Chemical Process Utilities
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Lecture - 12
Water

Welcome to the new chapter of water under the edges of chemical process utilities. We have discussed that water is an integral part of the utility system in any chemical process operation. We can see that there are so many uses of water, whether slurry preparation, boiler feed water, or sometimes it gives you an idea about the steam. So, water has enormous uses, and moreover, water finds its way into the chemical processes with respect to the utility just because its abundance in availability, cheap etc.

Water is also used as a heat transfer media in some cases. So, let us look at what different types of topics we are going to cover in this particular lecture. First, we will have a brief introduction.

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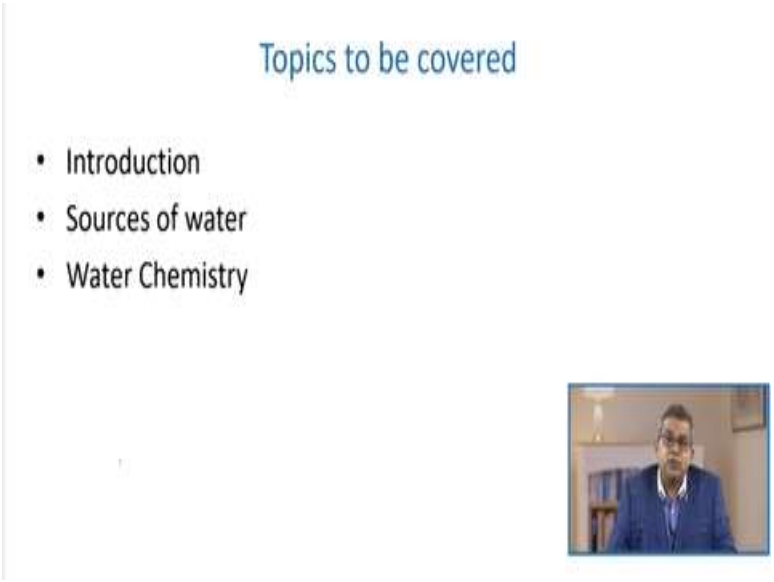

Then we will discuss various sources of water and water chemistry. The sources of water are important because of the large spectrum of water or large sources of water available as on date, ground water, surface water, subsurface water, sea water, well water, etc. So, we will discuss all these sources with respect to their availability with respect to the quality of the water.

Then since water has this n number of sources, then definitely the different types of ingredients, different types of impurities etc., are also enormous in the water source like river water or spring water or lake water is entirely different from what the water available in the seaway sea source. So, in this particular aspect, we will discuss the chemistry of water chemistry because, ultimately, chemistry knowledge is important.

Since we cannot use water as such, even if we are using the drinking water, it needs to be purified before it becomes potable water. Similarly, if we are using the water as a source of dilutant, then, in that case, we need to remove certain impurities. So, the chemistry of knowledge about the chemistry of water is quite essential. When we go for the introductory part, we all k that pure water is colorless, odorless, and tasteless.

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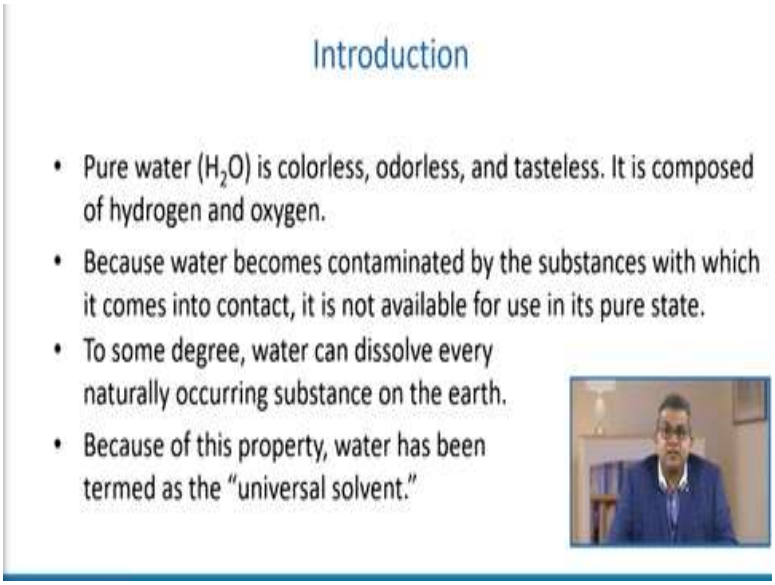

And there is basic chemistry composed of hydrogen and oxygen. Because water becomes contaminated by the substance with which it comes into contact, it is not available for use in its pure state. One of the reasons, just for the sake of an example, is that water is coming from the Himalayas or take the Ganges water then it is passing through various surfaces, and it may get contaminated it may have we have certain other impurities.

So, it may not be useful for the variety of purposes we discussed earlier. So, therefore it is said that it is not available for use in its pure form. To some degree, we can say that water can dissolve

every naturally occurring substance on the earth because it is a very good solvent. Because of this property of solvency, water is termed a universal solvent and sometimes it is quite useful and sometimes quite disadvantageous.

We will discuss this particular aspect in due course of time. Although solvency power is beneficial to humankind, it poses a major threat to industrial equipment.

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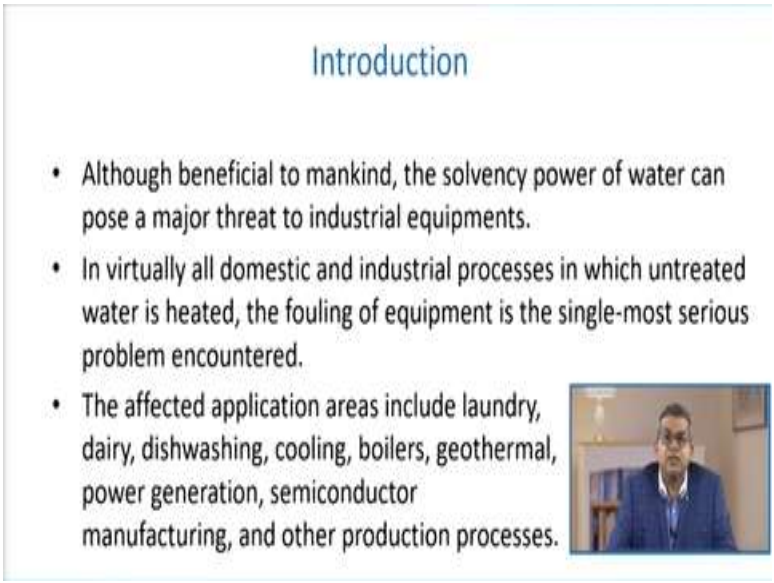

In virtually all domestic and industrial processes in which untreated water is heated, the falling of equipment is the most serious problem encountered. In this way, the energy efficiency or economic aspects of those equipment are negative. So, let us have a brief look at the affected application area. These may be included laundry, dairy, dishwashing, cooling, boiler feed water, geothermal power generation, semiconductor, and other production processes.

So, this can badly affect the impurity of the water, or the hardness of the water can badly impact all these operations. These are the generalized operation. We will discuss some specific operations in due course of time.

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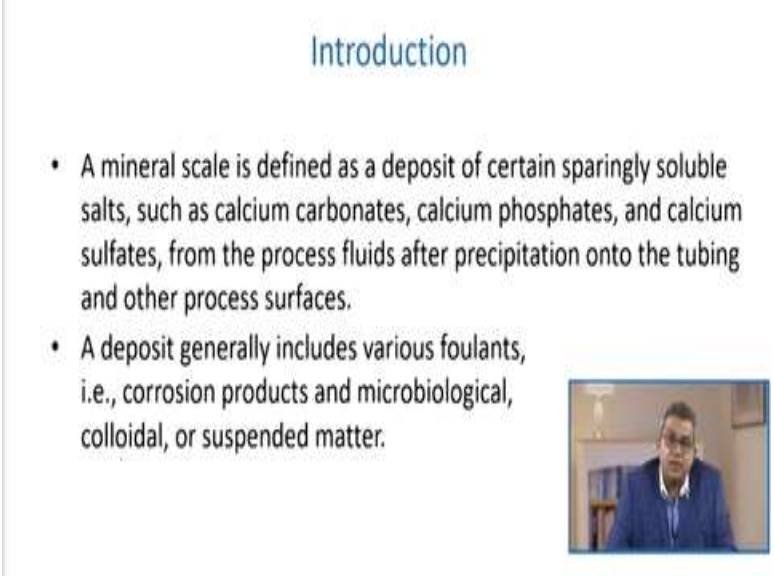

A mineral scale usually is defined as a deposit of certain sparingly soluble salts, such as calcium carbonates, calcium phosphates, and calcium sulfate, from the process fluids after precipitation into the tubing and other process surfaces. So, over time, it may get deposited or the inner surface and the energy efficiency problem with the malfunctioning of the equipment may occur.

So, these deposits generally include various foulants like corrosion products, and microbiological colloidal or suspended manner.

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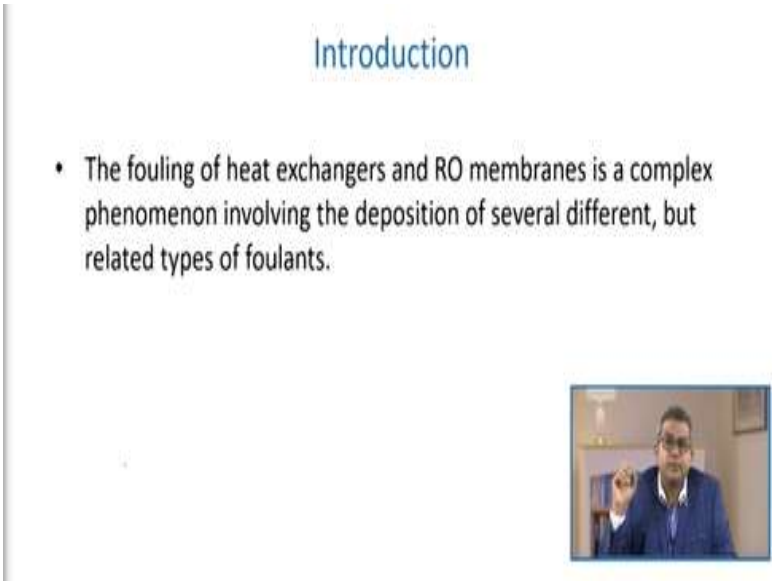

One of the examples is the fouling of the heat exchanger or reverse osmosis membrane; usually, it is a complex phenomenon. This involves the deposition of several different but related types of

foulants. So, we need to look into whether, if we take the reverse of the osmosis membrane, different types of fouling may create a problem, and the efficiency of these membranes may deteriorate over time.

So, this affects the system's energy efficiency and creates an economic problem, and sometimes replacement of these membranes, etc, may take place. So, we need to address such kind of inherent property of the water. Since we briefly discussed water, we all know that water is extremely important for chemical processes. So, let us have a look at the different sources of water.

Almost 97% of the earth is submerged in seawater. But we cannot use the seawater as such. So, the first source we will discuss is the sea water.

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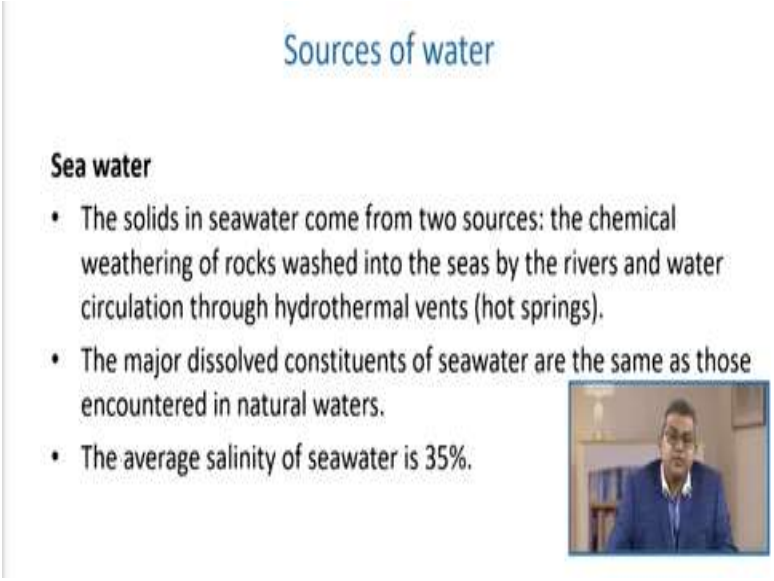

The solids in seawater come from two sources; the chemical weathering of rock washed into the seas by rivers and water circulation through hydrothermal vents that are called the hot spring. The major dissolved constituents of seawater are the same as those encountered in natural waters. So, the average salinity of seawater is almost 35%. This is again very high. Another source of water is lake water.

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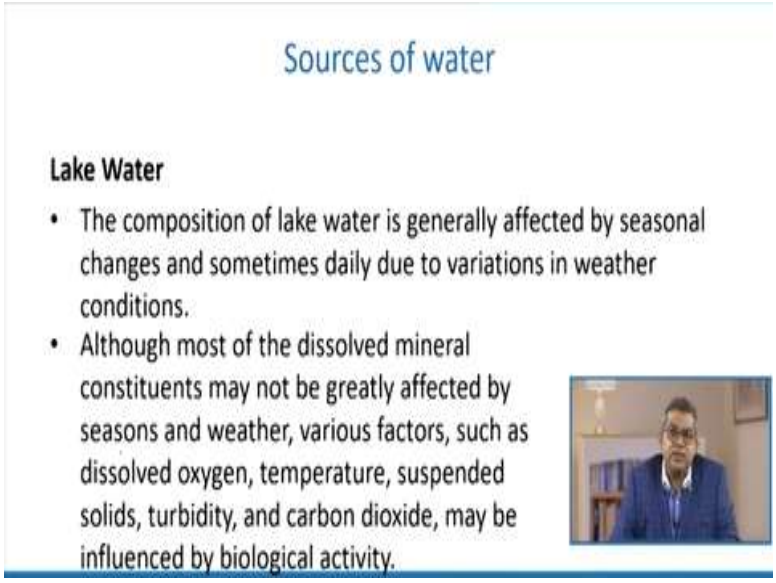

Generally, the composition of lake water is affected by seasonal changes and sometimes daily due to the variation in the weather condition. Above all, the source of water is important in the case of the composition of lake water. Most of the dissolved mineral constituents may not be greatly affected by seasons, weather, and various factors such as dissolved oxygen, temperature, suspended solids, turbidity, and carbon dioxide may be influenced by various biological activities.

So, stagnancy also plays a very vital role because it promotes the biological activity of the lake water. Another is the surface water.

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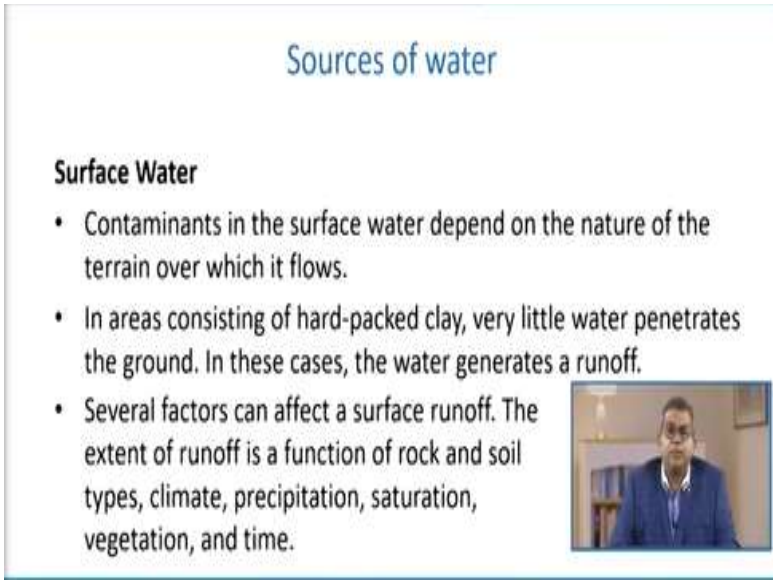

Depending on the nature of the terrain over which it flows, the contaminants in the surface water may be a river, some tributaries of the river, maybe a canal, etc. So, in areas, those who are consisting of hard-packed clay, very little water penetrates the ground. In this case, the water generates a runoff. Although several factors can affect a surface runoff, the extent of runoff is usually a function of rock and soil types, climate, precipitation, saturation, vegetation, and time. So, all these parameters usually pose an effect on the surface runoff.

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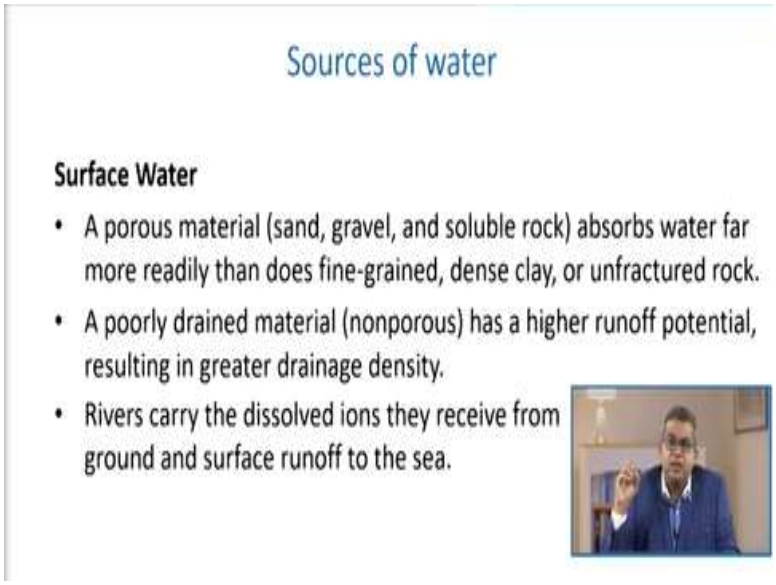

Porous materials like sand, gravel, and soluble rocks absorb water far more readily than fine-grained, dense clay or unfractured rock. A poorly drained material, usually termed non-porous has a higher runoff potential, resulting in greater drainage density. Rivers usually carry the dissolved ions receive from the ground and surface runoff to the sea. Apart from this river, there may be certain other inherent contamination when we are talking about the river.

It may be due to the discharge of Municipal Corporation or some other discharge from small villages, etc. It may also become the contaminated part of those waters when we were talking about the dissolved ions. So these dissolved ions include Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, HCO^{3-}, CO_3^{2-}, PO_4^{3-}, and Cl^{-}. The total dissolved solids in rivers are about 100 milligrams per liter; these figures may vary.

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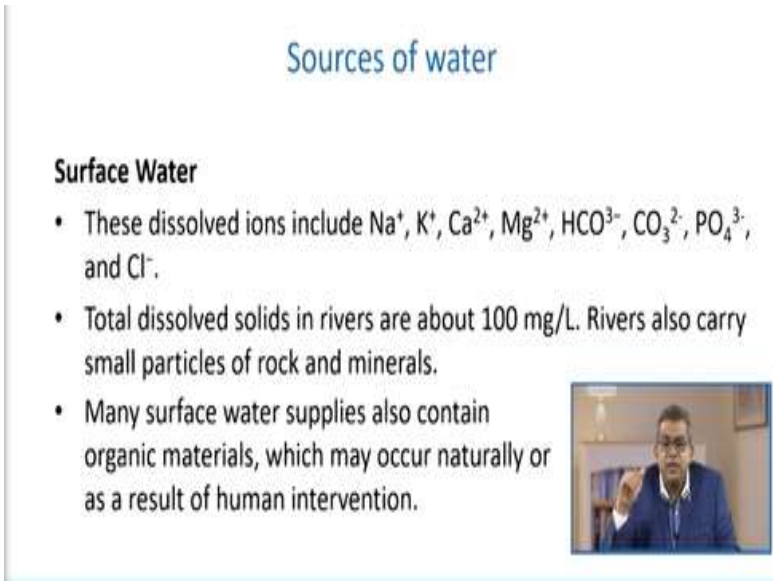

Rivers also carry small particles of rocks and minerals over the period of time that may get the grind, and then we become part and parcel of the surface water. Also, it may become the total dissolved solids or total and dissolved solids or total suspended solids etc. many surface water supplies also contain organic material, which may occur either naturally or as a result of human intervention.

As we discussed, sometimes this river water may get contaminated by sewage may be contaminated by industrial effluents, etc. So, all these things are clubbed and may become contaminants in the river water.

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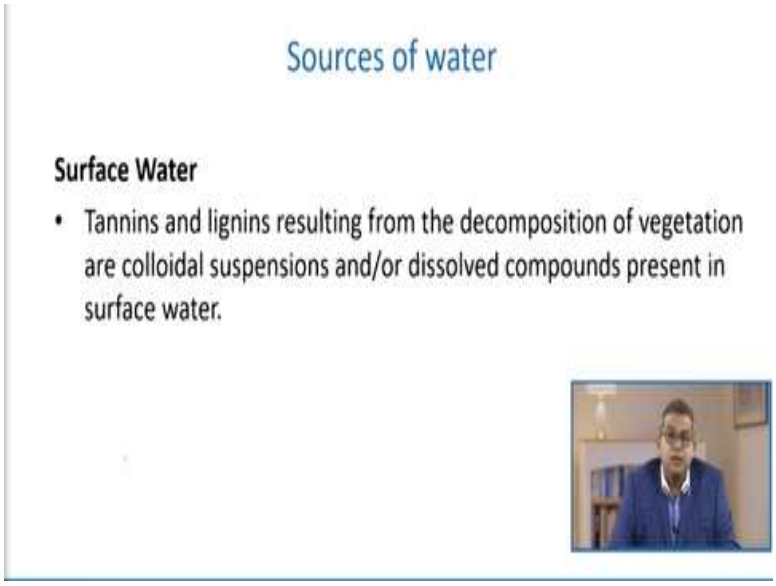

Various kinds of tannins and lignins resulting from the decomposition of vegetations are also the colloidal suspect from the colloidal suspension or the dissolved compound present in the surface water. It may create a problem, and therefore identification and removal of all these are again very important. When we talk about surface water, some animal debris or other debris also become the contaminant part of the surface water.

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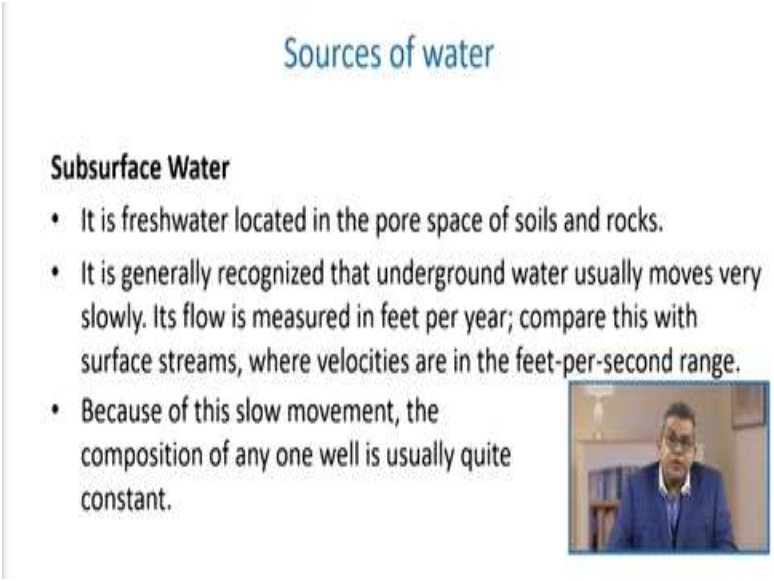

Let us have a look at the subsurface water. It is fresh water located in the pore space of soils and rocks. It is generally recognized that underground water usually moves very slowly. Its flow is measured in feed per year compared with the surface stream, where velocities are in the feet per second range. So, the migration of this water is very slow, or water bodies are very slow.

Because of this slow movement, the composition of any well is usually quite constant. So, this is again you can say it is in one way it is a very plus point that it gives you a dependable supply of water in which you can rest assured or you can stably design the things. Let us go to the water chemistry, and again we will come back about the different sources of water in due course of time.

The impurities in the water can be classified into different categories. So, we have enlisted five broad categories: the dissolved inorganic compound such as bicarbonates, carbonates, sulfates, fluorides of calcium, magnesium, barium, strontium, and a small amount of iron, magnesium, aluminum, and other substances. Number two is the dissolved organic compound such as humic

acid, fulvic acid, tannins, insoluble organic matters such as leaves, dead bacteria, stems and other biological products, and industrial waste.

Third category the gases such as oxygen, nitrogen, carbon dioxide, sulfur dioxide, hydrogen sulphide, methane, absorbed from the atmosphere and subsurface sources. The knowledge and sometimes removal of these gases are essential because if they become the part and parcel of your process, then either may create a problem for the chemical reactions and if used as a source for steam production or a boiler feed water.

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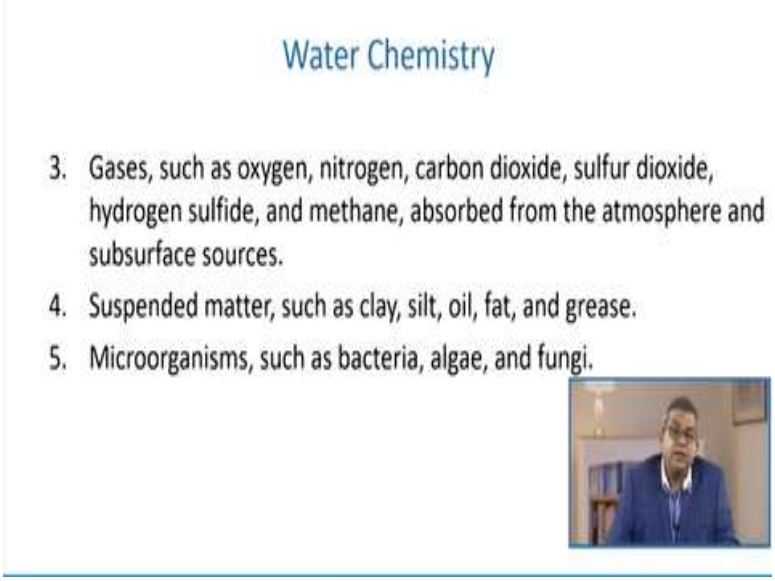

Sometimes, it may create the problem of falling, foaming, etc. We k that foam does not carry any kind of eating value and may hinder further processes. The fourth category is suspended matter such as clay, silt, oil, fat, and greases, and the last category, which is very important, is called the microorganism such as bacteria, algae, fungi, etc.

So, we need to look into this thing, and before processing these waters, we must identify the basic chemistry of the water in question and try to adopt the proper methodology for removing such kinds of impurities if needed. Let us have a look at the physical water chemistry of water. The first one in this category is color because color maybe just because of various kinds of constituents present in the water.

It is a human perception that we always look for colorless water, but if there is some coloring compound, then it is quite obvious that we are not going to accept it.

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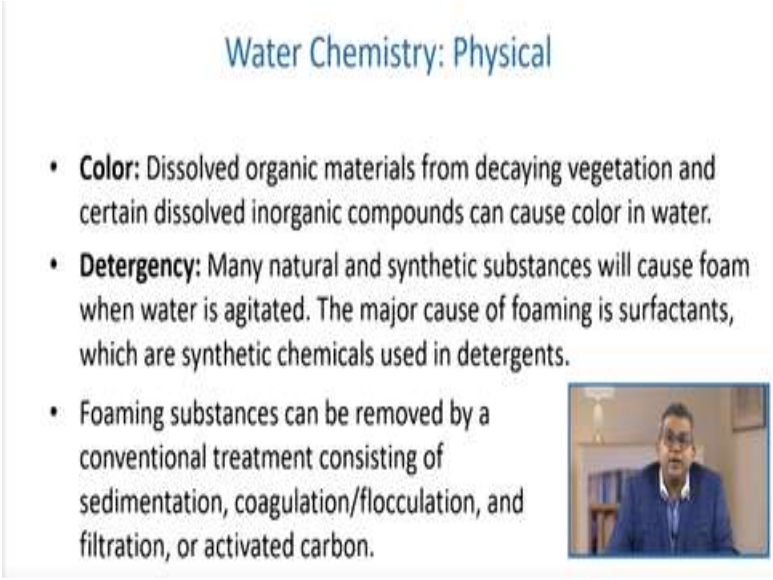

So, the color is dissolved organic materials from decaying vegetation, and certain dissolved inorganic or organic compounds may cause color in the water. Another physical phenomenon is detergency. Many natural and synthetic substances may cause foam when water is agitated. Agitation of water is quite common in the chemical engineering phenomena. The major cause of foaming is a surfactant.

That means the alteration of surface tension or surface energy that synthetic chemicals may usually create is used in detergent. Foaming substances can be removed by a conventional treatment consisting of sedimentation, coagulation or flocculation, and filtration or activated carbon.

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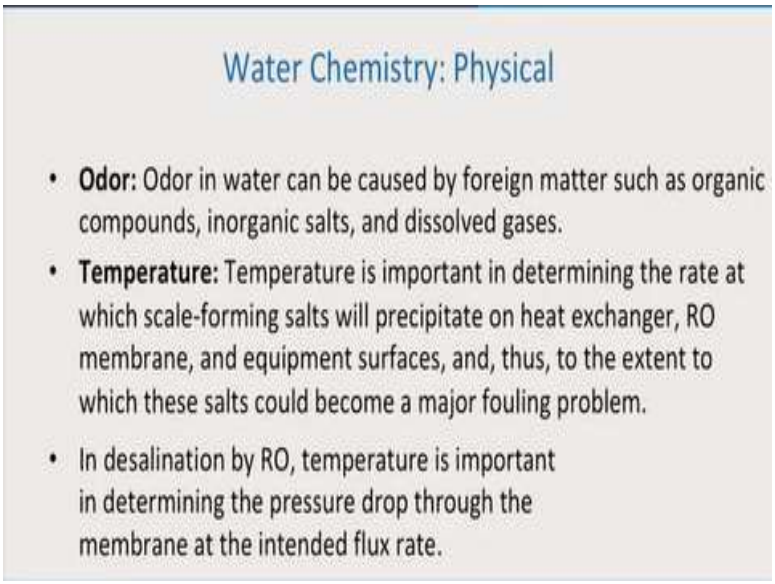

Another very important thing, as we discussed that water is odorless. So, odor in the water can be caused by foreign matter such as organic compounds, inorganic salt, and dissolved gases. So, off-flow off-odor sometimes creates a problem, and sometimes we look into these aspects to prevent the problems in future chemical processes.

Another thing is which we need to look at is temperature. Temperature is important in determining the rate at which scale forming a salt, precipitate on heat exchanger or reverse osmosis membrane or equipment surface and thereby to the extent to which these salts could become a major falling problem. And once are creating the falling problem, then obviously the issue pertaining to the wear and tear issue pertaining to the energy efficiency or economic aspect always come forward.

In desalination by reverse osmosis, the temperature is extremely important in determining the pressure drop at the intended flux rate through the membrane. So, therefore this is again a very important thing which we need to look. Next is turbidity.

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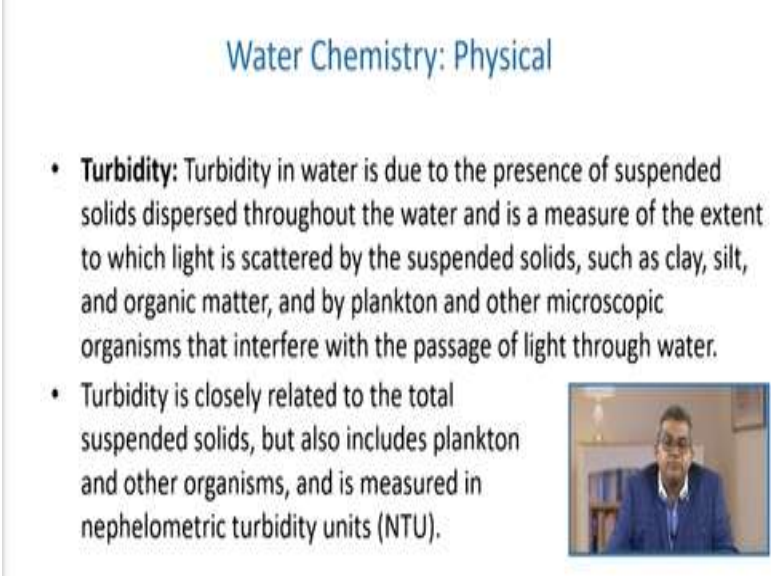

Turbidity in water is usually due to the presence of suspended solid dispersed throughout the water and is a measure of the extent to which light is scattered by the suspended solids such as clay, silt, organic matter by the plankton, and another microscope organism that interfere with the passage of light through water. And above all, this turbidity is closely related to the total suspended solid and includes plankton and other organisms, and is measured in nephelometric turbidity units or referred to as NTU.

So, this is an essential thing because everywhere we talk about the turbidity odor coloring compound again, there is a chemical intervention and this needs to be addressed a priory before we go for any chemical processes.

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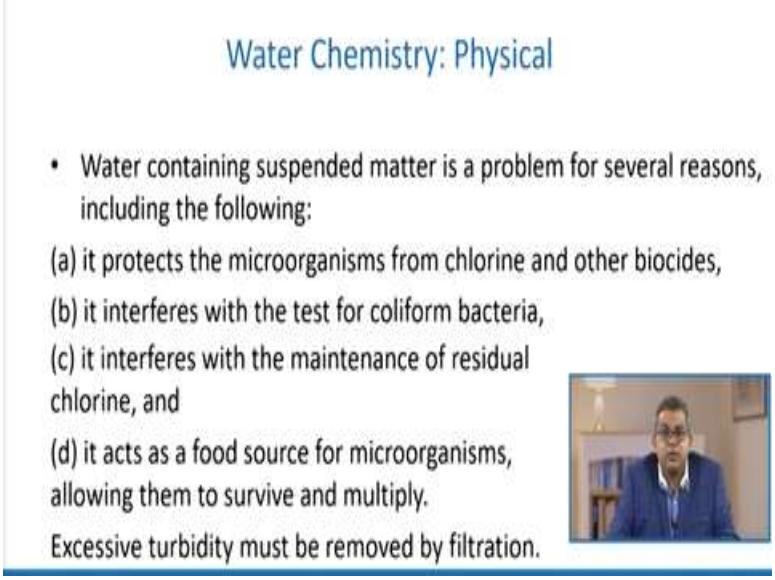

Water containing suspended matter is again a serious problem, and it creates it may be attributed to several reasons. Maybe it protects the microorganism from chlorine and other biocides. It interferes with the test of coliform bacteria, interferes with the maintenance of residual chlorine, and acts as a food source for microorganisms, allowing them to survive and multiply.

Therefore, the filtration must remove excessive turbidity, and because again, I am coming back to the human perception that always looks for clear water. So, turbidity of any kind is usually not acceptable. Let us have a look at the chemical aspect under the edges of water chemistry. So, first is aluminum. Aluminum-based compounds such as sodium aluminate and aluminum sulfate have been used for years as a coagulant aid to clarify industrial and municipal waters.

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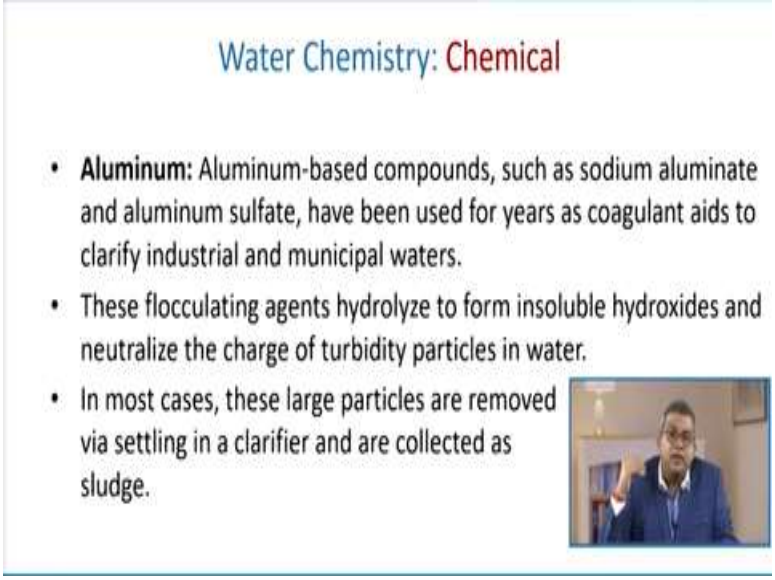

These flocculant agents hydrolyze to form insoluble hydroxides and neutralize the charge of turbidity particles in water. So, in most cases, these large particles are removed via settling in a clarifier and collected as sludge.

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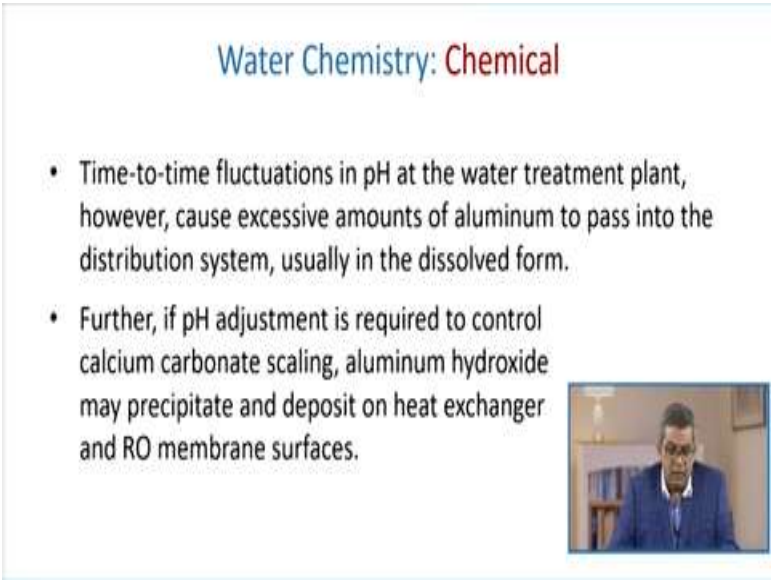

The timely fluctuations in pH at the water treatment plant can cause an excessive amount of aluminum to pass into the distribution system, usually in the dissolved form. Further, if pH adjustment is required to control calcium carbonate scaling, aluminum hydroxide may precipitate and deposit on the heat exchanger and RO membrane surfaces.

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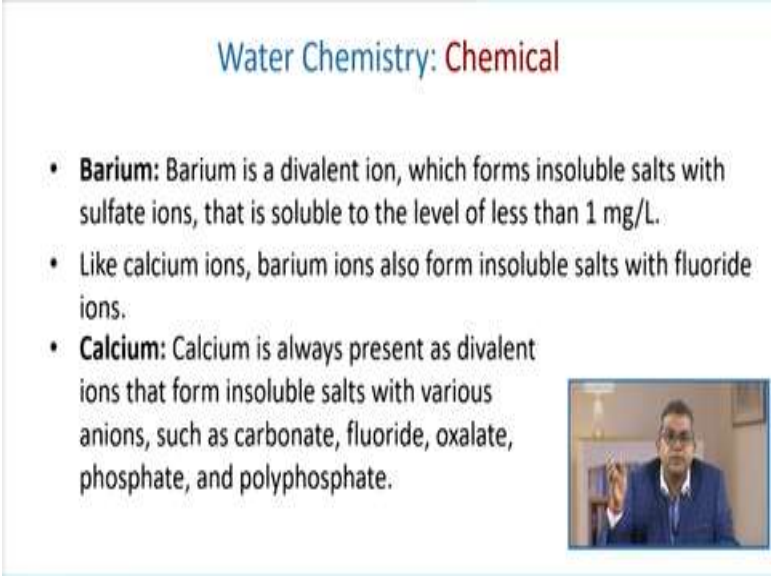

Barium is divalent iron, which forms insoluble salts with soluble sulfate ions to less than 1 milligram per liter. So, like calcium ions, barium ions also form insoluble salts with fluoride ions. Next is calcium. Calcium is always present as divalent iron that forms insoluble salts with various anions such as carbonate, fluoride, oxalate, phosphate, polyphosphates etc.

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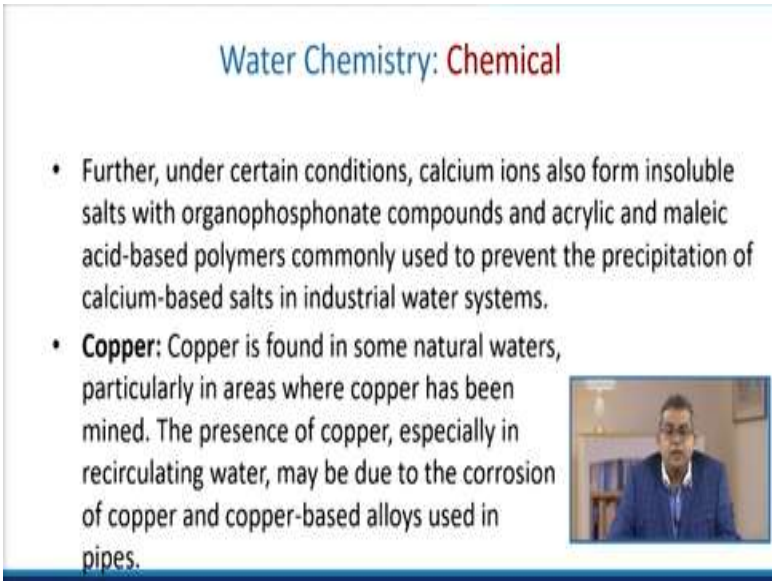

So, under certain conditions, calcium ions also form insoluble salts with organophosphate compounds and acrylic and malic acid-based polymers commonly used to prevent the precipitation of calcium-based salt in the industrial water system. Another common metal is copper. Copper is found in some natural waters, particularly in an area where copper has been mined. And the

presence of copper, especially in recirculating water, may be due to the corrosion of copper or copper-based alloy used in the pipe.

So, especially when we use water as feed water for the boiler, we must look into this. Apart from this, copper is a very good catalyst for various catalytic operations. So, if we are using water for any kind of chemical reaction thing, we need to look at the presence of copper. Otherwise, it may create a problem that may catalyze or unwanted catalyze the reaction.

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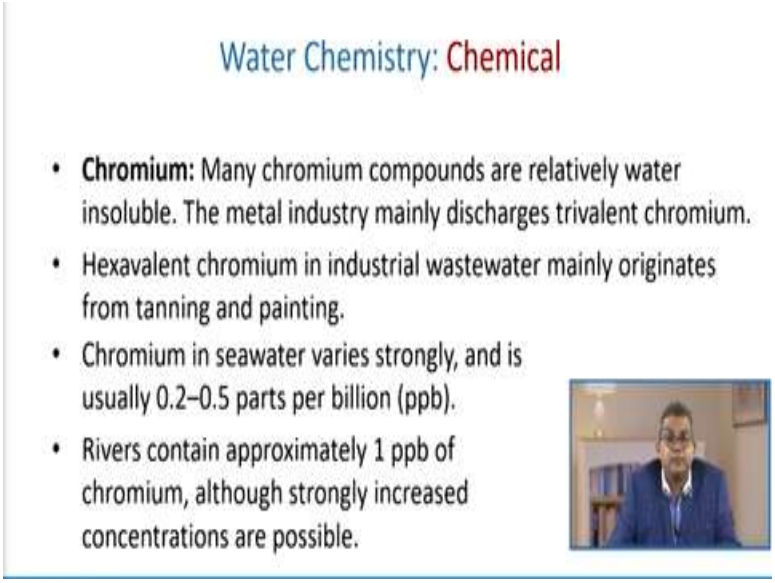

Another important thing is chromium. So, many chromium compounds are relatively water-insoluble. The metal industry mainly discharges trivalent chromium. Hexavalent chromium in industrial wastewater mainly originates from tanning, painting, and other allied industries. And it is a serious problem in all those chemical industries. Chromium in seawater varies strongly, and it is usually 0.2 to 0.5 ppb or the parts per billion.

The river contains rivers that contain approximately one ppb of chromium, although strongly increased concentrations are sometimes possible.

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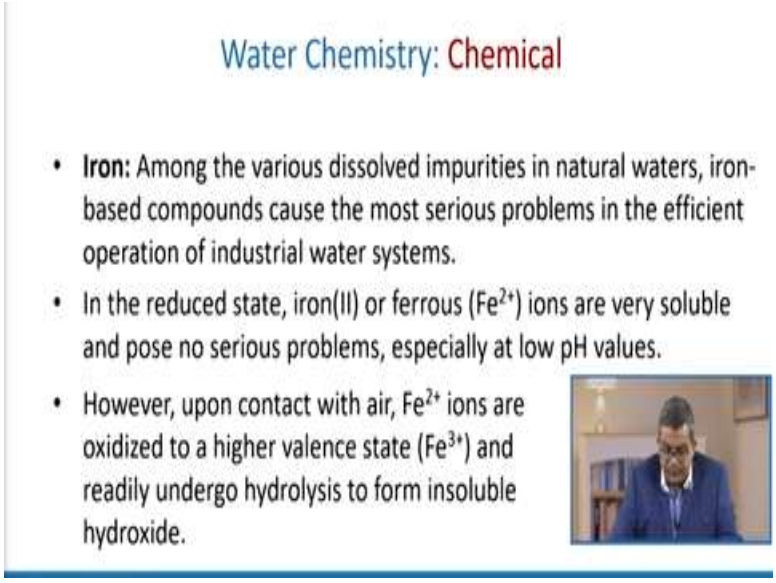

Another very important is iron, and usually, it is found in the surface water, subsurface water etc. So, you can see that among the various dissolved impurities in natural waters, iron-based compounds cause the most serious problem in the efficient operation of the industrial water system. Again, it is a very good catalytic thing. So, in the reduced state Fe^{2+} ion are very soluble and pose no serious problem, especially at low pH values.

However, upon contact with the air affected, ions are oxidized to a higher valence state Fe^{3+} and readily undergo hydrolysis to form insoluble hydroxides.

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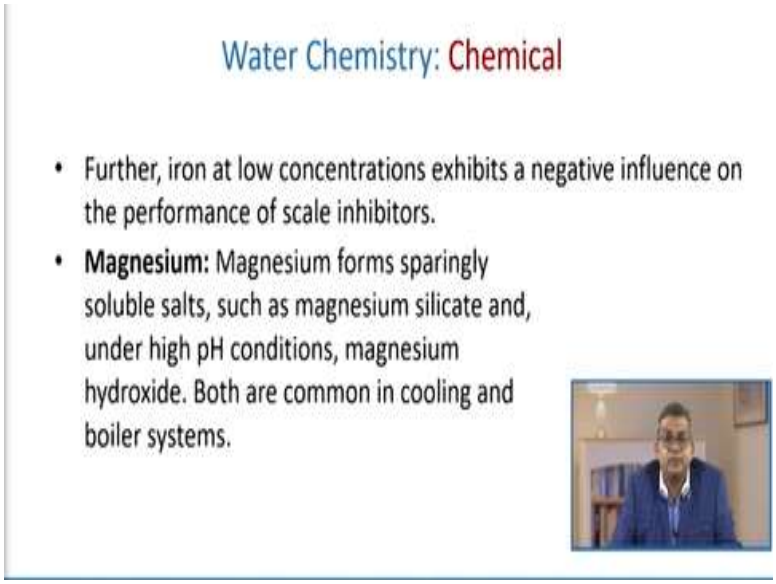

Iron at a low concentration exhibits a negative influence on the performance of scale inhibitors. Another important metal is magnesium. Magnesium forms sparingly soluble salts such as magnesium silicate, and under high pH conditions, magnesium hydroxide. Both are common in cooling and boiler system. So, before we use water for these systems or these operations, we need to look at these particular aspects.

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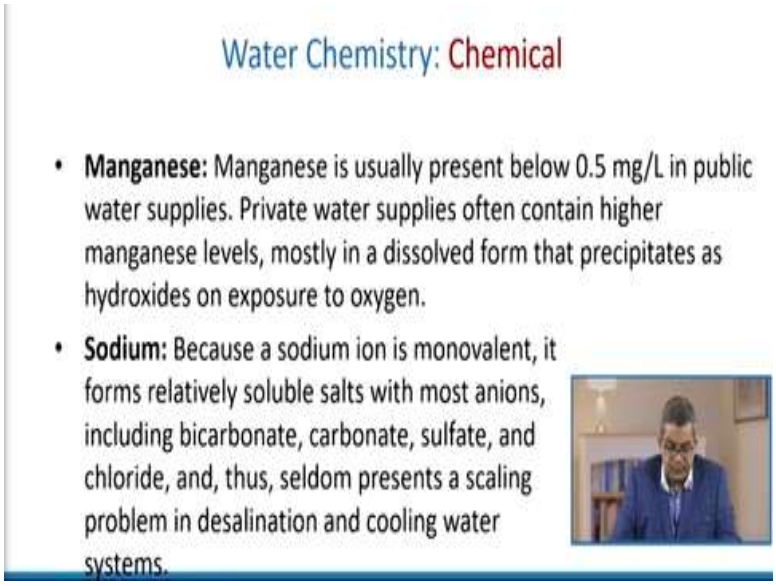

Manganese is usually present below 0.5 milligrams per liter in public water supplies private water supplies. Private water supplies often contain higher magnesium levels and are mostly in a dissolved form that participates as hydroxide on exposure to oxygen. Sodium, usually a sodium ion, is monovalent, so it forms relatively soluble salt with most ions, including bicarbonates, carbonates, sulfates, and chlorides. Therefore, it seldom presents a scaling problem in desalination and cooling water systems.

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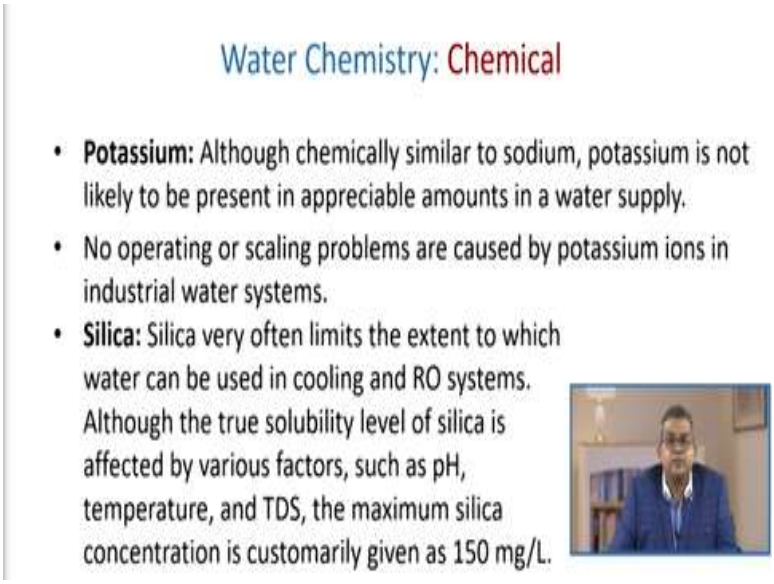

Potassium: Chemically similar to sodium, potassium is not likely to present in an appreciable amount in a water supply. No operating or scaling problems are caused by potassium ions in the industrial water system. silica is another component; silica is often limited to how water can be used in the cooling and RO system. Although true; the solubility level of silica is affected by various factors like pH temperature, TDS etc.

The maximum silica concentration is customarily given as 150 milligrams per litre, although it is sometimes dictated by the various regulatory bodies like the central pollution control board or environmental regulators of different states. Let us have a look at the bicarbonates. Bicarbonate ions do not form insoluble salts.

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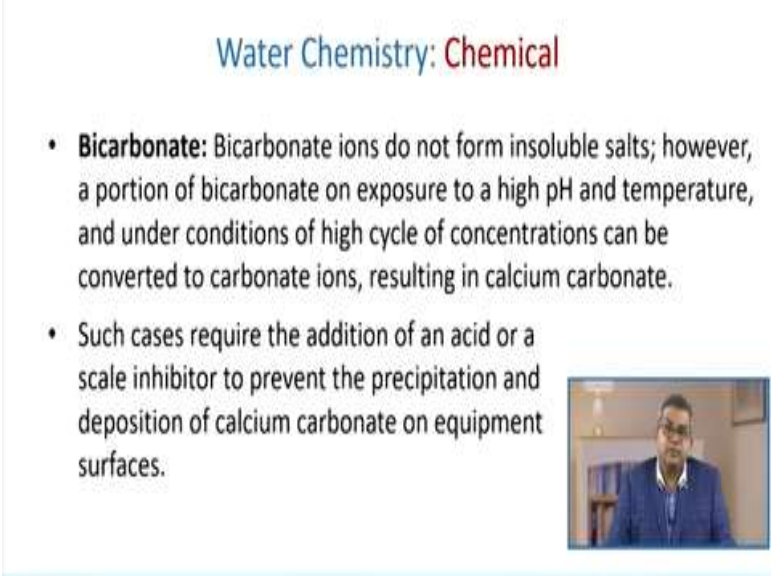

However, a portion of bicarbonate on exposure to a high pH and temperature and under the high cycle of concentration can be converted to carbonate ions, resulting in calcium carbonate. Such cases require the addition of an acid or scale inhibitor to prevent the precipitation and deposition of calcium carbonate on the equipment surface. So, again the problem of scaling problem of low energy efficiency problem of wear and tear all these things may take place.

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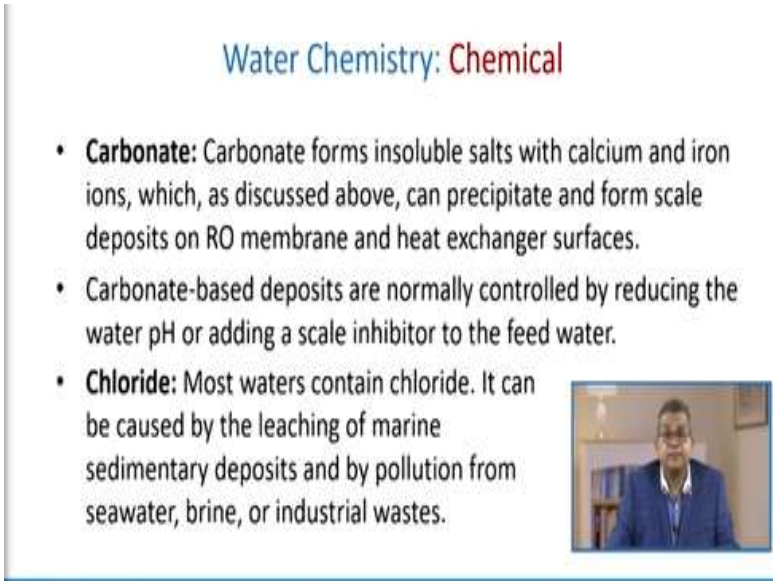

Let us have a look at the carbonate. Carbonate forms insoluble salts with calcium and iron ions which are discussed previously, and it can part precipitate to form scale deposition on various RO membranes and heat exchanging surfaces. Carbonate-based deposits are normally controlled by reducing the water pH or adding a scale inhibitor to the feed water. Let us discuss the chloride.

Most waters contain chlorides. It can be caused by leaching of marine sedimentary deposits and pollution from sea water, brine, or industrial waste.

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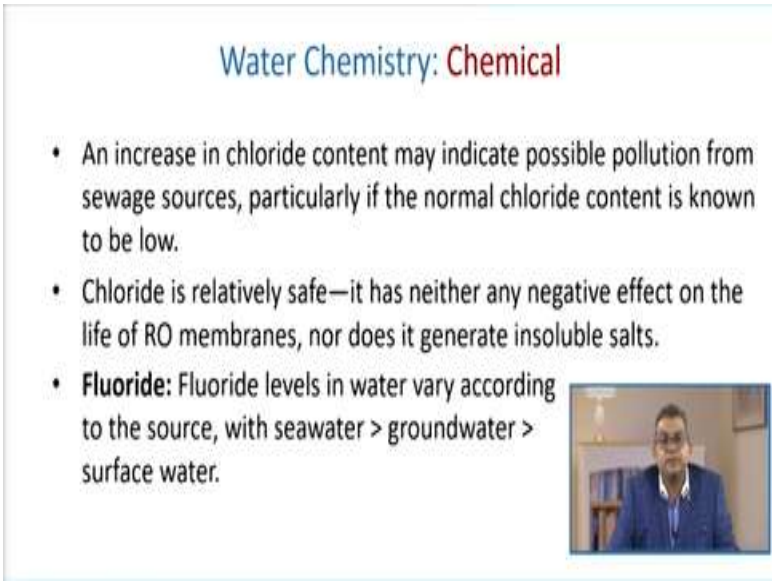

An increase in chloride content may indicate pollution from sewage sources, particularly if the normal chloride content is known to be low. Chloride is relatively safe it has neither any negative effect on the life of the RO membrane nor does it generate insoluble salts. A brief discussion about fluoride. Fluoride is sometimes posed various health issues. So, fluoride level in water varies according to the source with sea water having the maximum amount of fluoride than groundwater then surface water.

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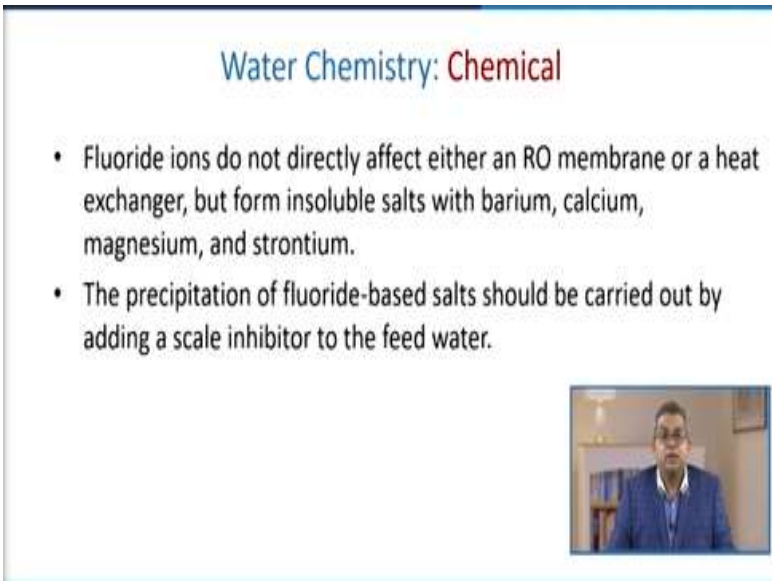

Fluoride ions, do not directly affect either an RO membrane or heat exchangers but form an insoluble salt with the barium, calcium, magnesium, strontium etc. So, the precipitation of fluoride-based salt should be carried out by adding a scale inhibitor to the feed water.

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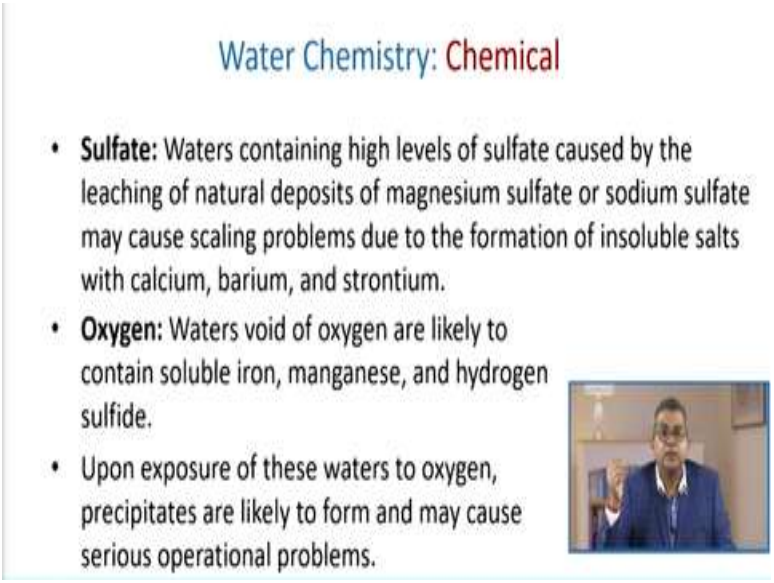

Sulfate water containing a high level of sulfate caused by leaching of natural deposits of magnesium sulfate or sodium sulfate may cause a scaling problem due to the formation of insoluble salts with calcium, barium, and strontium. Let us have a look at the oxygen water void of oxygen are likely to contain soluble iron manganese and hydrogen sulfide. Upon exposure of these waters to oxygen, precipitates are likely to form and may cause serious operation problems which are briefly discussed at the start of this lecture.

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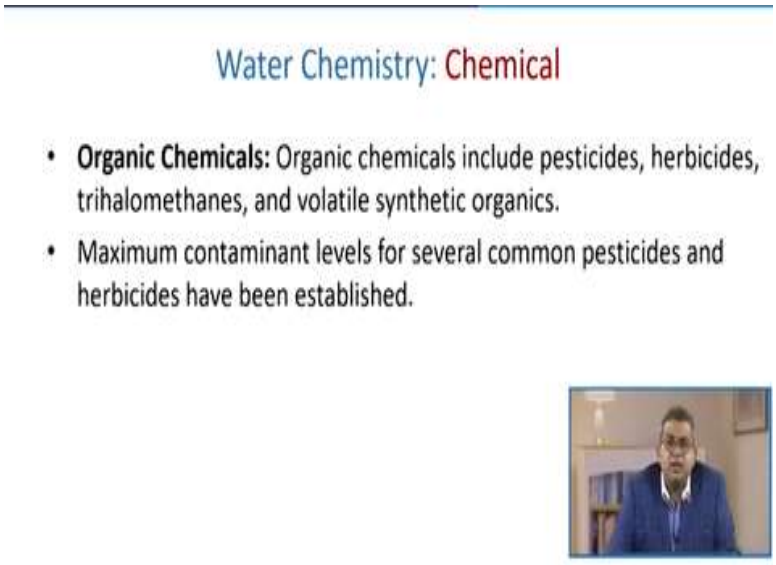

There are certain organic chemicals. Organic chemicals include pesticides, herbicides, different types of trihalomethanes, volatile synthetic organics, etc. The maximum contaminants level of several common pesticides and herbicides have been established. In this particular chapter on this particular lecture, we have discussed the different sources of water.

And what are the different contaminants present in the water in a broad spectrum or a theoretical aspect.

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if you wish to refer further then we have enlisted couple of references in this particular slide, you can have a look and you can see it can go into the detail. Thank you very much.