmental friendly therefore waste from water treatment plant requires further processing in ETP. Water treatment plant is the first in a series of modern textile finishing system. Without it no process will get desired end result. Hard water must be softened before application in any process. Otherwise it creates a lot of problems that hampers production badly. So if we want to survive the challenge to produce quality textile product without hampering environment we must use an efficient water treatment plant that will generate best quality soft water for all the coloration and finishing processes.

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