Chapter Two

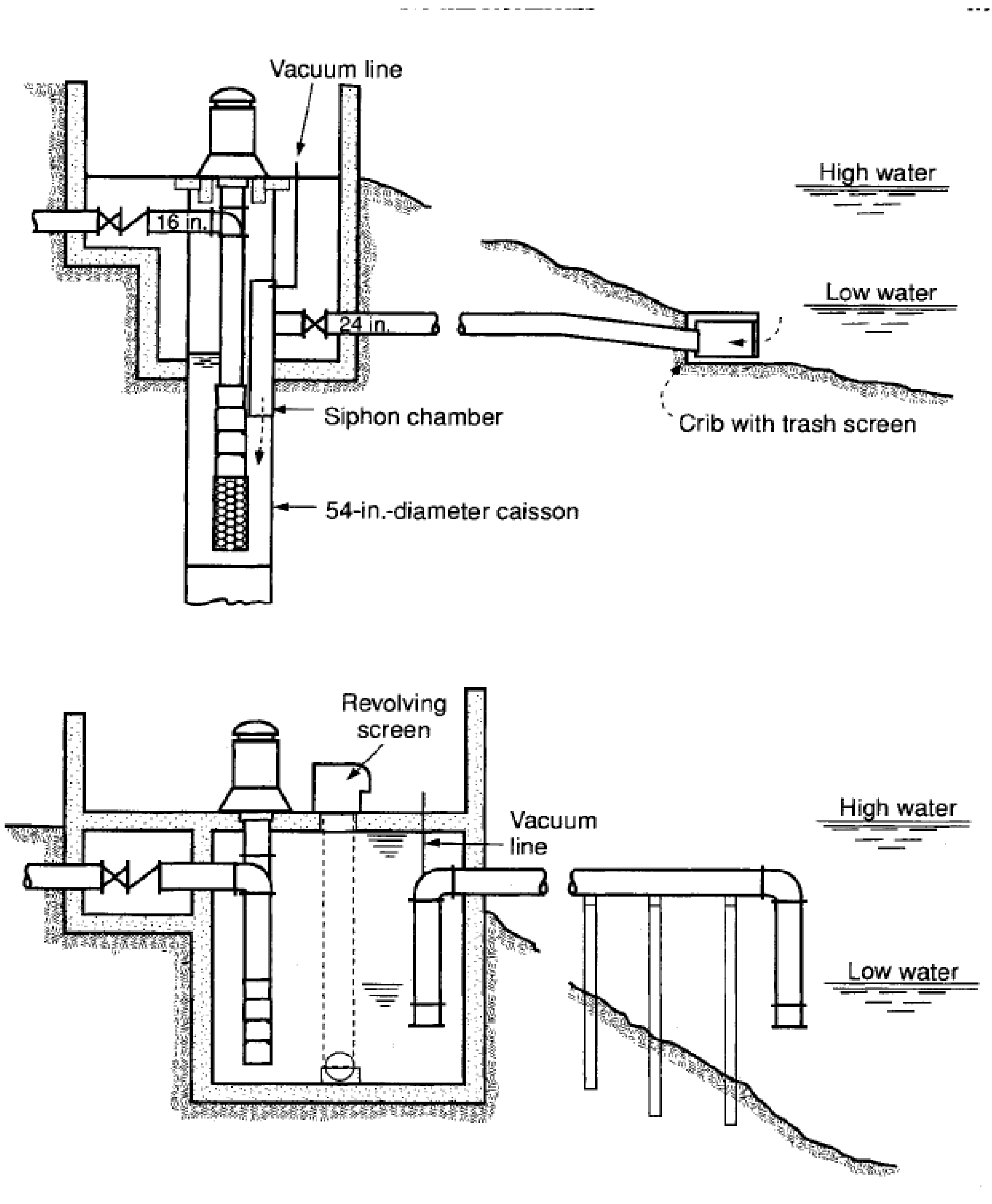
INTAKE FA CILITIES

INTAKE

Intakes are structures built in a body of water for the purpose of drawing water for human use. As discussed in this chapter, intake systems include the facilities required to divert and transport water from a supply source, such as a river, lake, or reservoir, to a shore well or pumping station. For small water supplies, the intake system may be relatively simple, consisting of little more than a submerged pipe protected by a rack or screen. In contrast, for major water supply systems, intake systems can be extensive, with diversion accomplished by intake tower structures or submerged inlet works. An intake system may also include transmission conduits, screens, pumping stations, and, in some instances, chemical storage and feed facilities. This chapter presents a brief review of intake features, describes types of intake systems, and provides a discussion of intake design
considerations. The design of racks and screens is also discussed.

2.1. Intake Features

The purpose of an intake system is to reliably deliver an adequate quantity of water of the best available quality. Reliable intake systems are costly and may represent as much as 20% of the total water treatment plant investment. Pipeline construction associated with intakes may involve extensive underwater work and the use of specialized marine equipment. As a result of these and other factors, the cost of such work would be 2.5 to 4 times more than that for a similar land project. An intake system must possess a high degree of reliability and be able to supply the quantity of water demanded by a water utility under the most adverse conditions. Intakes are exposed to numerous natural and artificial perils, and it is important that the designer anticipate and make provision for operation under adverse conditions. Conservative structural and hydraulic design and careful selection of intake location should be priority considerations. Changing and increasingly stringent drinking water regulations present new challenges that potentially impact the design of intake facilities. Application of chemical treatment at the intake facilities may be advantageous to achieve water quality or treatment goals. Problems associated with zebra mussels provide additional challenges to intake system design. [**3**].



Fig(2.1): Siphon well intake[3].

2.2. Mixing, Coagulation, and Flocculation

Coagulation and flocculation may be broadly described as chemical and physical processes that mix coagulating chemicals and flocculation aids with water. The overall purpose is to form particles large enough to be removed by the subsequent settling or filtration processes. Particles in source water that can be removed by coagulation, flocculation, sedimentation, and filtration include colloids, suspended material, bacteria, and other organisms. The size of these particles may vary by several orders of magnitude. Some dissolved material can also be removed through the formation of particles in the coagulation and flocculation processes. The importance of dissolved material removal has become much more critical in recent years with increased regulatory emphasis on disinfection byproducts and total organic carbon removal. There are several excellent discussions on the theory of coagulation and flocculation in Water Quality and Treatment and other AWWA publications listed at the end of this chapter.[**3**].

2.3. Definitions

Terms used in this chapter are defined as follows:

• Coagulation is the process in which chemicals are added to water, causing a reduction of the forces tending to keep particles apart. Particles in source water are in a stable condition. The purpose of coagulation is to destabilize particles and enable them to become attached to other particles so that they may be removed in subsequent processes. Particulates in source waters that contribute to color and turbidity are mainly clays, silts, viruses, bacteria, fulvic and humic acids, minerals (including asbestos, silicates, silica, and radioactive particles), and organic particulates. At pH levels above 4.0, particles or molecules are generally negatively charged. The coagulation process physically occurs in a rapid mixing process. Mixing is commonly referred to as flash mixing, rapid mixing, or initial mixing. The purpose of rapid mixing is to provide a uniform dispersion of coagulant chemical throughout the influent water.

• Enhanced coagulation is a phrase used by the U.S. Environmental Protection Agency (USEPA) in the Disinfectants and Disinfection By-products Rule. The rule requires that the coagulation process of some water supplies be operated to remove a specified percentage of organic material from the source water, as measured by total organic carbon (TOC). Enhanced coagulation (removal of TOC) can be achieved in most cases by

either increasing coagulant chemical dosage or adjusting the pH during the coagulation reaction.

• Coagulant chemicals are inorganic or organic chemicals that, when added to water at an optimum dosage, cause particle destabilization. Most coagulants are cationic when dissolved in water and include chemicals such as alum, ferric salts, lime, and cationic organic polymers.

• Flocculation is the agglomeration of small particles and colloids to form settle able or filterable particles (flocs). Flocculation begins immediately after destabilization in the zone of decaying mixing energy following rapid mixing, or as a result of the turbulence of transporting flow. In some instances, this incidental flocculation may be an adequate flocculation process. A separate flocculation process is most often included in the treatment train to enhance contact of destabilized particles and to build floc particles of optimum size, density, and strength.

• Flocculation aids are chemicals used to assist in forming larger, denser particles that can be more easily removed by sedimentation or filtration. Cationic, anionic, or nonionic polymers are most often used in dosages of less than 1.0 mgFL.

• Direct filtration is a treatment train that includes coagulation, flocculation, and filtration, but excludes a separate sedimentation process. With direct filtration, all suspended solids are removed by filtration. In the process sometimes called in-line filtration, flocculation occurs in the conduit between the rapid mixing stage and the filter, in the volume above the filter media, and within the filter media.

• Solids contact clarifiers are proprietary devices that combine rapid mixing, flocculation, and sedimentation in one unit. These units provide separate coagulation and flocculation zones and are designed to cause contact between newly formed floc and settled solids.

• Low-pressure membranes are hollow-fiber membrane systems that provide micro- or ultra filtration. These systems have pore sizes that are 10 to 100 times smaller than those of primary protozoa of concern (i.e., Cryptosporidium and Giardia lamblia). The membrane is a thin layer of polymer capable of separating materials based on size and chemical properties. These membrane systems typically operate in the range of - 12 psi vacuum to 40 psi pressure.[**3**].

2.4. The Coagulation Process

Coagulation reactions occur rapidly, probably taking less than one second. Principal mechanisms that contribute to the removal of particulates when

coagulating chemicals such as alum or ferric chloride are mixed with water include chemical precipitation, reduction of
electrostatic forces that tend to keep particles apart, physical collisions between particles, and particle bridging. Several factors affect the type and amount of coagulating chemicals required, including the nature of suspended solids and the chemical characteristics of the influent water.[**3**].

2.5. Coagulant Chemicals

The most commonly used coagulants are:-

• Alum (aluminum sulfate), A12(SO4)3 • 14H20. The most common coagulant in the United States, it is often used in conjunction with cationic polymers.

• Polyaluminum chloride, AI(OH)x(C1)y. This is efficient in some waters ,requiring less pH adjustment and producing less sludge.

• Ferric chloride, FeC13. This may be more effective than alum in some applications.

• Ferric sulfate, Fe2(SO4)3. It is effective in some waters and more economical in some locations.

• Cationic polymers can be used alone as the primary coagulant or in conjunction with aluminum or iron coagulants.

Although alum is by far the most widely used coagulant chemical, ferric chloride or ferric sulfate forms a better-settling floc in some waters and may be more consistently effective in removing natural organic matter as compared to aluminum-based coagulants. Additionally, polyaluminum chloride often produces a better-settling floc in colder waters and often results in lower dosages, thereby producing less sludge than alum and ferric coagulants.[**3**].

2.6. Flocculation Aids

Floc formed in many waters with alum is light and fragile and somewhat difficult to settle. Polymers and other additives can often help form a floc that is more efficiently removed by settling and filtration. Typical additives used for flocculation aids are

- High-molecular-weight anionic or nonionic polymers.
- Activated silica.
- Bentonite.

These chemicals are normally added after the application of coagulants, from 5 to
600 s after mixing. If the water to be treated with a flocculent aid is already in the flocculation stage, the chemical should be added so that it can be spread across the flocculation basin.[**3**].

2.7. Chemical Selection

power costs, in an effort to reduce ozone requirements, many recently constructed ozone facilities incorporate ozonation after clarification or filtration.

Oxidation with air and chemical oxidants such as chlorine and potassium permanganate may also aid coagulation by oxidizing iron and manganese, which can aid floc formation. Carbon addition, typically in the form feasible. However, due to the increasing of powdered activated carbon (PAC), may also improve

coagulation, as it would remove a fair amount of organic matter prior to the coagulation process, thereby, reducing coagulant demand and the associated levels of sludge production as well as improving overall turbidity and organics removal. Similarly, new, specialty adsorbents/resins are actively being considered in the drinking water treatment community. One such adsorbent, a magnetic ion exchange (MIEX) resin by ORICA Water care (Melbourne, Australia, and Englewood, Colorado), is specifically designed to remove low-molecular-weight organics, which are a primary contributor to many DBP precursors.

As the DBP rules become more and more stringent in future years, there is little question more specialty-type coagulant aids will continue to be developed to further improve the removal of these precursors. The selection of coagulant chemicals and flocculation aids for use in a particular plant is generally based on economic considerations along with reliability, safety, and chemical storage considerations. The best method of determining treatability, the most effective coagulants, and the required dosages is to conduct bench-scale and, in some cases, pilot tests. Jar tests can be used to determine treatability and estimate chemical dosages. If possible, testing should cover all critical seasonal conditions. Pilot plant design and construction are discussed. When one is designing for coagulant application, as much flexibility as possible should be allowed, to accommodate changing conditions. Several points of addition for coagulant chemicals, particularly polymers, should be provided in the rapid mixing and flocculation processes. The order of chemical addition is also important in almost all waters. Sludge quantity and disposal are important considerations in selecting the coagulant to be used. Metal-ion coagulants produce considerably larger volumes of sludge than polymers. The ability to predict the exact reaction and quantity of sludge that will be produced[3].

solely by the reaction formulas is limited. For this reason, predictions of treatability, chemical dosages, and sludge quantities must generally be determined by laboratory and pilot plant tests. The coagulation process may, in some cases, be improved by preozonation. Ozone may significantly reduce coagulant requirements to the point where low residual solids (or filtration efficiency) make direct filtration.[3].

2.8. Adjustment of pH

Control of pH and alkalinity is an essential aspect of coagulation. The optimum pH for coagulation varies but is generally within the following ranges for turbidity removal:-

• Alum: pH 5.5 to 7.5; typical pH 7.0 .

• Ferric salts: pH 5.0 to 8.5; typical pH 7.5 .

It can be necessary to adjust the pH of some source waters to achieve optimum coagulation. The pH is often lowered by adding carbon dioxide or an acid. Alum and ferric chloride consume alkalinity and can lower pH; however, reducing pH by adding more chemical than is required for coagulation should be avoided as it increases overall chemical costs and sludge production/costs. In some source waters with low pH or low alkalinity, it may be necessary to add caustic soda or lime to raise pH and to offset the acidity of metal-ion coagulants, even in an enhanced coagulation mode of operation. A thorough discussion of the effects of pH on coagulation appears in Water Quality and Treatment. For waters that require enhanced coagulation to remove organic matter, the pH of coagulation should be lowered as compared to coagulation for turbidity removal only. Typically, the optimum pH for organics removal with alum is between 6.0 and 6.5, and between

5.5 and 6.0 for ferric coagulants. Often, polyaluminum chloride can provide organics removal without as significant a decrease in pH. There are a number of secondary impacts of utilizing the higher coagulant dosages and lower pH values for enhanced coagulation. A few of these impacts include the following:

• Increased solids. The higher coagulant dosages directly result in increased sludge volumes.

discusses the relationship between coagulant dosages and sludge production.

• Poorer dewatering characteristics. The increased metal (A13+ or Fe z+ or 3+) concentrations typically result in poorer dewatering characteristics. As a result, a change to enhanced coagulation may result in lower ultimate, dewatered solids concentrations.

• Increased concrete metal corrosion. The lower pH of the coagulated water for TOC.[**3**].

removal will be significantly more aggressive on concrete and metals as compared to the more neutral pH of water that has been coagulated for turbidity removal.

If pH is lowered to improve coagulation, it is typically necessary to raise the pH in the final effluent from the plant to provide a less corrosive finished water. The pH may be adjusted at one or more points in the treatment, including rapid mixing, prefiltration, and post filtration. If the pH is lowered to improve coagulation and organics removal, it is often recommended to readjust the pH after the filtration process as compared to prefiltration. This is due to the fact that some organic matter may be adsorbed onto the floc that may carry over from the clarification process, and any prefiltration pH adjustment may then result in the "release" of this organic matter, which could pass through the filters and contribute to subsequent DBP formation. For plants where only a small increase in pH is required, liquid caustic soda is most commonly used because of its ease of handling. When a large increase in pH is required, lime is normally the most economical choice. Lime, however, may add turbidity to a finished water; therefore, if lime is used for post filtration pH adjustment, it is generally best to use a lime saturator to minimize the potential of turbidity addition. Also, in some waters, the utilization of soda ash for precoagulation alkalinity adjustment often helps the overall coagulation process.[**3**].

2.9. Design of Chemical Mixing

Chemical mixing can be accomplished by several different types of equipment designed to ixm the applied chemicals with the source water as quickly as possible..

Mixing Intensity

The intensity of agitation required for optimum rapid mixing and flocculation is measured by the G value. The G value concept, developed by Camp and Stein in 1943, is widely used in designing rapid mixing and flocculation processes and is defined by the equation:-

$$G = \left(\frac{P}{\mu V} \right)^{1/2}$$

where G = root-mean-square velocity gradient, or rate of change of velocity, (ft/s)fft

P = power input, ft • lb/s

/.~ = dynamic viscosity, lb • sift 2

V = volume, ft 3

Equations are also available to calculate G for various types of mixing arrangements,

and manufacturers of mixing and flocculation equipment provide information on G values for their equipment. Another parameter used in designing mixing systems is *Gt,* which is the dimensionless product of G and detention time t in seconds.[**3**].

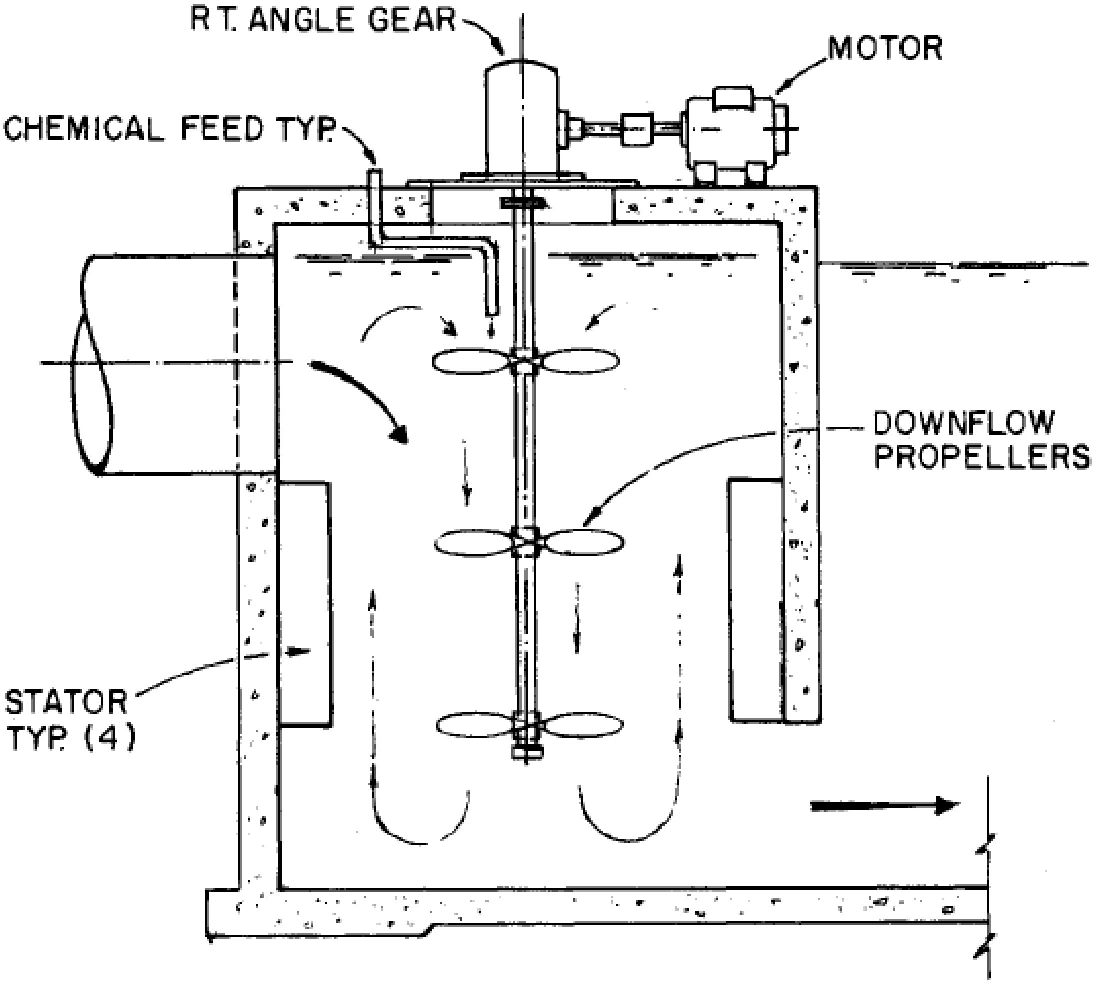


Fig (2.2): propeller-type mechanical flash mixer [**3**].

2.10. Flocculation Process Design

Building optimum size floc requires gentle mixing in the energy gradient range of 20 to 70 s-1 for a total period of approximately 10 to 30 min. Direct filtration requires a small, dense floc that can be formed at the higher end of the energy range. For settling in conventional basins and in units with settling tubes and settling plates, lower energy levels are applied to produce a large, dense floc that will resist breakup during contact with weirs and plates. Often, polymers are used to help form denser floc. Floc begins to form within 2 s of coagulant addition and mixing. If high turbulence or shear is subsequently applied to the water, the formed flocs may be fragmented, and broken floc may not readily settle or re-form.

Optimum floc that is efficiently settled or filtered is usually formed under conditions of gradually reducing energy. In large plants, it may be difficult to distribute water to flocculation basins or filters without quiescent stages and high-energy stages. Conduits handling mixed water should minimize head losses, but may, on the other hand, include water jets or air mixing to maintain G at values of 100 to 150 s- 1 before the water is transferred to the flocculation stage.

The gentle mixing process of flocculation is designed to maximize contact of destabilized particles and build settle able or filterable floc particles. It is desirable to maintain shear forces as constant as possible within the process. As a result, flocculator mechanisms tend to be slow and to cover the maximum possible cross-sectional area of floc basins. It is desirable to compartmentalize the flocculation process by dividing the basin into two or more defined stages or compartments, as illustrated in Figure(2.3). Compartments prevent short-

circuiting and permit defined zones of reduced energy input or tapered energy. To prevent short-
circuiting, baffles are typically placed between each stage of flocculation. For mechanical (no hydraulic) flocculation basins, baffles are designed to provide
an orifice ratio of approximately 3% to 6% or a velocity of 0.9 ft/s (27 crrds) under
maximum flow conditions.

2.11. Incidental Flocculation

As coagulated water is transferred to flocculators in small plants, distances are short enough that incidental flocculation is negligible. But in large plants transfer may involve distances of more than 100 ft (30 m) through low-velocity conduits, weirs, or other means of distributing water equally to each flocculation basin or compartment. This travel in large plants involves turbulence, and flocculation and incidental flocculation take place

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If velocities or levels between the conduits and the flocculation basin are not limited, floc may be fragmented and plant efficiency impaired. Higher coagulant feed rates may be required to overcome fragile floc problems.[3]

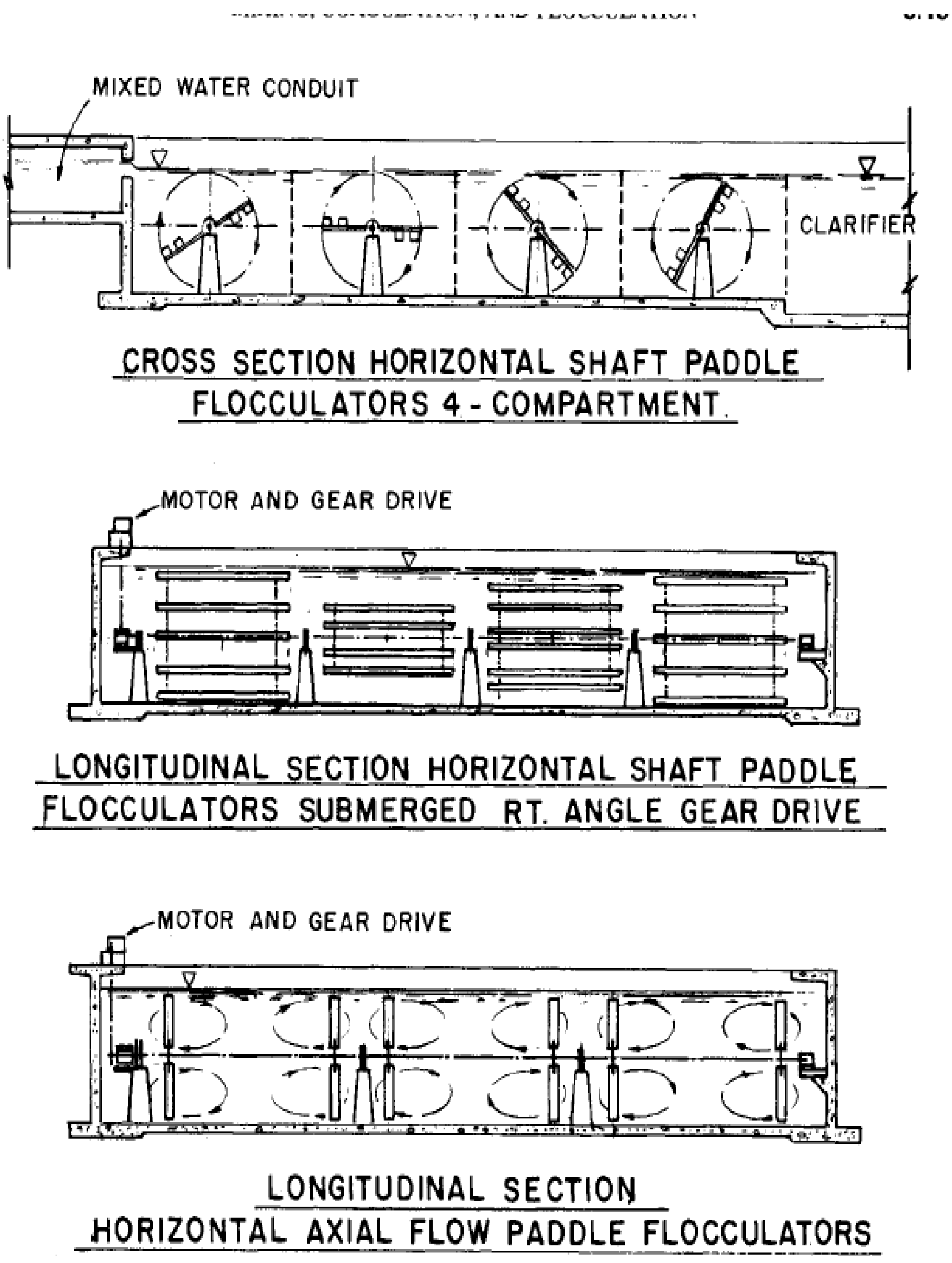

Fig (2.3): Sections through horizontal shaft paddle flocculator [**3**].

Chapter Three

CLARIFICATION AND HIG RATE FILTARATION

3.1 . Clarification

Clarification has more than one application in water treatment. Its usual purpose in a conventional treatment process is to reduce the solids load after coagulation and flocculation. A second application, a process called *plain sedimentation,* is removal of heavy settle able solids from turbid water sources to lessen the solids load on treatment plant processes. Material presented in this chapter deals primarily with settling flocculated solids. One way of designing the clarification process is to maximize solids removal by clarification, which generally requires lower clarifier loadings and larger, more costly units.

Alternatively, the clarifier may be designed to remove only sufficient solids to provide reasonable filter run times and to ensure filtered water quality. This latter approach optimizes the entire plant and generally leads to smaller, less expensive facilities. Typical loading rates suggested in this chapter or by regulatory guidelines are generally conservatively selected to provide a high-clarity settled water rather than optimization of the clarifier-filter combination. Clarifiers fall into two basic categories: those used only to remove settle able solids, either by plain sedimentation or after flocculation, and those that combine flocculation and clarification processes into a single unit. The first category includes conventional sedimentation basins Figure (3.1) and high-rate modifications such as tube or plate settlers and dissolved air flotation (DAF). The second category includes solids contact units such as sludge blanket clarifiers and slurry recirculation clarifiers. Also included in this category is contact clarification in which flocculation and clarification take place in a coarse granular media bed.[**3**].

3.2. Conventional Clarification Design

Most sedimentation basins used in water treatment are the horizontal-flow type in rectangular, square, or circular design. Both long, rectangular basins and circular basins are commonly used; the choice is based on local conditions, economics, and personal preference. states that long, rectangular basins exhibit more stable flow characteristics and therefore better sedimentation performance than very large square basins or circular tanks. Basins were originally designed to store sludge for several months and were peri- odically taken out of service for manual cleaning by flushing. Most basins are now designed to be cleaned with mechanical equipment on a continuous or frequent schedule.[**3**].

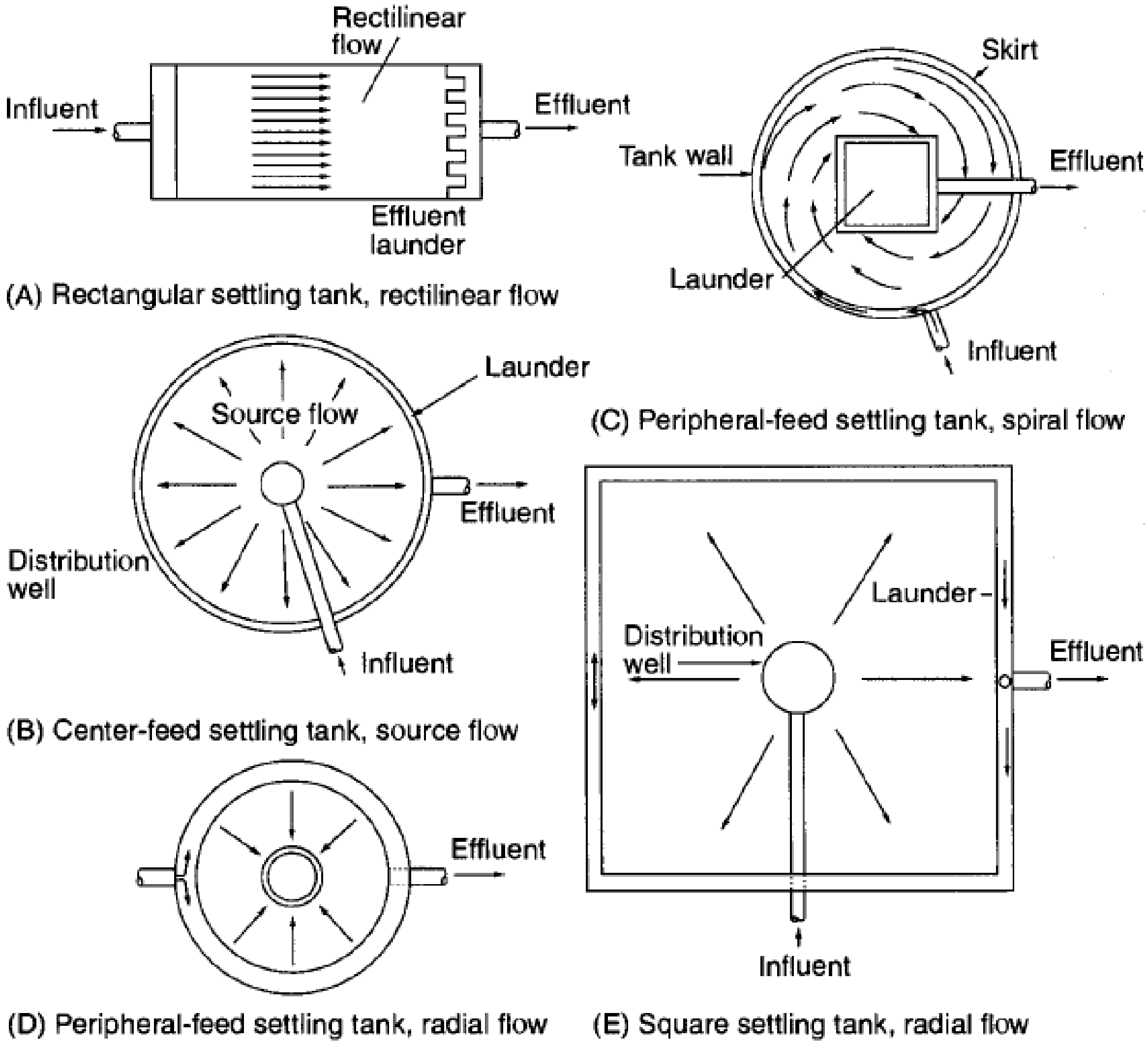

Fig (3.1): Typical conventional sedimentation tanks[**3**].

3.3.<u>Sedimentation Theory</u>

A complete discussion of sedimentation theory and its application can be found in Water Quality and Treatment. The designer is urged to become familiar with this theory before selecting and designing the clarification process. When flocculated particles enter a basin and begin to settle, particles' settling velocities change as particles agglomerate to form larger floc. Because the settling properties of

flocculent suspensions cannot be formulated, a basin's performance cannot be accurately predicted. However, for new plants, settling rates can be estimated from batch settling data developed with laboratory jar tests. For expanding existing plants, settling rates can be derived from evaluating the performance of existing basins during various influent water quality conditions. These evaluations often allow for increasing rates for existing basins mand establishing higher rates, as compared to published guidelines, for new basins. In an ideal continuous flow basin, sedimentation would take place as it does in the laboratory jar. However, in a real basin, wind, temperature density currents, and other fac- tors cause short-circuiting, disruption of flow patterns, breakup of floc, and scouring of the settled sludge. The designer must learn as much as possible about the settling properties

of the flocculated solids and then design basins to match these characteristics. When the designer does not have access to source water data, it is best to select design criteria known to have worked in similar applications, either from personal experience or from regulatory guidelines.[**3**].

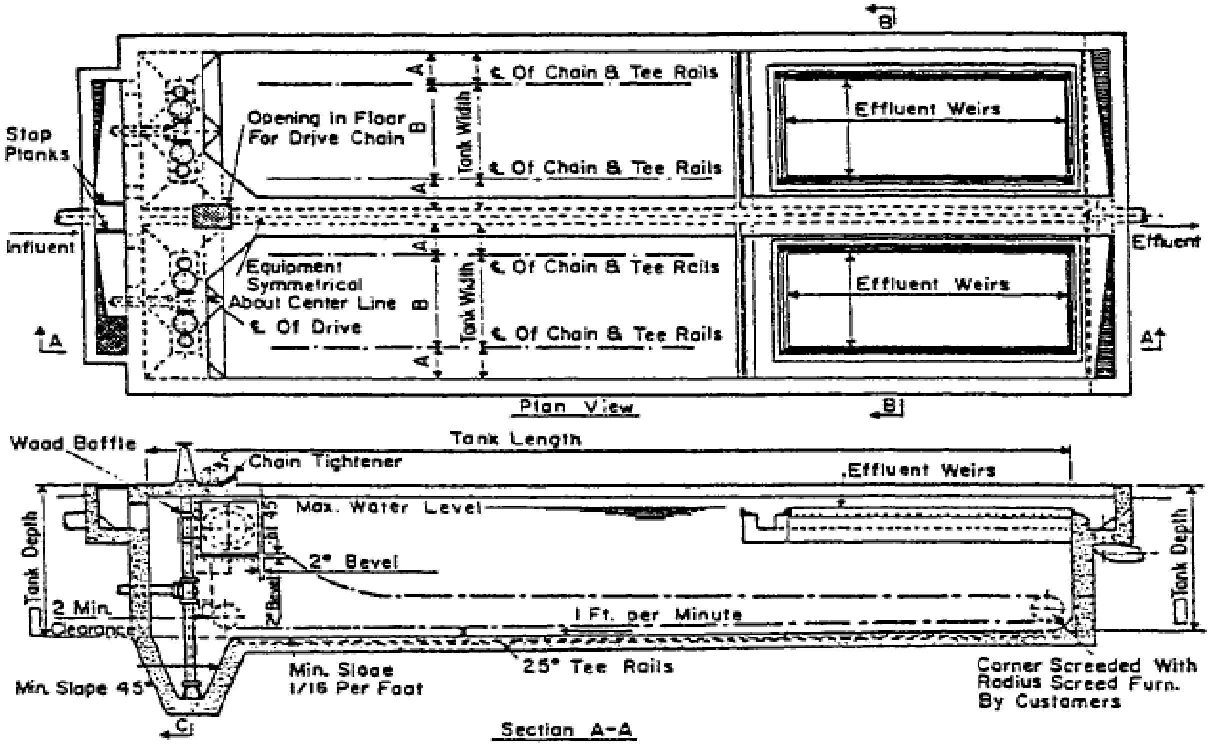

Fig (3.2): Typical rectangular basin with chain & fight collectors with sludge hoppers[**3**].

*3.4.**__Circular Basins__***

Have no bearings under water, resulting in longevity with little maintenance. In reasonable sizes--not exceeding 125 ft (38 m) in diameter--the circular center-feed clarifiers perform as well as long, rectangular basins provided there is a reasonably well-balanced radial flow from the center well with substantial water depth maintained at the center. Some circular basins are designed for rim feed with clarified water collected in the center. However, most circular basins used today are the center-feed type. Included in this category are square tanks with Circular sedimentation basins became more prevalent in water clarification when periodic
manual cleaning of long, rectangular basins became unpopular. The top-drive circular mechanisms used for sludge cleaning center feed that are used for their feature of lower cost by means of common wall construction. A typical circular clarifier is shown in Figure 3.2. A circular clarifier with a center flocculation zone is shown in Figure3.3.

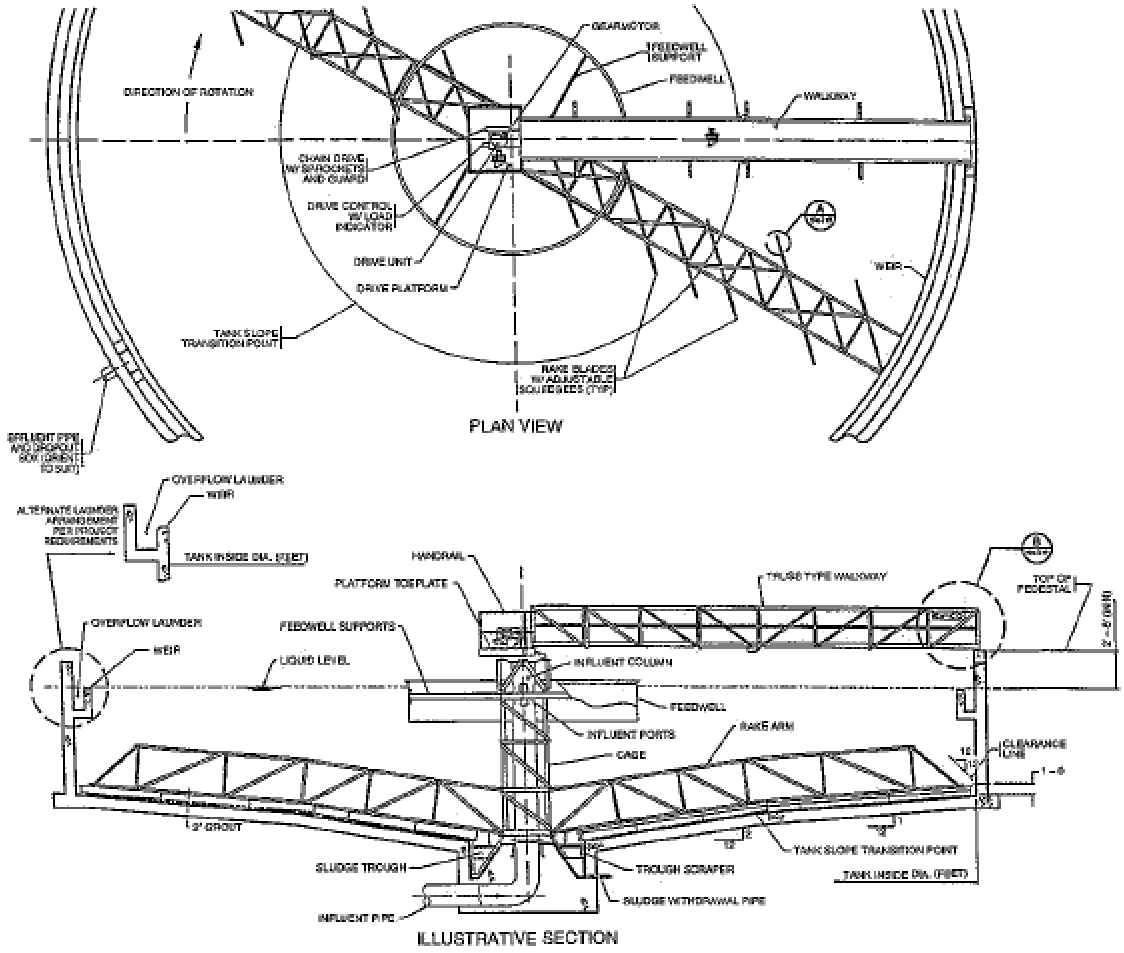

Fig (3.3):typical circular clarifier (courtesy of Eimco water technologies)[**3**].

3.5. ***High-Rate Granular Media Filtration***

Filtration, as it applies to water treatment, is the passage of water through a porous medium to remove suspended solids. the earliest written records of water treatment, dating from about 4000 B.C., mention filtration of water through charcoal or sand and gravel. Although a number of modifications have been made in the manner of application, filtration remains one of the fundamental technologies associated with water treatment. Filtration is needed for most surface waters, to provide a second barrier against the transmission of waterborne diseases. Although disinfection is today the primary defense, filtration can assist significantly by reducing the load on the disinfection process, increasing disinfection efficiency, and aiding in the removal of precursors to disinfection by-product (DBP) formation. The Surface Water Treatment Rule (SWTR) and Enhanced Surface Water Treatment Rules (ESWTR) recognize three categories of granular filtration techniques:

- Rapid sand
- Slow sand
- Diatomaceous earth

This chapter covers the design of the first category of filters. However, in this instance the term rapid sand includes not only sand, but also other types of filter media such as crushed anthracite coal and granular activated carbon (GAC). covers the other two categories of granular filtration techniques. discusses activated carbon processes, including GAC filters/absorbers.

3.6. Mechanism of Flocculation

Removing suspended solids by high-rate granular media filtration is a complex process involving a number of phenomena. Attempts to develop theories that quantitatively predict solids removal performance with sufficient precision and versatility to be of use in practical filter design have met with relatively little success. Consequently, filter media selection is often an empirical process. Pilot investigations are common tools for assessing the performance of a particular filter design . In current high-rate granular media filtration techniques, solids removal occurs primarily as a two-step process . During the initial transport step, particles.[**3**].

are moved to the surfaces of media grains or previously captured floc. Transport is believed to be caused largely by hydrodynamic forces, with contact occurring as stream lines converge in pore restrictions. The second step is particles' attachment to either grain or floc surfaces. Electro kinetic and molecular forces are probably responsible for the adherence of particles on surfaces within the bed , Physical straining through the surface layer of solids and biological growth is the principal

filtration mechanism of a slow sand filter, but it is generally a minor means of solids removal in high-rate granular media filters.[**3**].

3.7.Pretreatment

Effective operation of a high-rate granular media filtration system requires pretreating the source water. The nature, as well as the quantity, of suspended material in the pretreated water is critical to filter performance. Unflocculated water can be difficult to filter regardless of the type of medium in use .Dual-media filters showed that if the applied water is properly coagulated, filtration at rates of 4 or 6 gprn/ft 2 (10 or 15 m/h) produces essentially the same filtered water quality as filtration at a rate of 2 gpm/ft 2 (5 m/h). Subsequent investigations have shown similar results for mixed-media filters. Recent research has pushed the filtration rates for deep-bed filters to as high as 10 to 12 gpm/ft 2 (24 to 30 m/h); however, polymer filter aids and deeper coarse bed filters were required to achieve these rates and the raw water quality was excellent. Extended pilot studies and regulatory consultation are recommended when filtration rates above 4 gpm/ft 2 (10 m/h) are proposed., Chemicals used in conjunction with high-rate granular media filtration are limited primarily to metal salts or cationic polymers as primary coagulants. Primary coagulants are ideally fed into rapid mixing basins preceding flocculation. Whether clarification is also required depends on the quantity of suspended solids, metals, and algae in the source water. Primary coagulants are intended to produce agglomerations of natural and chemical solids. Nonionic or anionic polymers are often added with the coagulant as a coagulant aid to assist in strengthening and growth of these agglomerations during flocculation. These same polymers can also be added as a filter aid to the filter influent water or to the wash water to increase the strength of adhesion between media grains and floc in coarse to- fine filters. Proper pretreatment and mixing is essential to filter performance, especially at higher filtration rat. Pretreatment may also include aeration or introducing an oxidant if an objective of water treatment is to remove iron or manganese. A filter aid polymer can improve floc capture, provide better filtered water quality, and increase filter runs with higher head loss before turbidity breakthrough. Filter aid polymers are not generally used with fine-to-coarse filters because they promote rapid surface clogging. Filter aids are often fed at low dosages in dilute liquid form to allow dispersion without mechanical agitation just before filtration. Filter aid polymer doses to gravity filters are usually low (0.02 to 0.05 mg/L). Doses required for pressure filters may be higher because of the higher operating head losses normally employed. Because water viscosity increases with decreasing temperature, breakthrough as a result of floc shearing is more likely at lower water temperatures. Consequently, increased polymer doses and a longer contact time before filtration may be required in cold weather.

Assuming that adequate coagulation is feasible, the designer must decide whether clarification is desirable. In the past, settling has been provided before high-rate granular media filtration when turbidities exceeded roughly 10 ntu . The increased storage capacities of dual- and mixed-media filters have made filtration of water with higher turbidities practicable. The primary advantage of providing direct filtration is the elimination of capital and operating costs associated with clarification. (For the purpose of this chapter, direct filtration is defined as high-rate granular media filtration directly following flocculation, without a clarification process.) The higher solids load on the filter will, however, shorten run times and increase the portion of product water required for filter washing. Although the point at which advantages outweigh disadvantages varies with local conditions, a number of investigators have suggested conditions that would justify consideration of direct filtration. Development of packaged or pre-engineered filtration systems in the 1970s has led to a hybrid process hereafter referred to as two-stage filtration. Two-stage filtration combines traditional high-rate granular media filtration (gravity or pressure) preceded by a high-rate clarifier or roughing filter, generally in an up flow configuration. Direct filtration and two-stage filtration are generally employed for higher-quality waters with lower and more consistent turbidity and lower organic content. It is imperative that pilot studies be conducted to determine the feasibility of direct filtration or two-stage filtration for each application.[**3**].

3.8.<u>Filter Media</u>

Although the selection of filter media type and characteristics is the heart of any filtration system, selection is usually based on arbitrary decisions, tradition, or a standard approach. Pilot plant studies using alternative filter media and filtration rates can determine the most effective and efficient media for a particular water.

In drinking water applications in North America, the most commonly used filter media are natural silica sand, garnet sand or limonite, crushed anthracite coal, and GAC. Selecting appropriate filter media involves a number of design decisions concerning source water quality, pretreatment, and desired filtered water quality. Filter media cleaning requirements and under drain system options depend on the filter configuration and filter media selected. Media variables the designer can control include bed composition, bed depth, grain size distribution, and, to a lesser extent, specific gravity. In addition to media design characteristics, media quality

can be controlled to some extent through specifications covering, where applicable, hardness or abrasion resistance, grain shapes, acid solubility, impurities, moisture, adsorptive capacity, manner of shipment, and other such factors. Suggested criteria and a discussion of the applicability of these parameters can be found in the Standard for Filtering Material and Standard Granular Activated Carbon. In the United States, granular media have been traditionally described in terms of effective size (ES) and uniformity coefficient (UC). The ES is that dimension exceeded by all but the finest 10% (by weight) of the representative sample. It is also referred to as the "10% finer" size. The UC is the ratio of the "60% finer" size to the ES. Common practice in Europe is to express media sizes as the upper and lower limits of a range. These limits may be expressed either as linear dimensions or as passing and retaining sieve sizes (that is, 1.0 to 2.0 mm or -10 + 18 mesh). The filtration process also affects the selection of the filter bed because of the special requirements of each type of process. The direct and in-line filtration processes must have filter beds with a large floc holding capacity. A reverse-graded filter bed, such as a dual media or coarse deep bed, satisfies this requirement. In two-stage filtration, the filter bed of the first stage acts as a roughing filter and carries out the flocculation process. Data obtained from pilot filter tests and actual installations using the two-stage filtration process

indicate that the first-stage filter bed may be designed in the same fashion as an ordinary filter. Rapid sand filtration, with filtration rates ranging from 2 to 3 gpm/ft 2 (5 to 7.5 m/h), usually uses medium-sized sand (0.5-mm ES). High-rate filters of 5 to 10 gpm/ft 2 (12.5 to 25 m/h) always consist of a reverse-graded filter bed or a deep, large-sized mono media. Filter beds may be classified as graded fine-to-coarse, ungraded, graded coarse-to-fine, or uniformly graded, depending on the

distribution of grain sizes within the bed during filtration. Transition from the ungraded media of a slow sand filter to the fine-to-coarse high-rate granular media filter resulted from dissatisfaction with the low loading rates and laborious cleaning procedure characteristic of slow sand filters. Filters with uniformly graded or coarse-to-fine beds are now operated at higher filtration rates and for longer run times than are feasible with conventional rapid sand filters[**3**]..

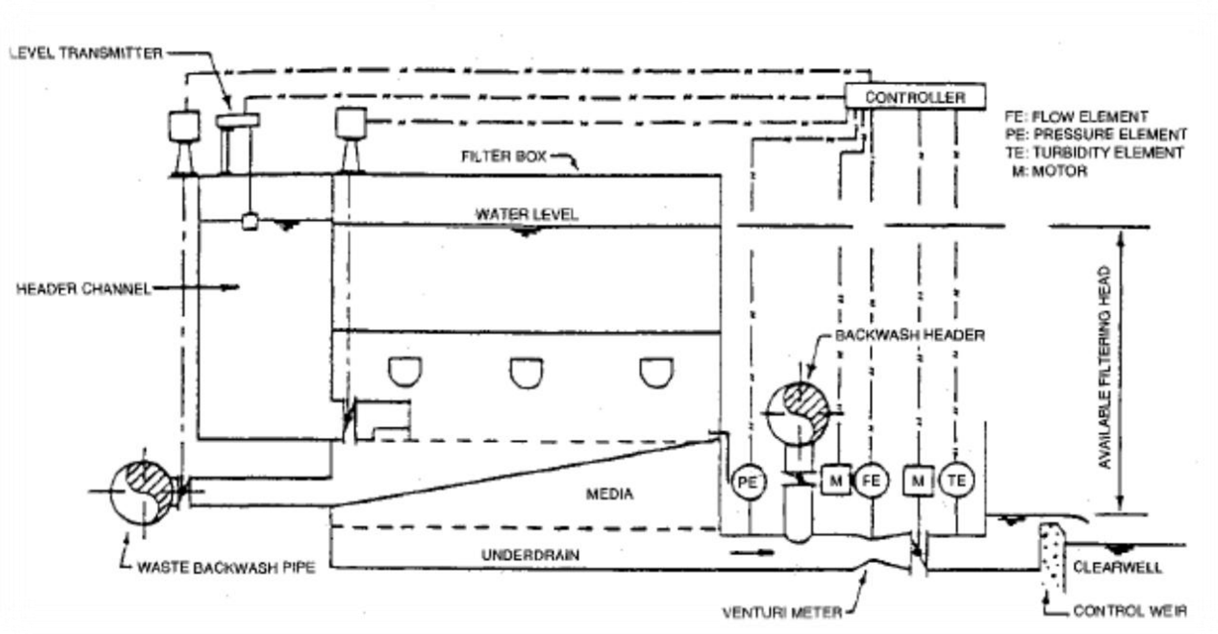

Fig (3.4): Constant-rate filter with rate –flow controller [**3**].

Chapter Four

OXIDATION AND DISINFECTION

4.1. __Oxidation and Disinfection__

The principal health risk from drinking water in most locations is waterborne diseases from microbial contamination. According to the World Health Organization, an estimated 1.7 million deaths a year can be attributed to unsafe water supplies. Within the United States, waterborne diseases are a lower risk, but serious outbreaks still occur with some regularity. The Centers for Disease Control and Prevention (CDC) reported that for the 24-month period, there were 39 outbreaks of waterborne disease associated with drinking water in 25 states. Of the outbreaks for which the cause was identified, 90% were associated with pathogens, and the remainder were associated with chemical poisoning.

Most outbreaks in community systems are a result of improper treatment or breaks
in the distribution system that allowed for system contamination. Consequently, recent regulations have emphasized improved microbial controls through multicarrier techniques including improved watershed protection to minimize contamination at the source, filtration for contaminant reduction, disinfection for inactivation of the remaining pathogens, and residual disinfectant for the distribution system. Also, recognizing that encysted waterborne protozoan's are more resistant to traditional disinfection practices, the regulations are forcing higher levels of disinfection and use of alternative technologies. Concurrently,

other regulations seek to reduce the levels of disinfectant chemicals and their reaction byproducts, which are considered long-term health risks. This, then, is the designer's challenge, to provide comprehensive microbial reduction to minimize the risk of waterborne disease while also minimizing the formation of disinfection by-products. This chapter provides a discussion of chemical oxidants that can be used for disinfection, as well as other treatment objectives. Disinfection by ultraviolet light (UV) is covered. The concept of waterborne disease was first realized in the during a cholera epidemic in London. But it wasn't until almost 20 years later that Louis Pasteur and Robert Koch developed the germ theory of disease, and it was another 30 years before the regular use of disinfectants to kill the germs. Continuous chlorination was used for the first time in Lincoln, England, in to arrest a typhoid outbreak. Since that time, disinfection has become an accepted water supply practice throughout the world. Chlorination has been the dominant method employed, but ozonation has been widely used also. There has also been increasing use of chlorine dioxide as a disinfectant in the United States and Europe. Some of the physical constants for the three most common disinfecting agents, chlorine,
ozone, and chlorine dioxide, are listed. Note that all three normally exist as gases, although chlorine dioxide liquefies at a temperature near 10 ° C. Chlorine is available as a compressed liquid, but ozone and chlorine dioxide must be manufactured on-site (ozone because it decomposes, chlorine dioxide because it is dangerous to store in a concentrated compressed form). Chlorine can also be provided as one of the hypo chlorites available as a bulk liquid or generated on-site. Oxidants are used in water treatment to accomplish a wide variety of

treatment objectives besides disinfection, including mitigation of objectionable tastes and odors, removal of color, removal of iron and manganese, and oxidation of organic chemicals. Oxidation of contaminants in water by means of aeration is covered in detail in Information on the chemicals used in water treatment is provided in Appendix A . Information on chemical handling and chemical feed equipment is covered in. For additional information on the theory and chemical reactions involved in oxidation and disinfection, refer to the companion text Water Quality and Treatment. Disinfectant Contact Requirements. Most water systems using a surface water source must use sedimentation and filtration to ensure adequate removal of pathogens. Under the SWTR requirements, only water systems with extremely low-turbidity source water may be allowed to operate without filtration, and then it is under very stringent operating and monitoring conditions. All surface water and GWUI systems, whether they provide filtration

or not, must practice disinfection under highly specific conditions. Disinfection requirements must be met prior to the water reaching the first customer. The effectiveness of a chemical disinfectant in killing or inactivating pathogens depends on:-

• The type of disinfectant used
• The disinfectant residual concentration (denoted by C)
• The time the water is in contact with the disinfectant (denoted by T)
• Water temperature
• The pH of the water, which has an effect on inactivation if chlorine is used

The residual concentration C of a disinfectant in milligrams per liter (mg/L), multiplied by the contact time T in minutes, is called the CT value. The *CT* values required by the SWTR to guarantee the necessary reduction in pathogens by various disinfectants may be obtained from tables in publications referenced at the end of this chapter. Each water system's treatment must be sufficient to ensure that the total process of removal plus inactivation achieves at least 99.9% (3-log) inactivation or removal of *Guardia* cysts and 99.99% (4-log) inactivation or removal of viruses. Source waters that are particularly vulnerable to microbial contamination may require greater log reductions, at the discretion of the primacy agency. Credit for physical removal of pathogenic organisms is given to properly operated filtration processes, as indicated in. The remaining log inactivation is required to be achieved by the disinfection process. Application of the *CT* concept is discussed further under the design consideration section for each oxidant. Approval of Lower CT Values. The *CT* values presented in the tables provided by USEPA are generally considered to be conservative. Each primacy agency may allow lower *CT* values for individual systems based on on-site studies showing that adequate inactivation is achieved under all flow and raw water conditions. Protocols and requirements are extensive but may be justified for systems that have unusual circumstances warranting the studies. Single Point of Disinfection. Systems with only one point of disinfectant application may calculate the *CT* that is being achieved by the entire system by measuring the disinfectant residual at the exit of the contact volume. The multiplication of this residual concentration C and the contact time T through all basins and piping from the application point to the measurement point will provide a conservative *CT* value. This is the simplest calculation, but as indicated in , this simple *CT* calculation does not take credit for the higher disinfectant residual that exists in the contact volume prior to the exit. An alternate method to calculate the level of disinfection is to use segregated flow analysis (SFA). SFA estimates disinfection in a contact volume by calculating disinfection in a number of theoretical "packets" of water that enter the contact volume. Some packets have very short contact times T but are exposed to high disinfectant concentrations C, while other packets have very long contact times T but are exposed to low disinfectant concentrations C. The *CT* values for each packet are estimated by multiplying the disinfectant residual with time curve C and the "F curve" T from the tracer test of the contact volume. The *CT* value for each packet is used to calculate the log inactivation, and then all the log in activations are summed to calculate the overall level of disinfection in the contact volume. SFA is most applicable to disinfectants with rapid decay rates, such as ozone, because of the conservative nature of the To concept. However, SFA must be approved for individual systems by each primacy agency. A similar comprehensive approach is the Integrated Disinfection Design Framework (IDDF). Information regarding the IDDF. Multiple Disinfectants or Application Points. Systems that apply disinfectant at more than one point will have to profile the system by computing the *CT* for each section between application points. For some systems it may also be advantageous to divide the

treatment train into additional sections between the disinfection application points to achieve the greatest *CT* credit. Performance Ratio. The concept of performance ratio is a convenient way to monitor and report CT compliance because the required *CT* often varies with pH and temperature. The performance ratio (also called inactivation ratio) is the actual CT divided by the required *CT* and must always be at least 1.0. Many water treatment plants target a performance ratio in excess of 1.0 to operate at an increased level of safety and ensure compliance.

Variations in Peak Hourly Flow. The inactivation credit in each disinfection section of a system is to be determined under the conditions of peak hourly flow.

However, in some systems with large reservoirs, peak hourly flow may not occur at the same time in all sections. To simplify determination of peak hourly flow, USEPA suggests that *CT* values for all sections be calculated during the hour of peak flow through the last section. This is best determined by a flow meter immediately downstream of the last section. Determination of Contact Time. The contact time T used in calculating *CT* values is the time it takes water to move the residual is measured. This time T varies with the configuration and physical from the disinfectant application point to the point at which characteristics of each individual basin or conveyance, as short-circuiting will occur more in some basins or conveyances than in others. Contact Time in Pipes. The time during which water is in contact with a disinfectant while flowing through pipes is straightforward. It assumes that water moves in a relatively uniform manner between two points and can be calculated on the basis of uniform plug flow as:-

$$T = \frac{\text{internal volume of pipe}}{\text{peak hourly rate through pipe}}$$

Contact Time through Reservoirs. Under most conditions, water does not move through reservoirs, tanks, and basins in a uniform manner. Therefore the time T used to compute *CT* in reservoirs depends on the design of the reservoir, such as the shape, inlet and outlet design and locations, and the baffling. In general, reservoirs with a large length to- width ratio and with good inlet and outlet baffling minimize short-circuiting and provide the most uniform flow. The contact time used to calculate the *CT* is the detention time at which 90% of the water passing through the reservoir is retained within the reservoir--in other words, the time it takes for 10% of the water to pass through the reservoir. This detention time, or contact time, is designated as . The value for a reservoir at various flow rates may be determined experimentally by tracer studies or theoretically by approximation. The most accurate method of determining contact time through reservoirs is by experiments using tracer chemicals such as fluoride or lithium. The studies are performed.[**3**].

By feeding controlled amounts of the tracer chemical at the reservoir inlet and making repeated analyses of samples collected at the outlet. Unfortunately, both the contact time and the detention time under various flow rates are not linear functions, so it is recommended that tracer studies be performed using at least four flow rates that span the normal flow range. This information can then be used to construct a curve of detention time versus flow rate that can be used to determine T~0 at any flow with fair accuracy. Under certain conditions, the state primacy agency may allow the contact time for a reservoir to be determined by an approximation. The method involves multiplying the theoretical contact time (plug flow) of a reservoir by a rule-of-thumb factor that takes into consideration the reservoir design. Examples of reservoirs with poor, average, and superior

baffling conditions are shown in Figures(4.1), and(4.2). The shaded areas on the figures indicate areas with little or no flow (dead space) in both a horizontal and vertical perspective, which causes much of the flow to short-circuit directly from the inlet to the outlet. summarizes the baffling conditions and the proportion of the theoretical contact time for each classification.[**3**].

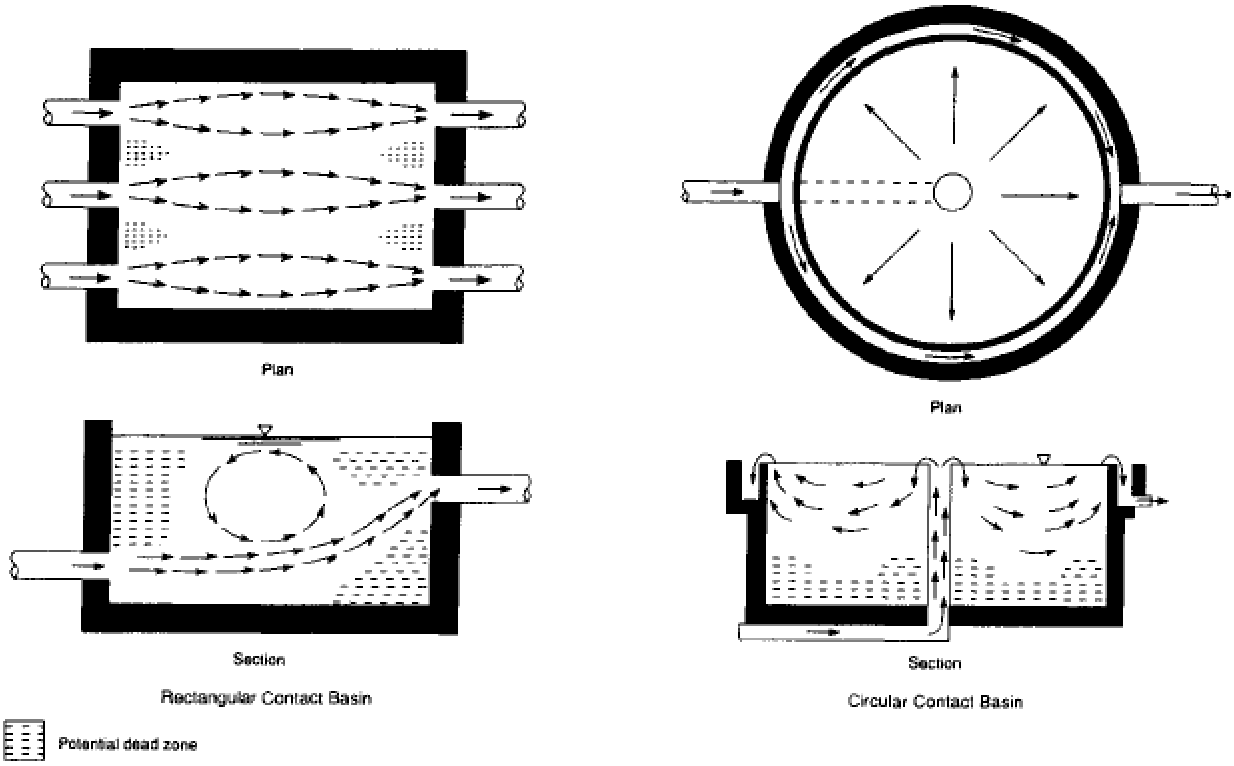

Fig (4.1): Poor baffling condition in basin[**3**].

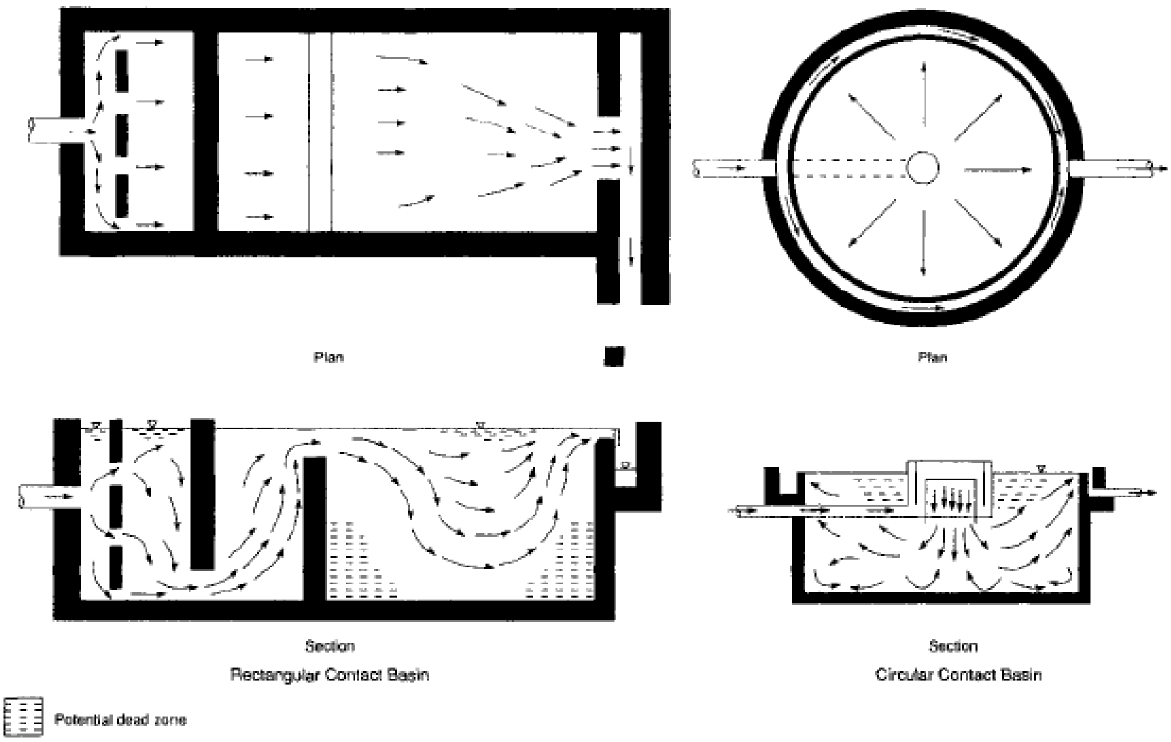

Fig (4.2): Average baffling condition in basin[**3**].

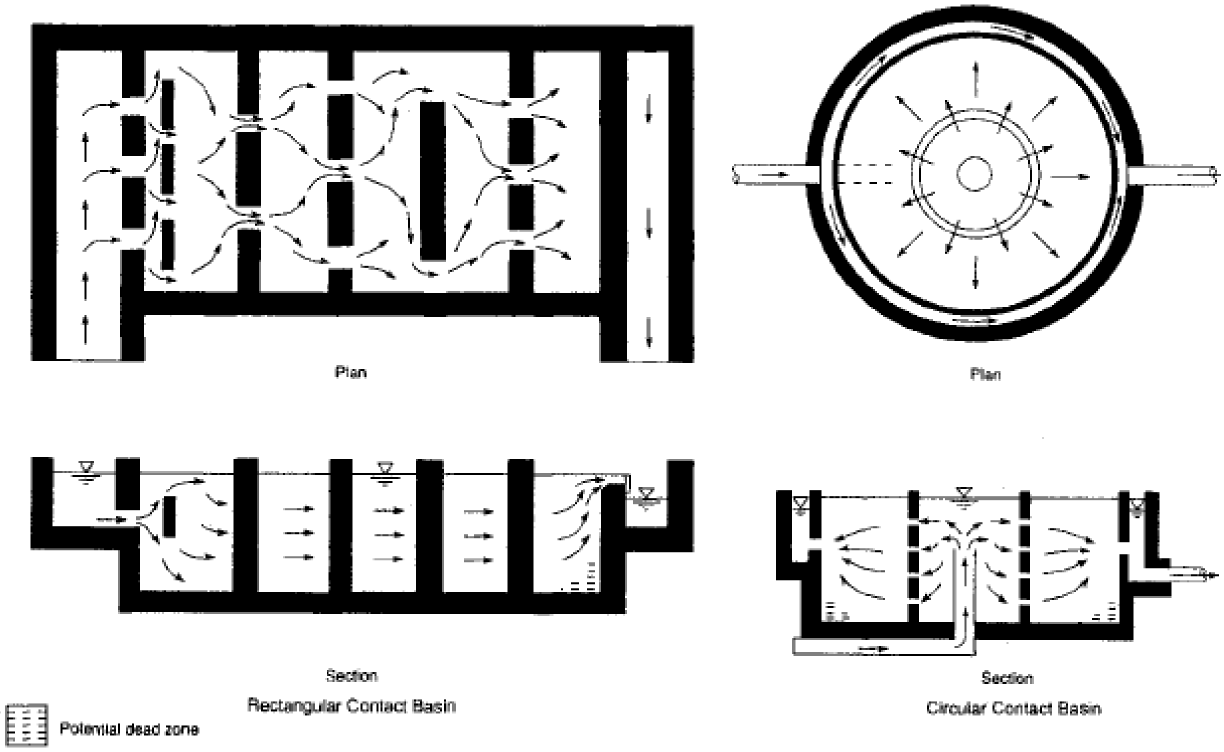

Fig (4.3): Superior baffling condition in basin[**3**].

4.2.<u>effect of water characteristics on health people</u>

4.2.1.<u>effect of hardness:-</u>

1.stauies and sediments that remain on showers and sinks.

2.Need large amount of soap when using for cleaning of cloth, hair,…etc.

3.Bad test and Oder .

4.If not treated will from a large on metal. Which will effect the performance of same equipments like greasers and washing machine, and will increase the power required to operate them.

4.2.2.<u>. effect of chlorine(cl_2)</u>:-

The large amount of the chorine may cause cancer to the people ,because the chlorine if compare with the organic material in water will from the chlorophorm which cause cancer .

4.2.3.<u>. effect of Ph</u>:-

The lower values of Ph in water effect the balance of the carbonate and be-carbonate and result is(co_2) release to water ,while Alkanitiy cause pipe erosion .

4.2.4.<u>. effect of magnesium(mg) and calcium(ca) </u>:-

Increasing the value of(mg) more than 125(mg/L), consider harmful to mans health and water consider not good for daily use .

4.2.5. effect of chlorides:-

If present in high concentration will effect pipe erosion also will effect the test if combined will sodium ion and will from (sodium chloride) (food salt).[4]

4.2.6. effect of water Temperature and conductivity :-

If increase more than (250c) the concentration of soluble salt will increase . and if help the increscent of (co_2) absorption and Ammonia from the atmospheric ,also the density will increase .

4.2.7. effect of Turbidity :-

Increasing the turbidity will head to probability of presence of bacteria and the mineral materials among the suspended solids . [4].