DEVELOPMENT OF A IRON REMOVAL PLANT FOR GROUND WATER BASED SUPPLY SYSTEM IN APARTMENT BUILDINGS

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DECLARATION

It is thereby declared that except for the contents where specific reference have been made to the work of other, the study contained in this thesis are the result of investigation carried out by the author under the supervision of Dr. Miah M. Hussainuzzaman, Associate Professor and Head, Department of Civil Engineering, Daffodil International University.

No part of this thesis has been submitted to any other university or other educational establishment for a degree, diploma or other qualification (except for publication).

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Finally, we would like to express a very special indebtedness to our Father and Mother whose encouragement and support was a continuous source of inspiration for this work.

DEDICATION

Dedicated

To
Our Family

ABSTRACT

Now a day's groundwater is one of the major sources of water supply in Bangladesh, though it has an excessive iron content. Iron exists naturally in, underground water in Bangladesh. Presence of iron has negative impacts on aesthetic features of supplied water. Besides this iron precipitations cause damage to sanitary and water supply fittings and fixtures. To avoid such nuisance and to improve the quality of life for the residences of an apartment building, a treatment plant to fit the demand of a typical apartment building is designed in this research project. This project considered the different water flow pattern for buildings as well as the space constraints and made adjustments for those matters. A small physical model is created and tested in a small scale to understand and demonstrate its efficiency.

সারমর্ম

বাংলাদেশের বড় বড় শহরগুলোতে ধীরে ধীরে জলাশয়ের পানি পরিশোধন করে সরবরাহ করা হলেও সব জায়গায় এটা সম্ভব নয় এবং বাকী অংশ এখনও ভূগর্ভস্থ পানির উপরে নির্ভরশীল। ভূগর্ভস্থ পানিতে প্রচুর খনিজ লৌহের (আয়রন) উপস্থিতি একটা সমস্যা কারণ এই লৌহের যৌগ বাতাসের সংস্পর্শে অদ্রবনীয় অধঃক্ষেপে পরিনত হয় এবং পানি সরবরাহ ব্যবস্থার বিভিন্ন স্থানে জমে পানিকে যেমন ঘোলা এবং অনাকর্ষনীয় করে, তেমনি ব্যবহৃত স্যানিটারী ফিটিংগুলোর গায়ে জমে এটার রং নষ্ট করে ফেলে। এছাড়া অধঃক্ষেপের স্তর জমা হওয়ার ফলে বিভিন্ন ফিটিংসের কর্মক্ষমতা হ্রাস পায়, পানি চুঁইয়ে পড়ার সমস্যাও সৃষ্টি করে। এসব সমস্যা সমাধানের জন্য একটা ভাল উপায় হতে পারে পানি পরিশোধনের ব্যবস্থা করা। যে সকল স্থানে প্রশাসনিকভাবে এটা করা হয় না কিংবা সুযোগ নাই, সেসকল এপার্টমেন্ট ভবনে ছোট আকারের একটি পরিশোধনাগার করা হলে তা সেই ভবনের জীবনযাত্রার মান বৃদ্ধিতে বেশ ভাল ভূমিকা রাখবে। এই গবেষনামূলক প্রকল্পে এপার্টমেন্ট ভবনে স্থাপনের উপযোগী পরিশোধনাগারের পরিবর্ধিত নকশা উন্নয়নের চেষ্টা করা হয়ছে। পাশাপাশি সেই নকশার ছোট প্রতিকৃতি তৈরী করে সরাসরি সেটার কার্যদক্ষতা দেখার ব্যবস্থা করা হয়েছে। বিশ্বব্যাপী করোনা মহামারী পরিস্থিতির কারণে কাজটি যথাসময়ে শেষ না হলেও নকশার নমুনা হিসাব এবং প্রতিকৃতি তৈরী করে সেটার কার্যকারীতা সীমিত আকারে পরীক্ষা করা হয়েছে। এছাড়া এপার্টমেন্ট ধরণের ভবনের পানি সরবরাহের ভিন্ন নিয়ম এবং জায়গার স্বল্পতা এই নকশায় বিবেচনা করে এজন্য উপযুক্ত পরিবর্ধন করা হয়েছে।

Table of Contents

CHAPTER 1: INTRODUCTION

1.1 General

An essential for [1]great wellbeing is an satisfactory supply of water that's of palatable sterile quality. It is also important that the water be appealing and tasteful to induce it utilize; something else, shoppers may choose to utilize water of doubtful quality from a adjacent unprotected stream, well or spring. In the urban regions, where a metropolitan water supply passes close a property, the proprietor of the property should be encouraged to associate to it since such supplies are usually beneath competent supervision. But when a metropolitan water supply isn't accessible, uncommonly in the provincial regions, the tubewell water is the most secure water source for drinking, individual cleanliness and other household purposes. DPHE, Bangladesh and other organizations introduce most of the tubewells used within the rustic regions. Ahmed[1] has watched that the greater the utilize of tubewell water for all household purposes the less is the rate of diarrheal assault. But the physical quality of water is a vital calculate for the acknowledgment of it to the rural individuals. Bacteriological quality carries small importance to the country individuals, they incline toward water which tastes great and is odorless and which does not alter the color of nourishment or does not stain dress.Ground water drawn from tubewells contain press in larger concentrations in numerous places of Bangladesh. An investigation made by Ahmed, Hossain, Khan and Badruzzaman[2] appears that in some places like Rajshahi, Jessore, Khulna, Kushtia, Rangpur, Kurigram, Pabna, Sirajganj, Tangail, Chittagong and several regions of Dhaka the concentration of press changes from to 5 mg/l and in a few places, it has been found as tall as 25 mg/l.

1.2 Explanation of the Problem

Groundwater of our nation more often than not features a tall press substance and in some regions, stores go distant past the resistance of local individuals. The nearness of press in water is objectionable primarily since the accelerates of these metals modify the appearance of water turning it turbid yellow-brown to dark. In addition, the statement of these accelerates stains dress and teeth. In spite of the fact that discoloration from accelerates is the most serious issue related with water supplies having excess iron, foul tastes and odors can be created by the development of iron bacteria. These filamentous microscopic organisms, utilizing diminished press as an energy source, accelerate it, causing pipe incrustations. Decay of gathered bacterial sludges makes hostile tastes and odors. Press substance water gives a taste to water which is depicted as metallic, astringent or therapeutic. At last, the accelerates of these metals may lead to trouble with water treatment 3 processes such as particle alter. Press meddled with laundering operations. It confers a taste to water which is recognizable at very moo concentrations. Iron-bearing waters are frequently called ferruginous water. They have a sharp taste and, in combination with the tanin, give an inky color to tea mixtures. They also impart a brown-colored store on vegetables amid washing and cooking. Water bearing press too by and large favors the development of several groups of microscopic organisms counting Crenothrix, Leptothrix etc. These bacteria require as it were a little sum of discuss to develop and since they flourish in dull, they may be found in pneumatic tanks, pipe lines or lifted capacity tanks. The fast development of these bacteria reduces the stream rates in or to a pipe line. In addition, if they break free, the expansive masses will clog spouts, lines and valves. The microbes as they rot confer a especially bad taste and odor to the water making it questionable to drink or utilize for sterile purposes. The issue of press expulsion because it is confronted by regions and industrial supplies is effectively taken care of, since they have large aeration types of gear and can utilize coagulation methods for precipitation and filtration. The most issue exists in removing iron from rustic water supplies e.g. hand tubewe11s etc., as the rural individuals have not one or the other any hardware for air circulation nor any chemical for coagulation or flocculation. Hence an press removal plant for handpump tubewe11 ought to ought to be planned so that it 4 can evacuate press from ground water without additional fetched of aeration or the expansion of chemicals for coagulation.

1.3 Basis of the Study

Water supply in Dhaka city & most other cities is from underground water between which iron is a common problem in Bangladesh. The cause of iron sludge are frozen in pipe and tank which passes through the tube well to the users. Due to the iron layer the water supply fittings are wasted fast and also geyser. Drinking water filters become jammed quickly that’s why filter has to be changed rapidly. Soap isn’t easily foam, as a result soap consumption rises. And sanitary fixtures are damaged by stains. Which all have an economical value. Creating & operating a treatment plant will not have the economic pressure and its one-time cost.

1.4 Objectives

This work has the following objectives:

- Design an iron treatment plant for an apartment building to supply pure water.
- Designed to fit the design of an apartment building with an underground reservoir.
- Design like that easy to operate and maintain.
- Creating a proportional model to examine the effectiveness.

1.5 Organization of the report

First chapter of this report includes the background, rational and objectives of this work. The second chapter describes the necessary literature that helps to explain the experiments and design background. The third chapter includes the planned and executed processes followed to achieve the objectives of this work. The fourth chapter analyzed the achieved data and presents the outputs supporting the stated objectives. The fifth chapter summarizes all the work and declares how much objectives are achieved or not. This chapter also describes the recommendations for further study in this context. References are accumulated at the last section.

1.6 Summary

This first chapter described the background and objectives of this experimental works. The next chapter explains all the necessary literature required to explain the works or designs.

CHAPTER 2: LITERATURE REVIEW

2.1 General

This chapter describes the necessary theory available to explain the problem as well as the design and testing procedures.

Groundwater is the major source of drinking water throughout the world. Iron being the fourth most abundant element and the second most abundant metal in the Earth's crust (Silver 1993;WHO 1996), it is a common constituent of groundwater. The presence of iron in groundwater is now considered to be a major problem throughout the world and produces numerous adverse effects. These problems are severe in the context of Bangladesh as groundwater is a vital source for the safe drinking water supply to its residential building's population. At present people use electric pump are regarded as the only means for collecting groundwater for drinking and other domestic purposes because of numerous socio-economical and technical reasons. High concentration of iron in groundwater which causes various problems is the main reason for this low consumption water supply.

2.2 Occurrence of Iron

The presence of iron in groundwater is generally attributed to the solution of rocks and minerals, chiefly oxides, sulfides, carbonates, and silicates containing these metals. Iron occurs in the silicate minerals of igneous rocks. Pyroxenes, amphiboles, and some micas generally contain iron. It also occurs in the form of various oxides, such as magnetite (Fe_3O_4.), hematite (Fe_2O_3), and limonite ($2Fe_2O_3 \cdot 3H_2O$). The sulfide and carbonate minerals are also important sources of iron. These include pyrite (FeS_2) and siderite ($FeCO_3$). Ferrous iron (Fe^{++}) is a soluble, invisible form that may exist in well waters or anaerobic reservoir waters. When exposed to air, this reduced form slowly transforms to insoluble visible, oxidized ferric iron (Fe^{+++}). Many ground water's are low in dissolved oxygen and are supersaturated with carbon dioxide, owing to weathering of carbonate rocks or to increased carbon dioxide concentration in the soil gas. The lower pH value of groundwater due to the presence of carbon dioxide and mineral acids and absence of dissolved oxygen creates favorable conditions to hold iron in high concentration in groundwater as ferrous bicarbonate [3].

$$Fe^{+2} + 2CO_2 + 2H_2O \dashrightarrow Fe(HCO_3)_2 + 2H^+$$

Iron may be present as soluble ferrous bicarbonate in alkaline well or spring waters; as soluble ferrous sulfate in acid drainage waters or waters containing sulfur; as soluble organic

iron in colored swamp waters; as suspended insoluble ferric hydroxide formed from iron bearing well waters, which are subsequently exposed to air; and as a product of pipe corrosion producing red water. Most soils, including gravel, shale and sandstone rock, contain iron. Decomposing organic matter in water removes the dissolved oxygen usually present in water; then the water dissolves mineral oxides, changing them to soluble compounds. Ferrous iron may be found in the lower levels of deep reservoirs, flooding soils, or rock containing iron on its compounds, hence it is best to draw water from a higher level, but below the upper portion, which supports microscopic growth like algae.

2.3 Iron Problem Areas of Bangladesh

Ground water collected through pump in Bangladesh carries a high concentration of iron and in many locations the concentration is much higher than the acceptable limit. Ahmed, Hossain, Khan and Badruzzaman [2] has prepared a map to show the distribution of iron in ground water of Bangladesh. The map has been presented in Fig 2.1. This map has been prepared compiling the available information about the ground water quality of the shallow aquifers. It has been observed that iron content of ground water in most of the places of Bangladesh is greater than1.00 mg/l and in many locations the iron content of ground water is more than 5 mg/l [2]. Fig. 2.1 also indicates that groundwater of about 65% of the area of Bangladesh has average iron content more than 2 mg/l.

The WHO (1983) suggested a guide line value of 0.3 mg/l for iron in drinking water. The limit can hardly be maintained in rural water supply in Bangladesh.

2.4 History of the Practice of Iron Removal

According to American Water Works Association [4] the first iron removal plant was constructed at Charlotte burg, Germany more than a century ago in 1874. In 1893, the first iron removal plant in the United States was placed in operation at Atlantic Highlands, New Jersey. The earliest plants employed aeration and filtration, sometimes supplemented by the addition of lime, to treat ground waters. The same method of treatment predominates today. By 1941 there were a reported 598 iron removal plants in the United States. The great majority served small communities and the total pump age was only 220 mgd(Millions of gallons per day) or as average of 370,000gpd per plant. By 1958, approximately 1340 water treatment plants, roughly 14 percent of the total in the United States, included processes for the removal of iron [4].

2.4.1 Previous Techniques for Iron Removal

According to Ahmed [5] iron removal at the attempted in some places of India and earthen pitchers placed one above the other. top pitcher dripped through a hole and pitchers filled with burnt wood charcoal and household level was Bangladesh with four Raw water from the passed through two sand. The treated water was collected in the bottom pitcher. Although it was a low cost system, it was very slow and unsuitable for all domestic uses. In some places a force and lift pump was used to spray the water onto a filter bed enclosed in a brick chamber and then allowed to pass through a gravel under-drainage system [5].

The filtrate was tapped slightly above the bottom. Efficient removal of iron was possible, but such type of a plant involved a high initial cost and the maintenance of a force pump, and frequent cleaning of the large filter bed was not easy. In other places, a 200 1 steel barrel, partially filled with filter materials, was placed below the discharge mouth of the hand pump by raising it to a higher elevated position from the ground [5]. Treated water was collected through a tap fixed at the bottom portion of the barrel. As the pump was fixed at a higher level, normal operation and maintenance facilities were greatly hampered. The operation and maintenance difficulties of the previous plants in rural areas led to the necessity to develop simple iron removal plants with easy operation and maintenance facilities which would be acceptable to rural people.

2.4.2 Some Other Research Works on Iron Removal

Wang [6] has shown that processes in which oxidation is followed by removal of suspended solids can effectively remove soluble iron and manganese from water. He has developed three common processes for removing iron and manganese, e.g., (1) aeration-filtration, (2) chlorination-filtration, and (3) potassium permanganate-manganese greensand filtration.

Ogedengbe, olasupo and adeniji [7] have shown that powdered palm kernel shells have good adsorption capabilities (surface area 22/6 sq.m/gm) and can remove taste, color, turbidity, acidity and iron from well waters, thus rendering them palatable. A simple household filter using powdered activated palm kernel shells has been constructed and tested.

Equina (1979) has made a study on the pretreatment of water containing iron and manganese using a horizontal-flow filter with crushed stone as the filter media., A regression analysis was made to determine the factor(s) affecting the filter performance. The length of the filter run was found to be the most important factor for the removal of iron from groundwater. At the filtration rate of 0.40 m J /m 2 /h, iron with the average concentration of 1.24 mg/L could be removed by 47 percent.

Zirschky and Carlson [8] have shown that overland flow, an effective waste water treatment process, can also be used for potable water treatment. Many groundwater contain excessive amounts of ferrous iron. that result in a water of poor aesthetic quality. The natural reaeration that occurs during overland flow oxidizes. ferrous iron to the more insoluble ferric form. The resulting precipitate then settles on the slope. An existing overland-flow treatment system in Salo, Finland, achieves 97 percent iron and manganese removal.

Kibret [9] has shown that dry filter is one of the alternatives that can be applied for iron. removal and the process uses the self purification capacities of iron bacteria. Investigations made on the pilot plants showed that iron removal process by dry filtration depends on the hydraulic load, filter depth, size of filter material, the development of the micro-organisms and iron concentration in the raw water. Dry filter does not only remove iron but it also removes manganese, ammonia, carbon dioxide and provides sufficient oxygen supply to the treated water. However, complete removal of iron by dry filter is feasible provided the best possible favorable combinations of the factors on which iron removal depends are found.

Frankel [10] has developed an appropriate technology type of water filter for supplying drinking water to rural communities in Southeast Asia. The filter consists of two stages, the first stage is made up coconut fibers and the second stage uses burnt rice husks. In. this type of filter, coliform removal as well as iron removal can be achieved. A typical design of a filter plant, whose total construction cost amounts to less than US$2 per capita, is shown for a community of 800 persons. It is believed that the quality of effluent from this treatment process is reasonably good for most villages where investment. in more expensive. water treatment plants simply cannot be afforded.

Bajracharya [11] has made a study which investigated the possibility of iron removal by a simple low-cost filtration technique, using coarse sand of effective size 3 mm and proposes a simple filtering unit that can be constructed in conjunction with hand pumps in iron prone areas. An attempt has been made to determine the possibility_ of backwashing under low heads.

2.5 The role of Iron in Geochemistry

According to Hounslow [12], the role of iron in geochemistry is very important. The reasons are;

a) Its natural abundance is high.

b) It is ubiquitous in occurrence.

c) It exists in two valence state.

d) At the aerobic-anaerobic boundary, iron changes from the ferric to the ferrous state.

e) It readily forms low solubility oxide-hydroxide and sulfide minerals, the former being ferric and the latter ferrous forms.

f) In aerobic waters, at a pH greater than about 3, ferric iron is quite insoluble and exists as a colloidal oxide-hydroxide. At a pH less than 3, ferric may become soluble, however, such conditions are unusual in most natural or polluted waters.

g) In anaerobic waters lacking hydrogen sulfide, soluble ferrous iron exists and moves readily in the subsurface. When such water becomes oxygenated, as for example at discharge zones of springs or rivers, reddish-brown ferric hYdroxide precipitates.

h) In anaerobic hydrogen sulfide waters, iron precipitates as iron sulfide .as mascavite or pyrite depending on pH.

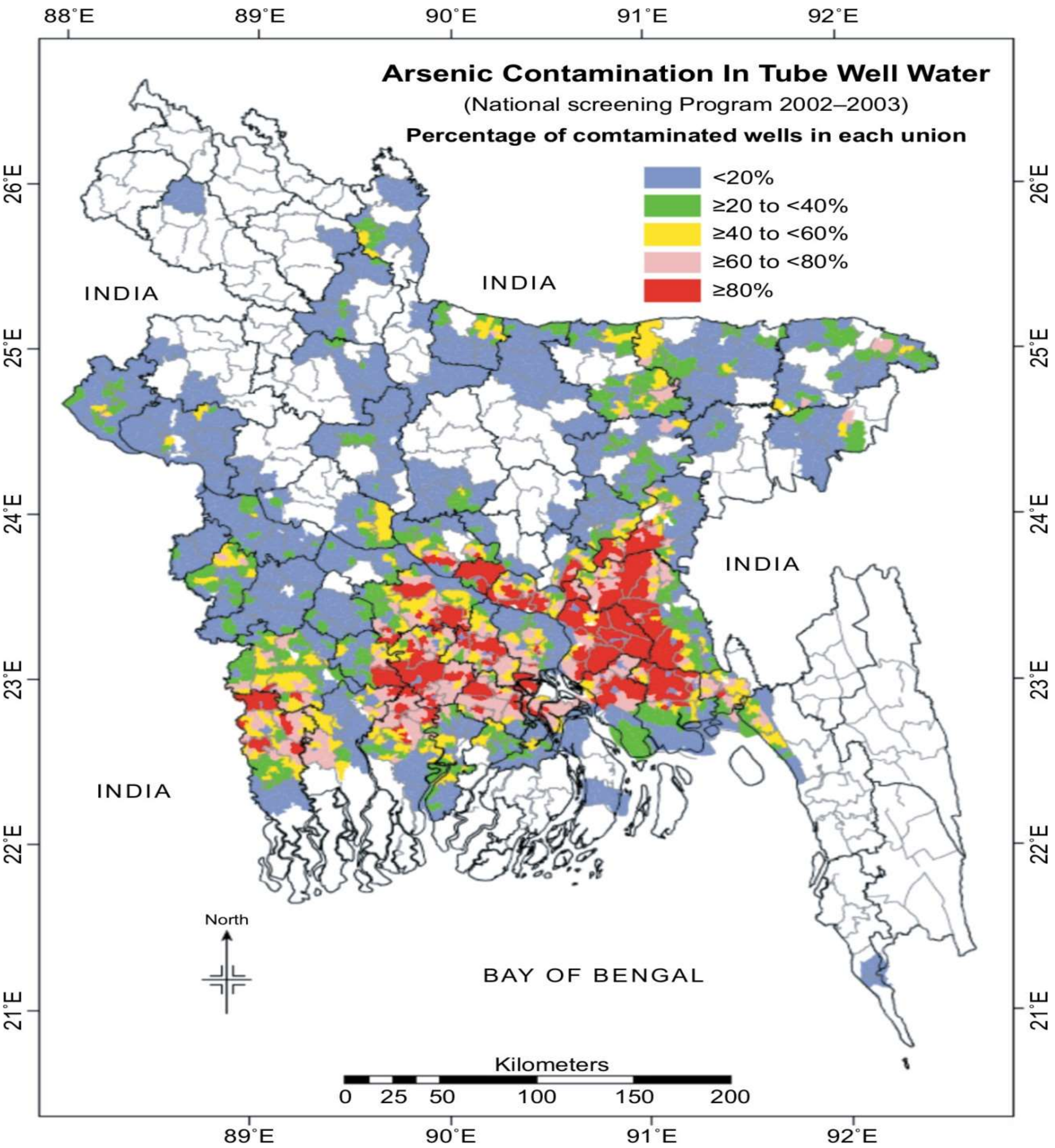

Figure 2.1: Arsenic contamination map of Bangladesh.

Source: National Arsenic Mitigation Information Center, BAMWSP

2.6 Chemistry Of Iron Removal From Ground water

Iron (II) is chemically a reduced and soluble form which exists in a reducing environment (absence of dissolved oxyzen and low pH). These conditions exist in groundwater and anaerobic reservoir water. When it is pumped from groundwater or anaerobic hypolimnion, CO_2 and H_2S are released, raising the pH. In addition, water become exposed to air creating an oxidizing environment. The reduced iron starts transforming to it's stable, oxidized, insoluble from of Iron (III)(Fe ll). The rate of oxidation of iron depends upon the type and concentration of the oxidizing agent, pH, alkalinity, organic content, presence of catalysts. In fact, the chemistry of iron removal in natural water system involves a number of factors like solubility of iron in water, oxidation and precipitation of iron, impact of organic complexing agents etc. [13]

2.6.1 Solubility of Iron

Ferrous iron as Fe{OH)$_2$ can dissolve up to 100 mg/L at a pH of 8 and upto.10,000 mg/L at a pH of 7. In the presence of CO_2 , the solubility of ferrous carbonate governs and is 1 to 10 mg/L for pH between 7 and 8 though it may

be up to 100 mg/L for pH 6 to 7. Organic substances, e.g., humic and tannic acids can create complexes with iron (II) ion holding them in the soluble state to higher pH levels. If a large concentration of organic matter is present, iron can be held in solution at pH levels upto 9.5 [4].

The solution of iron-bearing minerals is often attributed to the action of carbon dioxide in groundwater. Most of the carbon dioxide is presumably generated by the bacterial decomposition of organic matter leached from the soil. The solution of the minerals may take place under anaerobic conditions and in the presence of reducing agents (organic substances, hydrogen sulfide) capable of reducing the higher oxides of .iron to the ferrous, Fe (lI) states. Similar conditions are believed to be responsible for the solution of iron from the sediments of stratified lakes [14].

2.6.2 Kinetics of Iron oxidation And Precipitation

Rate of Iron Oxidation

The oxidation rate has been found to be strongly dependent on pH [15]. Various investigators have studied the rate of iron oxidation. At a pH equal or greater than about 5, the following rate law is applicable to the oxidation of iron(II) with molecular oxygen;

$(d[Fe(II)])/dt$= -K[Fe(II)] [PO_2] [OH^-]^2••••••• •••• •• (2.1)

Where

d[Fe(II)]/dt=Rate' of Iron (II) Oxidation, mol/ (L) (min)/.

Fe(II)= Ferrous ion concentration, mol/L

PO_2 = Partial pressure of oxygen, atmosphere

OH=Hydroxide ion concentration, mol/L

k = Reaction rate constant= 8.0 (+2.5)*10^{13} L^2/(min)(atm)(mol)^2 at 20.5^{0}C

All have concluded that the rate of ferrous iron oxidation is of the first order with respect to the ferrous iron concentration and the partial pressure of oxygen and second-order with respect to the hydroxide ion. The rate of oxidation of Fe(II) by oxygen is slow under condition of low pH as shown in Fig. 2.2. It has been shown [16] that oxidation of ferrous iron should be expected to Occur rapidly in well-oxygenated waters of pH values exceeding 1.2. In case of water having low pH, the pH value is increased by stripping carbon. dioxide or adding lime. Alternately, the rate of oxygenation may be increased by the use of catalyst. In the practice of iron removal, contact aerators and contact filters have long been in an effort to accelerate iron oxidation. The accumulations of deposited iron and bacteria on cokes, rocks, and sand grains were presumed to act as the catalysts.

Rate of Iron Precipitation

When groundwater supersaturated with respect to ferrous carbonate are aerated, the pH increases because of the loss of carbon dioxide, thereby further increasing the degree of supersaturation. As a result, the precipitate formed may be expected to contain both ferrous carbonate and ferric hydroxide. In Fig. 2.3 the rate of ferrous iron oxidation and rate of precipitation trends in water are plotted with time [5]. It is seen that the rate of precipitation of iron would therefore be determined by the rate of oxidation of ferrous iron plus the rate of ferrous carbonate precipitation.

2.6.3 Effect of Alkalinity

The concentration of iron found of solution of natural water is frequently limited by the solubility of its carbonate. Water of high alkalinity often therefore have lower iron content than the water of low alkalinity. For a given pH the solubility of iron carbonate in natural water is inversely proportional to the bicarbonate ion concentration [4].

Stumn and Lee [16] reported that the reaction rates obtained in solutions of lower alkalinities tend to be of smaller magnitude and more scattered than those obtained in solutions of higher alkalinities. Robinson and Dixon (1968)[17] mentioned that in order to obtain complete oxidation of the ferrous iron, the bicarbonate alkalinity of the water should be in excess of 100 mg/L as $CaCO_3$ Generally, if the concentration of alkalinity reaches 130 mg/L as $CaCO_3$ all of the ferrous iron will be oxidized almost immediately and any further addition of chemicals would appear to be unnecessary. Low alkaline water needs some oxidizing agent ($KMnO_4$) without raising pH and alkalinity or some chemical additive (Na_2CO_3)to raise both pH and alkalinity. Ghosh[15]observed that within a pH range of 7.49 to 7.78, an increase of alkalinity from 335 to 610 mg/L as $CaCO_3$, causes a 10 fold decrease in half-time.

2.6.4 Effect of Temperature

The reaction rate is dependent on temperature. For a given pH value, the oxidation rate increases about 10 fold for a 15°C increase in temperature, which is mainly caused by the change in hydroxile ion (OH-) concentration due to temperature dependence of the ionization constant of water [16].

2.6.5 Effect of Ionic Strength

Sung and Forbes (1984)[18] showed that the rate constant, K, is also a function of ionic strength and the presence' of complex forming anions. They observed a linear variation (decrease) of the rate constant up to an ionic strength of 0.25 Mole in their study. At values greater than this, increasing ionic strength actually increases the rate constant.

2.6.6 Effect of Chloride

Sung and Morgan [19] observed that chloride and sulphate ions have a significant retarding influence on the rate constant in the pH range from 6.5 to 7.2. Later, Sung and Forbes (1984) mentioned that for typical fresh water iron removal, chloro complexes of iron could probably be ignored, because the effect of ionic strength and chloro-complexation may not be as important as the effects of temperature and pH.

2.6.7 Effect of Organic Matter

The presence of organic matter often retards the oxidation rate [20]. Ferrous iron is capable of forming complexes with organic matter and, as such, is resistant to oxidation event in the presence of dissolved oxygen;

2.6.8 Catalytic Effects

For a given pH value and oxygen concentration, the addition of as little as 0.02 mg/L of cu^{2+} reduces the oxygenation time by a factor of 5 [16]. Sung and Morgan [19] studied the effect of ferric hydroxide on the oxygenation of ferrous iron and stated that auto catalysis is noticeable only for pH around 7 and above.Cox has described the use of contact bed oxidation in iron removal. The purpose of contact bed according to him, is to facilitate oxidation of iron or manganese through the catalytic action of previously precipitated oxides of these minerals on the gravel[19].

2.7 Unit Processes of Water Treatment

Process schemes for groundwater sources high in iron and manganese but with acceptable hardness, generally include a means of oxidizing and removing the precipitated iron and manganese compounds. Lime treatment is effective for iron and manganese removal but it is not economical unless softening is added. A general iron and manganese removal process is shown [20].

In water with high iron but low manganese concentration, only aeration and filtration may be required. In addition, coagulation, flocculation, sedimentation are needed when raw water has other unfavorable characteristics. The various unit processes of water treatment are described below:

2.7.1 Aeration

Aeration is the treatment process whereby water is brought into intimate contact with air for the purpose of

(a) Increasing dissolved O_2 ,

(b) Reducing dissolved CO_2, and

(c) Removing various organic compounds responsible for taste and odor.

In other words, it is a physical phenomenon in which gas molecules are. exchanged between a liquid and gas at a gas liquid interface. The solubility or addition of a gas depends on: it's partial pressure in the atmosphere in contact with water, the water temperature, and the concentration of impurities. The rate of precipitation or removal of a dissolved gas is controlled by the degree of supersaturation, the water temperature, and the interfacial area of a gas contact and water exposure

In iron removal process, aeration is required to precipitate the ferrous bicarbonate to ferric hydroxide in accordance with the following equations:

$$Fe(HCO_3)_2 \text{ ------------------------- } Fe(OH)_2 + 2CO_2$$

$$4Fe(OH)_2 + O_2 + 2H_2O \text{ ------------------ } 4Fe(OH)_3$$

In order that the reaction will go to completion and precipitate the ferric hydroxide, it is necessary that the pH approximately 7 or higher. If possible the reaction may take 15 minutes retention before it is complete and in some cases as much as 1 hour 'retention has been necessary [21]. The length of retention time depends on the degree of aeration and the dissolved oxygen content of the aerated water as it enters the retention zone. Aeration can be optimized by increasing contact time and interfacial area. In principle, following types of aerators are common for aeration purpose in groundwater treatment.

Gravity aerators

1 Cascades

The available difference of head is subdivided into several steps, expecting an increase of the amount of oxygen transferred. Water is allowed to fall as a thin sheet over one or more concrete steps.

For desorption of CO_2this increase is accomplished, because each step of a cascade leads to the formation of new interfacial area, promoting the desorption efficiency. Since the rate of oxygenation is primarily determined by the velocity of the nappe or its jets when submerging into the tailwater, sub division into several steps is likely to decrease the rate of oxygen transfer [22]. It gives 50-60 percent carbon dioxide ($C0_2$) removal (Walker, 1978)[21].

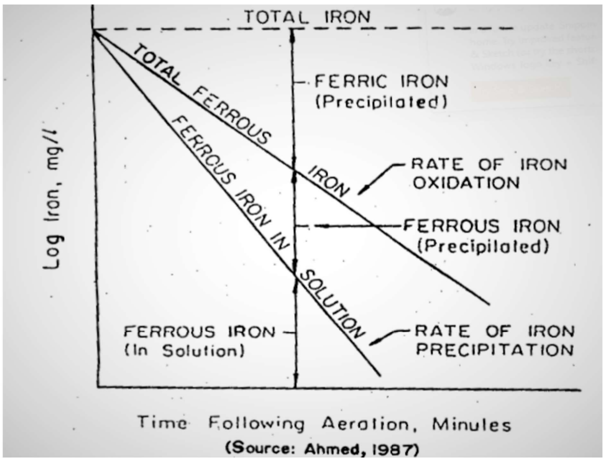

Figure 2.2: Rate of Iron Oxidation and Rate of Iron Precipitation [5]

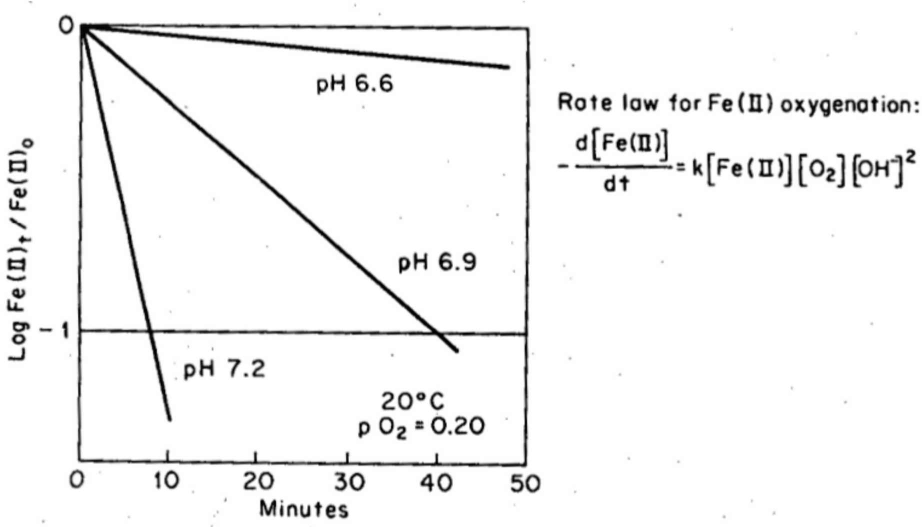

Figure 2.3: Oxygenation of Fe(II) [20]

2 Inclined aprons

It is often equipped with riffle plates to break up the sheet of water for surface renewal. Here water passes down as inclined channel fitted with studs or plates so that the flow is turbulent with a zigzag movement, 25-50 percent of carbon dioxide may remove here [21].

3 Tray Aerators

In these types of aerators water falls through a series of trays perforated with small holes. According to Walker (1978) the area of the trays required varies between 0.015 and 0.045 m^2 per cubic meter of water passing through each hour. Tray aerators are often built in stacks of four to six trays giving a total height of 1.2-3m. It gives 30-60 percent removal of CO_2•[21].

Spray Aerators

All the aerators discussed above can increase the dissolved oxygen in water to a desired extent. Among these spray aerators dissolve maximum amount of oxygen into water. By spray aerators the water is sprayed in the form of fine droplets into the air, thus, creating a .large gas-liquid interface for oxygen transfer. According to Walker (1978)[21] when water is already under a pressure head of 7 m or more, as when discharged from boreholes, it can be sprayed into basins through nozzles of special design. The basin should be large enough to catch wind-blown spray. up to 75 percent of the carbon dioxide can be removed in a spray aerator.

2.7.2 Flocculation

Flocculation is the process of gentle and continuous stirring of water for the purpose of forming floes through the aggregation of tiny particles present in water. It is thus the method of forming floes that can be readily removed by settling or filtration. The efficiency of the flocculation process is largely determined by the number of collisions between the particles per unit of time. There are two types of flocculators in use, e.g.

(a) Mechanical flocculators and

(b) Hydraulic flocculators. Mechanical flocculators require extra power.

In hydraulic flocculators, the flow of water is so influenced by small hydraulic structures that a stirring action results.

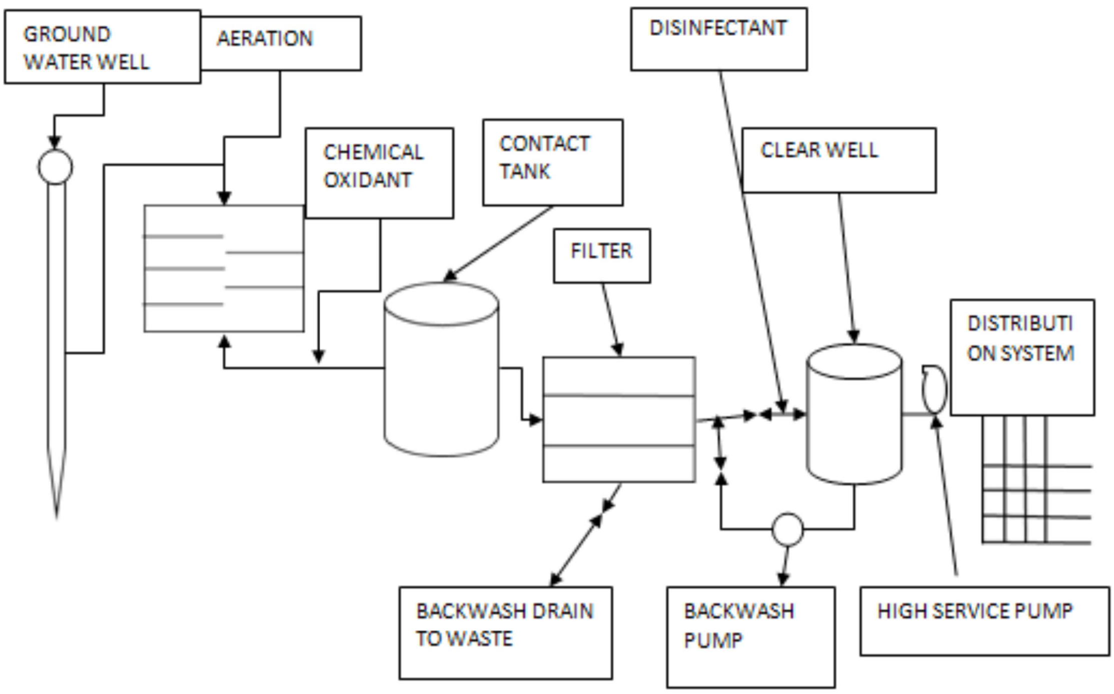

Figure 2.4: Typical iron and manganese treatment process from ground-water

Source:(A Handbook of community water supplies by American Water Warks Association.1990)

Typical examples of hydraulic flocculators are "gravel bed" flocculators. The particles come into contact with the gravels during converging flow. and. large floes are formed. The velocity gradient that is introduced into the bed is a function of the size of the gravel and rate of flow [14].

2.7.3 Sedimentation

Sedimentation is the process of separation of suspended heavier particles from water by gravity settling. The basic theory of sedimentation assumes the presence of discrete particles. When such a particle is placed in a liquid of lower density, it will accelerate until a limiting terminal velocity is reached.

The factors that effects sedimentation are, density of particle, density of water, size of particle, velocity of settling particle, drag coefficient, acceleration due to gravity etc. Sedimentation can be accelerated by increasing particle size or decreasing the distance a particle must fall prior to removal. The first is achieved by coagulation and flocculation prior to sedimentation. The second can be achieved by making the basin shallower or by providing tube settlers [13].

2.7.4 Filtration

Filtration is the process of water purification in which water is allowed to pass through a bed - a filter media usually of sand and gravel. The filter media are very efficient in retaining finer and colloidal particles of clay and silt. It also aids in removing color, odor, turbidity, iron and manganese. Three types of filtration are in use, e.g.,

Slow Sand Filtration (SSF)

Rapid Sand Filtration (RSF), and

Roughing Filtration

In SSF, high quality of treated water is found, since bacteria is almost completely removed. Its installation is limited by operational problem, for example, it can be operated satisfactorily with raw water of very low turbidity (20 NTU) [1].

RSF is quicker than SSF. Its efficiency in the removal of bacteria is less than that in SSF. Back washing is the main problem in RSF. Water of any turbidity can be used.

Roughing filtration uses much larger media than either SSF or RSF. The rate of filtration depends on (a) type of filter (b) the nature of the turbidity, and (c) desired degree of turbidity removal. Roughing filters are effective in removing Suspended solids. The raw water of turbidity 20 to 150 NTU [1] is used to prevent too frequent clogging and to ensure continuous operation for an extended period of time

According to Huisman et al.[23], a short comparison among Slow Sand Filter, Rapid Sand Filter .and Roughing Filter can be made as follows:

Slow Sand Filter

Rate of filtration = 0.1 – 0.3 m/hour (2-3 m^3/m^2/day)

Medium size = 0.15 – 0.35 mm

Bed thickness = 1.0 - 1.2 m

Suspended matters are retained in the upper 0.5 - 2.0 cm of filter bed.

Rapid Sand Filter

Rate of filtration = 5-15 m/hour (120-360 m^3/m^2 /day)

Medium size = 0.4 - 1.2 mm

Roughing Filter

The depth is divided into three layers; grain sizes of each layer are as follows:

1st layer = 10-15 mm

2nd layer = 7-10 mm

3rd layer = 4-7 mm

Rate of filtration = 0.5-4 m/hour; but the rate can be increased upto 20 m/hour.

Another possibility is the use of Horizontal filters. The depth is normally taken from 1 to 2 m. The filter is divided into three zones, each 5 m long. The. gravel sizes of each zone are 20-30 mm, 15-20 mm and 10-15 mm respectively. The horizontal flow rate is 0.5-1.0 m/hour [23]

2.7.5 Rates of filtration

The traditional rates for rapid filtration were 5 m/h, traced to the historic study of G.W. Fuller at Louisville in the late 1890s. Many studies in the 1950s and1960s, however, led to the wide use of rates up to 10 m/h, even with conventional sand medium and pretreatment schemes using only aluminum or iron salts for coagulation.

Increasing the filtration rate shortens the filter cycle roughly inversely with the rate. This problem was minimized by the use of dual or triple media filters that have become increasingly common in "high-rate" plants since the 1950s. These filters provide for better penetration of solids into the anthracite coal layer, which has a larger grain size than the traditional sand filter, and thus better utilization of the medium for solids storage during the filter cycle. The advent of synthetic organic polymers to assist both coagulation and filtration has permitted higher rates without deterioration of filtrate quality. Thus, the common high-rate filter plant today may use filtration rates up to 15 m/h and usually is equipped with dual- or triple-media filters and with filter aid polymer feed systems. In the United States, acceptance of high rates varies among state regulatory agencies, however, and plant or pilot-scale demonstrations may be required by some state agencies prior to acceptance.

Since about 1970, a few reports have been made of radically higher filtration rates in some plants, for example, 24 m/h at Contra Costa, Calif., and 33 m/h for the new Los Angeles direct filtration plant. The latter filtration rate was selected and approved by the state after more than 5 years of extensive pilot-scale studies. Both cases involve treatment of high-quality surface water in large plants with well-qualified management and operation. Thus, filtration rates of these magnitudes probably will not become common. With poorer source water and in smaller plants with less careful surveillance or operation, lower filtration rates will continue to be the prudent choice [20].

2.8 Common. Iron Removal Methods

There are four general methods used for the control of iron in public water supplies. The primary method involves precipitation followed by filtration. The second method involves ion exchange, and the third method involves stabilization of iron in suspension using dispersing agents to prevent the deposition of iron. Lastly the fourth method involves iron removal in the aquifer.

More specifically, the treatment processes or techniques employed in the control of iron deposition are summarized as follows:

1 **Precipitation and Filtration**

a Aeration, detention, filtration (with supplementary chlorination and/or the addition of lime).

b Oxidation by potassium permanganate, chlorine, or chlorine dioxide followed by filtration.

c Calcined magnetite - diatomaceous earth filtration

d Dry filtration

2 **Ion Exchange**

The use of water softeners for iron and manganese removal is fairly common. Due to the divalent nature of these compounds, they are readily removed on ion exchange materials. Generally following two process are available in this method [24].

a Ion-exchange (zeolite softening)

b The manganese - zeolite process

3 **Stabilization with Polyphosphates**

Polyphosphate can be instituted quickly and economically to control the precipited iron and manganese. The polyphosphate reacts to complex the iron and hold it in solution so that the consumer is not aware of it's presence.

4 **Subterraneous Removal**

The principle is oxidation of iron and manganese in the aquifer. Thus iron and manganese free water is extracted after injection of smaller amount of oxygen saturated water [24].

The above methods can be renamed and rearranged as follows:

1. a) Aeration - Filtration Method

   b) Iron Removal by Chemical Precipitation

   c) Dry Filtration Method
2. a) Water Softening Method

   b) Manganese Zeolite Process
3. Stabilization Method
4. Subterraneous Removal Method

2.8.1 Aeration-Filtration method

Aeration-filtration equipment typically includes an aerator, retention tank and filters. Oxygen (from the atmosphere reacts with iron in raw water to produce relatively insoluble salts of ferric oxide. The rate of reaction depends on pH. Retention time of several hours may be necessary after aeration depending on raw water characteristics. Sometimes sedimentation tanks with sludge collection and removal facilities are used instead of a simple retention tank if iron concentration is high. Pressure filters preferably with dual media of anthracite and sand are used to remove iron. The major disadvantage of this method is that the initial cost is high.

2.8.2 Iron Removal by Chemical Precipitation

Iron and manganese may be removed from water by various means. The most popular approach utilized in the United States involves oxidation of the more soluble iron(II) and manganese(II) sometimes en-countered in natural water to relatively insoluble iron(III) and manganese(IV) and subsequent removal of the precipitates thus formed by filtration. Molecular oxygen, free available chlorine, and potassium permanganate have all been used successfully as oxidizing agents. Because unnecessary application of chlorine in drinking water treatment is now generally discouraged, the use of chlorine as an oxidant should be viewed with caution. Both iron and manganese are effectively removed via precipitation softening, but the process is generally much costly to consider for iron removal alone [20]. Major disadvantages of this process are high operational costs associated with chemical requirements and filter bed deterioration if the pH falls below 7.1 . In some cases, chlorine is used in conjunction with $KMnO_4$to reduce chemical costs.

2.8.3 Dry filtration method

The characteristic difference is that rapid filters are submerged and dry filters are not. Together with water, air is drawn through the filter bed. Dry filtration was applied for the first time about a century age, the theory of their function however dates from the fifties. In this method with laminar flow, only a small part of the molecules to be removed come close to the catalytic active surface layer. When the flow is turbulent, more molecules approach the grains. Turbulence can be increased by raising the filtration rate, but it does not disturb a laminar layer on the grain surface. Dry filtration means that water and air simultaneously pass the bed. With air in the pores, the water trickle as down along the grains in extremely thin [25].

2.8.4 Water softening method

Lime-soda softening can remove iron. If split treatment is employed, $KMnO_4$can oxidize iron in water by passing the first stage excess lime treatment. Lime treatment has been used to remove organically bound iron from water. The process scheme aeration - coagulation - lime treatment - sedimentation-filtration can treat surface waters containing color, turbidity, and organically bound-iron.

2.8.5 Manganese Zeolite Process

Manganese zeolite is made by coating natural green sand (glauconite) zeolite with oxides. Manganese dioxide removes soluble iron until it becomes degenerated. The filter is regenerated using $KMnO_4$

$$Z - MnO_2 + Fe_2 \text{ --------------------------- } Z - Mn_2\,O_3 + Fe^{3+}$$

$$Z - Mn_2O_3 + KMnO_3 \text{ - - - - - - - - - - - } Z - MnO_3 \text{ (Regeneration)}$$

Manganese zeolite filters are generally pressure types. Disadvantages of the regenerative - batch process are the possibility of soluble manganese leakage when the bed is nearly degenerated, and the waste of excess $KMnO_4$ needed to regenerate the green sand.

2.8.6 Stabilization Methods

The alternative to iron removal is stabilization or dispersion. According to Clark et al.[26], sodium hexameta-phosphates at dosages of 5 mg per mg of Fe plus Mn have been used for this purpose. While this treatment will stabilize iron in suspension, it is reportedly not suitable where iron concentration of I mg/L exceed. Moreover, when the water is heated, the polyphosphate will revert to orthophosphate and lose its dispersing properties. The application of polyphosphate must take place prior to aeration or chlorination because the polyphosphate does not effectively stabilize precipitated ferric hydroxide. Polyphosphate dosages are limited to less than 10 mg/L because the availability of phosphorus may stimulate bacterial growth in distribution system.

2.8.7 Subterraneous Removal Method

With conventional iron removal, adsorption follows oxidation, with dry filtration they occur almost simultaneously and with subterraneous iron and manganese removal, adsorption is followed by oxidation. The principle is oxidation of iron and manganese in the aquifer, iron and manganese free water is extracted after injection of smaller amount of oxygen saturated water.

The designers themselves give an explanation for the good performance of the activity of aerobe iron and manganese oxidizing micro-organisms. By injecting oxygen-saturated water in an aquifer the anaerobic groundwater is forced back, leaving behind the constituents absorbed on the grains. There upon these constituents (Fe^{2+} and Mn^{2+}) are oxidized by the oxygen of the injected water and Fe_2O_3 and Mn_3O_4 (or Mn_2O_3,MnO_2) is been formed on the grains.

All Fe^{2+} and Mg^{2+} approaching the well will be retained until the absorption sites are spent. Subsequently the iron and manganese will reach the well and be extracted. Then the time has come to inject new oxygen-rich, degassed water into the well and the same process repeated [25].

CHAPTER 3: METHODOLOGY

3.1 General

This chapter describes the step by step processes followed to achieve the objectives of this work. The overall outline of the methodology is as follows:

1. Study the existing technology.
2. Study the existing plants so that they can be adapted to the design.
3. Create model.
4. Operate model.
5. Iron test by refined samples.
6. Primary detail drawing for a few different needs.
7. Estimation of materials.

The background and study on the existing technology and plants were covered in the previous chapter. Here the following steps are described.

3.2 Study and selection of design components

The use of space in buildings are limited and studied carefully so that the new design does not interfere with the regular functions of the residence. A suitable position and technique was selected in this part so that it makes sure the best use of the precious space.

3.3 Create a model

A small model of the treatment plant was constructed using available materials to demonstrate and understand the behavior of the system under new arrangements, so that the final design parameters can be realized.

Materials used to construct the model are as follows:

- Plastic Bucket: 30 litter – 1 pc.
- Rectangular plastic container with lid: 20 litter – 1 pc.
- Bib-cock
- Drinking Straw required according to design
- Super Glue

Figure 3.1 Shows the arrangement of the elements in the model of the treatment plant. The lid of the rectangular box was separately laid on upside-down and has been used as an aeration plate for the raw water coming from the bucket. The water than falls inside the rectangular sedimentation chamber from one edge. The drinking straws are glued together

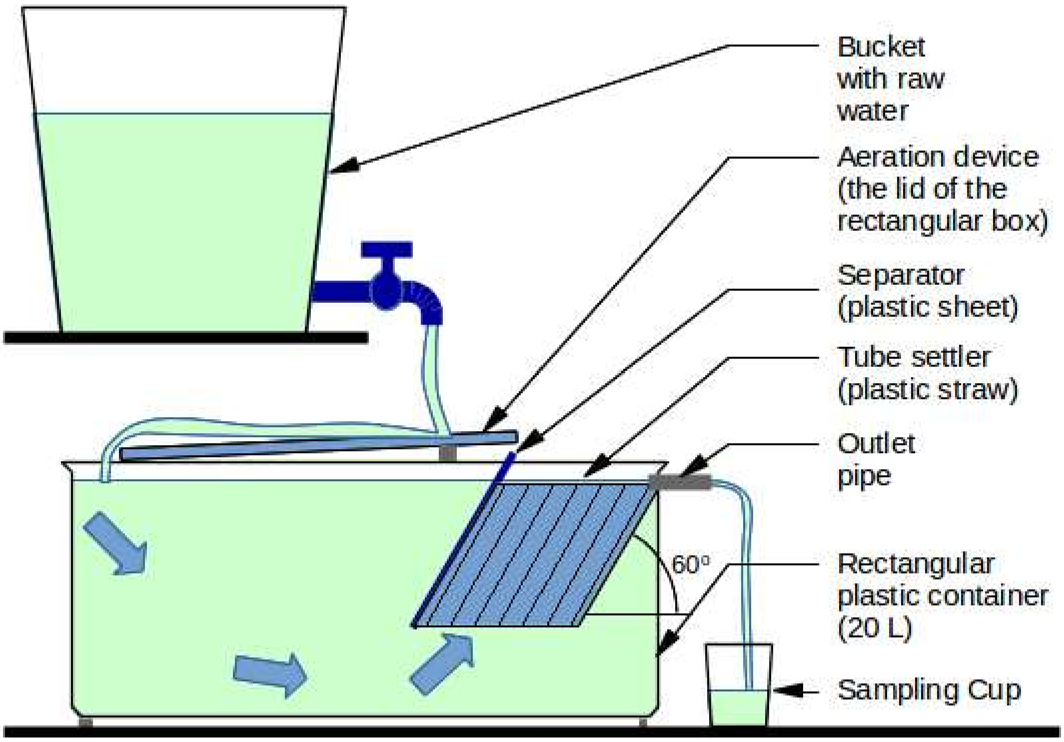

Figure 3.1: Sketch of experimental model setup

to form the tube settler and was glued to the rectangular container so that its axis makes a 60° angle with the plane. A plastic sheet, collected from a plastic file cover is also glued to make a separator so that water flow is guided through the tube settler.

Two overflow pipes were fixed with the two overflowing holes at the other edge of the rectangular container so that water flows out of them after being passed through the tube settler.

3.4 Operate the model

3.4.1 Selection of a water source

To operate the model the first priority was to find a suitable source of ground-water which contains high amount of iron. Sample for two tubewells were tested and proved to be not suitable for this experiment as they have trace amount of iron. Later, an apartment complex was selected where high iron concentration of supply water was reported as a main problem.

There were four deep tubewells to extract groundwater for the large apartment complex. The tubewells are operated by the operator at certain times and it was not possible to arrange the experiments run with that water on the site as it was located far away from the lab.

Therefore the experiments were run with the tap water from that apartment complex. Tap water was tested for iron concentration.

3.4.2 Conduction of performance test

Iron precipitates were collected from water boiling utensil and were mixed with tap water to get a murky water for the testing.

Another batch of murky water was created by mixing fine dust/soil to the water. The test was conducted just to see the sedimentation performance of the model before starting the testing with finer iron precipitate spiked raw water. Flow rate was controlled by controlling the bib-cock to deliver the water in a way that certain amount of water is released in a certain time. Several trials were performed using this technique.

Samples were collected from the overflow water by a glass and turbidity checked with eye estimation. All these initial tests were conducted to visually observe the sedimentation

Figure 3.2: Conduction of field test

performance of the constructed model. Transparency of the effluent was visually compared with the fresh tap water.

3.5 Measurement of Iron concentration

The sample are collected from several location of the plant and tested according to the following procedure. the all laboratory tested use kit

Procedure:

- Remove the cap from the plastic vessel. Rinse the plastic vessel with water sample, fill it to 10ml mark.
- Add 1 packet of iron reagent (HI3834-0)
- Replace the cap and mix solution until solid dissolve.
- Remove the cap and transfer the solution into the color comparator cube. Let set for 4 minutes.
- Determine which color matches the solution in the cube and record the result as mg/l (ppm) iron
- Calculation: The amount of iron present in the sample mg/l= ml of the standard iron solution used.

3.6 Primary detail drawing for a few different needs.

A preliminary drawing was made for the stated treatment plant, which shows the tentative arrangements of the different elements and its positioning in the apartment building. Sizing for appropriate demand shall be done in the follow up project.

3.7 Estimation of materials

This project had intension to investigate and prepare a detailed design and estimate of the cost and materials for the stated treatment plant so that a complete package can be offered to the client. But this step could not be completed due to lack of progress in the previous step and is planned to be done in the follow up project.

CHAPTER 4: RESULTS AND DISCUSSION

General

This chapter presents the results of the works as described in the previous chapter and explains those outcomes. The following sections present the outcomes of the activities sequentially.

4.1 Model Selection

Positioning: Space is very costly in apartment buildings. Even the space on the ground surface is important to construct parking space. A place above requires heavy construction to carry all the load of the instruments of the treatment plant (IRP). On the other hand, utilities like septic tank or underground water reservoirs are constructed below plinth level without hampering any activity on ground or plinth level. Therefore, the position of the treatment plant should be placed below plinth level. Water from ground water will flow to this treatment unit first and will then overflow to the underground reservoir (UGR). A backwash pipe, that brings cleaned water to this unit from the overhead tank (OHT). Figure 4.1 Shows the positioning scheme.

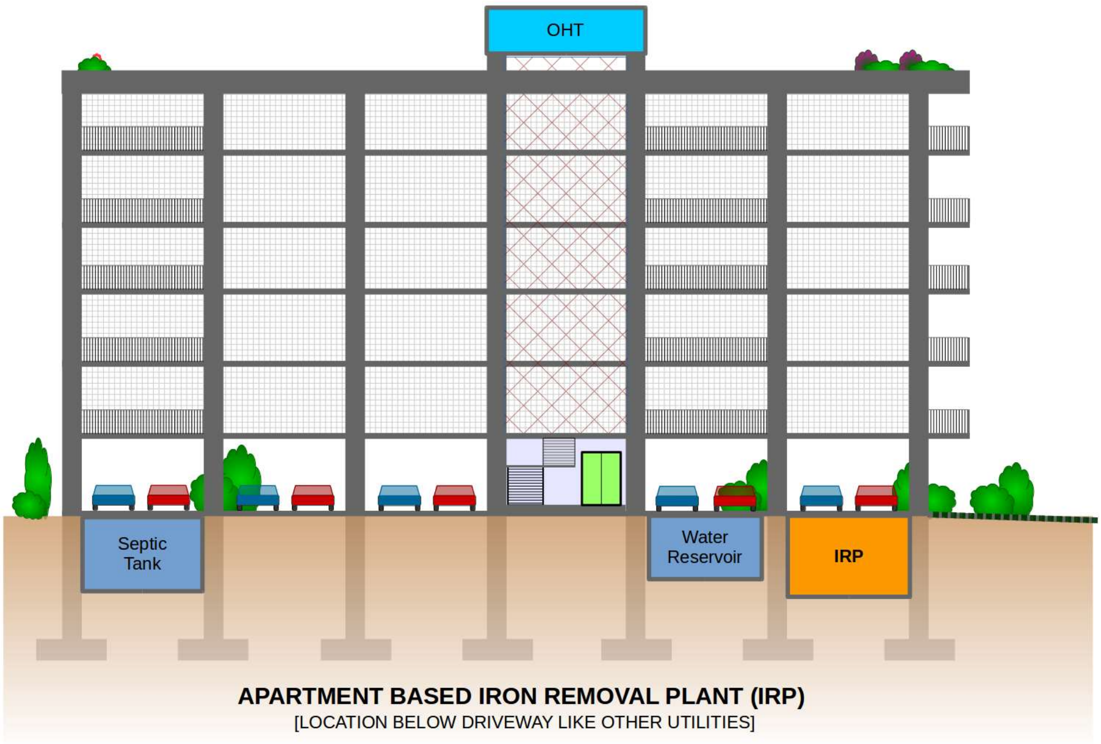

Figure 4.1: Positioning of the Iron Removal Plant (IRP)

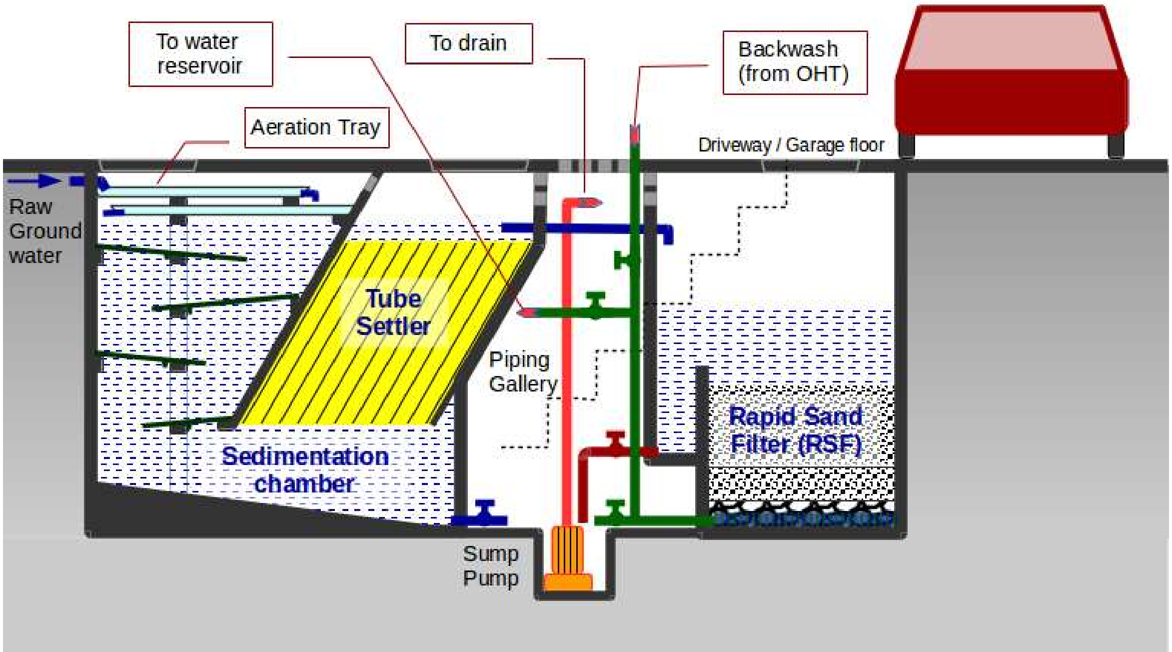

Figure 4.2: Functional units of the treatment plant (IRP)

Functional elements: The most natural way of iron removal by aeration – precipitation – filtration process is selected for the iron removal plant (IRP). Tube-settler system is adopted to enhance the settling performance. A backwashing system will be included for the rapid sand filter (RSF) unit. Piping gallery will have a sump pit to accumulate the sludge discharges from the sedimentation chamber as well as the backwash effluent from the RSF. A sump pump will be placed to drain the sump-pit to the existing building drain. Necessary trap-door/ hatch door and stairs will be provided to provide easy access to the piping gallery for regular operation and maintenance works. Figure 4.2 Shows a sectional schematic diagram of the arrangements.

4.2 Operation of the model

4.2.1 Difficulty in finding raw water source

It was difficult to find a proper source of groundwater with sufficient iron content to run and test the model treatment unit. Even though the selected apartment building had severe problems of dissolved iron in the the source water, it was difficult to get that water directly due to the pumping schedule. The well was located within the apartment premises and is not operated round the clock. Generally, the well is operated early in the morning and in the late evening to extract water to the UGR. Therefore, it was impossible for the research team to get that water directly from the pump outlet.

The extracted groundwater gets sufficient aeration while delivered to the underground chamber and majority of the iron precipitates inside that reservoir. Some of the precipitates also forms in the overhead reservoir which settles in those tanks. Those precipitates only comes out through the taps while the reservoir is cleaned. Therefore even though the raw water is heavily loaded with iron, the water that generally comes though the taps is free from iron for most of the time.

4.2.2 Flow rate during experiment

The target of the test runs was to see the efficiency of the units and to determine the maximum flow rate that can be safely used in the main design. Therefore the plan was to flow raw water with dissolved iron in different flow rates to see the output qualities and see the amount of precipitations it generates. The raw water bucket had a rated volume of 30 liters. The attached bib-cock left some dead volume (2-3 L) in the bottom. With that limitation, the bucket was filled with about 2-3 inches left at the top as free-board. Then it was allowed to drain the bucket through the bib-cock till there is a good flow rate. The draining event took about 30 minutes and hence it can be estimated that the flow rate was about 40L/hr.

4.2.3 Performance of sedimentation

The experiments could not be continued due to the pandemic (COVID19). Initially the test was run to see whether particles settle inside the sedimentation chamber or not. In all the test runs it was observed that the murky water gets very transparent as the tap water when it flows out of the outlet.

It was also observed that some sedimentation occurred even on the aeration device (the lid of the box container). The water in the sedimentation chamber (box) seemed murky with eye observation but the water is cleared after passing through the tube settler.

The outlet water was collected in a beaker and was observed against the bright open sky to find any turbidity or particles. The water was as clean as the tap water. Even though the water was crystal clear, in some samples some fine particles were observed when observed against the bright light source.

This performance test only tested whether sedimentation chamber with tube settler works or not. This did not include any RSF. The test results were enough to establish the fact that the settling chamber works with this flow rate.

4.3 Design

Difference between a large treatment plant and an apartment based treatment plant is maintaining the uniform flow rate for maximum efficiency. Generally when an apartment receives water from a water supply authority, the UGR is filled once or twice a day by the amount equal to daily water demand. Similar pattern follows when the tubewell is located inside the premises of the house. Therefore it would be wise to design the IRP adopting to this water supply system.

Therefore, the flow rate for aeration chamber should accommodate that flow rate. The sedimentation chamber should have a holding capacity equal to the UGR, and in that way it ensures that sufficient detention time is provided before that water is pushed out by the new inflow. The RSF should also accommodate to the flow rate.

4.3.1 Aeration:

Aeration is the first treatment process of water treatment plant. Aeration is required to convert dissolved iron to insoluble iron products so that those can be removed by sedimentation and filtration at the later stages. There are 3 types of aeration arrangement:

1 Gravity aerator. (remove 50%-65% CO_2)
2 Spray aerator. (remove 75% CO_2)
3 Air diffuser basis.

As the existing system already have pumps lifting the water, it is better to use the static head provided by the pump and use gravity type aerator for this system. In this way, this unit operation can be achieved without the need of any extra equipment or maintenance.

4.3.2 Primary sedimentation tank

In this system primary sedimentation is the second process of water treatment plant in apartment building. In this system water will be settled by gravity or own weight of the precipitates. The sedimentation enhances the filtration process by removing particles. Following shows a sample calculation for treatment plant design for a five story residential building. Water supply schedule are:

A Morning-11:00 AM TO 01:00 PM
B Evening-07:00 PM TO 09:00 PM
C Night-03:00 AM TO 05:00 PM

This data collect from the house caretaker. The WASA water supply interval is enough for water sedimentation. The sedimentation tank collects water for 2 hours and that determines the required tank size:-

The apartment building has five floors, this buildings total population is 120 persons. this treatment plant design sufficient water required for 2days.

Per day water collect 6h.

Number of population=120 person

Per day water required per person=135 liters

Daily water required=120*135=16200 liters

6h water collected=16200 liters

1h water collection=(16200/6) liters=2700 liters

2h water collection =(2700*2)liters =5400 liters

We know,

For 1000 liter water, required volume 1m^3 (cubic meter)

For 5400 litter water required volume =(5400/1000) m^3=5.4m^3

Assume,

The tank height is=3m

Area is =sqrt (5.4/3)=1.79m^2=1.34m x 1.34m

Free board is=1 ft=0.30m

Collected water by 0.0254 or (1inch) diameter pvc pipe

Q =2700 L/h

$= \left(\frac{2700}{1000*60*60}\right) m^3/sec$

=0.00075 m^3/sec

The water velocity is: $V=\frac{Q}{A}$

$$= \frac{0.00075}{\frac{3.1416*(0.0254)^2}{4}} m^3/sec$$

=1.48 m/s

Total height of the tank is =3+.3=3.3m

The sedimentation tank dimension is (3.3 x 1.34 x 1.34) m

4.3.3 Sedimentation particle settling velocity and dimension

Assume size of the settling flock/iron particle,d_{50}=0.3mm

$v_s = \frac{g(s-1)}{18\gamma} * d2$

=(9.81(2.65-1)*.0003/18*1.004*10^{-6}.

=0.08 m/s

Maximum settling time required = 3 m ÷ 0.08 m/s = 37.2 s

Size of settling flocs, d_{20} = 0.1 mm=0.0001m

=(9.81(2.65-1)*0.0001^2)/(18*1.004*10^{-6})

=8.96*10^{-3}m/s

Maximum settling time required = 3 m ÷ 8.96 × 10^{-3}m/s=335sec

=5 min 55 sec

4.3.4 Tube settler/Secondary iron sedimentation tank

This is the third step of apartment building iron removal plant. In this step water will pass through the tube settler. Tube settler is multiple tubular channels. This tube channels are placed at 60 degree angle and adjacent to each other, which combine to form an increased effective settling area. When water passes through the tube settler then iron particles settle rapidly. This provides for a particle settling depth that is significantly less than the settling depth of a conventional clarifier, reducing settling times. The solids fall to the tube surface, where they slide by gravity down to a sludge collection surface. Secondary sedimentation tank only design for place the tube settler.

Tube settler: If there are finer flocs they will be removed here (design flock size is d=0.02mm)

We know that,settling velocity of stock's law:

$$v_s=\frac{g(s-1)}{18\gamma}*d^2$$

$$=(9.81(2.65-1)*.00002^2)/(18*1.004*10^{-6})$$

$$=0.000358 \text{ m/s}$$

Velocity along the tube settler: $V_o=\frac{Q}{A}$

$$=> V_o=\frac{2.7}{0.67*1.34} \text{ m/hr}$$

$$=0.000835 \text{m/s}$$

we know,

$S=\frac{Vs}{Vo}(\sin\theta+L*\cos\theta)$ S=4/3 for circular pipe

$=>4/3=(0.000358/0.000835)*(\sin60^0+L\cos60^0)$

$=>L=4.49$m

$L'=0.58N_R$

$=>L=0.58*DVo/\gamma$

$=>L=0.58*0.00002*0.000835/1.004*10^{-6}$

$L=0.000964$ m

use 1.5"pipe then required pipe length

$L=l/d - l'$

$=>4.49=(l/0.0381)-0.000964$

$=>l=0.171$ m

$=>l=6.73$"

For safety. Safety factor 1.5

$l=6.73*1.5=10$"

Dimension of tube settler: 0.67*1.34

4.3.5 Reserve Tank

The reserve tank is designed for 2.5 days required water of apartment building. Above the per day water requirement is calculated to be 16200 liters for 135 persons.

Water required for 2.5 days=16200*2.5=40500liters

We know,

For 1000 liters water, required volume 1m^3(cubic meter)

For 40500 liters water, required volume =(40500/1000) m^3=40.5m^3

Assume,

The tank height is=3m

Area is =sqrt (40.5/3)=7.34 m^2=3.67m*3.67m

The dimension of reserve tank is=3.67m*3.67m*3.61m

4.4 Laboratory Test

Even though it was planned to conduct extensive laboratory test for the samples, due to the lock-down due to COVID19 situation it was not possible to conduct the tests. Hopefully the follow up project will complete the required testing.

4.5 Analysis of Data

There were no chemical tests conducted other than that of iron concentration in the raw waters, when searching for a suitable source of raw water. The analysis will be carried on when next phase starts.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 General

This chapter reviews the final outcome and describes the achievements against the set objectives of the project. This chapter also sets forward the recommendations to further enhance this research/ project outputs.

5.2 Conclusion

All the targeted objectives could not be attained in this project in the stipulated time due to the lock-down situation during COVID19 pandemic. However, several key points were achieved in this process which will help the next attempt.

Initial design decisions and unit selection was completed. But total design was not completed due to the lack of testing results. But a sample design calculations for the volume of different units was completed which can be replicated with some modification to achieve different design results for different capacities.

The new design concept accommodates all the limitations regarding water supply pumping rate and space constrictions in its design and hence this particular objective is fulfilled.

The new conceptual design has accommodated easy operation and maintenance and accordingly functional elements and units has been selected and hence this objective is fulfilled.

A model was created for relatively new and critical sedimentation unit for testing and understanding its dynamics. Initial tests indicated good performance and this model can be used for further testing of the full functional treatment plant with the right kind of raw water and using a filtration unit. Therefore the objective of creating a model is fulfilled but it needs further testing.

5.3 Recommendations

Further testing with the model is required for better understanding and to demonstrate the concept to the potential clients of such product.

- During the further testing flow rate and detention time can be the variables for performance testing.
- A control system without tube settler can be made to run it side-by-side to visualize the difference so that the potential clients are convinced.
- A detailed design for different population size (different standard sized apartments) can be prepared.
- 3D models can be prepared with all the detailing and animated operation.

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