POTENTIAL OF SHALLOW GROUNDWATER UTILISATION THROUGH RIVERBANK FILTRATION IN ALOR PONGSU

by

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ABSTRAK

Permintaan air yang semakin meningkat setara dengan pertumbuhan bilangan penduduk dunia amat membebankan sistem bekalan air konvensional. Permintaan yang semakin banyak ini memerlukan sistem bekalan air alternatif yang mampan. Justeru, kaedah penapisan tebing sungai (RBF) yang pernah diguna sebelum ini tetapi tidak diterokai dengan sepenuhnya telah disarankan sebagai penyelasaian. Dalam menilai potensi RBF, beberapa aspek utama memerlukan kajian yang terperinci. Kajian awal menggunakan kaedah Pengimejan Profil Keberintangan Bumi (RIP) untuk menentukan lokasi air bawah tanah dan lokasi bawah tanah yang sesuai bagi operasi RBF. Proses "boring" dan analisa tanah dijalankan bagi mengesah hasil RIP. Beberapa parameter penting mengenai kaedah RBF yang perlu diteliti adalah kualiti, kuantiti, kesesuaian dan kemampanan kaedah ini. Ujian hidrokimia dan mikrobiologi dijalankan untuk menentukan kualiti air tapis manakala ujian pengepaman air dan isotop alam dijalankan untuk menentukan kuantiti, kesesuaian dan kemampanan kaedah RBF. RBF didapati dapat menapis kebanyakan ion yang merbahaya dalam air RBF dan kebanyakan sample air RBF tergolong dalam kualiti air kumpulan I-II. Bakteria juga dapat dibuang sepenuhnya di BH5 dan BH8. Bagi ujian pengempaman pula, akuifer menunjukkan ciri-ciri fizikal lapisan pasir berkadar alir tinggi manakala kajian isotope alam menunjukkan percampuran sehingga 85% air sungai. Jarak minimum bagi RBF yang efektif pula adalah >33m. Secara keseluruhannya, RBF merupakan kaedah rawatan air yang amat mejaminkan dan berpotensi besar dalam pembangunan sumber air yang mapan di Alor Pongsu.

POTENTIAL OF SHALLOW GROUNDWATER UTILISATION THROUGH RIVERBANK FILTRATION IN ALOR PONGSU

ABSTRACT

The ever increasing demand for water in par with world population growth spurt has put an immense pressure on the conventional water supply system. Thus the distress for more water supplies has called for an alternative sustainable water resource. Riverbank Filtration (RBF) method, an existing but not fully explored area is now the subject of interest as the possible solution to all the water problems faced. As its potential needs assessment, few key areas requires detailed study and research. In preliminary studies, Earth Resistivity Image Profiling (RIP) is utilised to determine the existence of groundwater and suitable subsurface area for RBF setup. Boring and soil analysis were then carried out to verify the RIP results. Few important parameters of RBF method are looked into such as its quality, quantity, practicability and sustainability. Hydrochemical and microbiological tests were carried out to determine water quality while pumping test and environmental isotope tests were carried out to determine its quantity, practicability and sustainability. RBF had effectively removed most hazardous major ions in the mixture of river water and groundwater and most RBF water falls under class I-II quality. Total bacteria removal was also discovered at borehole 5 and 8. Whereas for pumping test of the aquifer, the results shows physical characteristics of a typical fast flowing sand layer while environmental isotope analysis shows degree of mixing up to 85 % of river water in groundwater. The minimum distance for an effective RBF is stipulated as more than 33 m in this research. Overall, RBF is a viable water treatment method and it holds a large potential in sustainable water resource development for Alor Pongsu.

CHAPTER 1

INTRODUCTION

1.1 General

Water has always been the most precious resource on earth to mankind. Being able to sustain all life form on earth, water became an essential need in our daily life. Despite the fact that 70% of earth consists of water, only a small amount can actually be used and it is called fresh water. This amount dwindles further as great amount of fresh water are trapped in glaciers, ice caps, in the atmosphere and below the earth surface, leaving only a small amount of water above the ground surface as readily available water resource. In the context of water resource which involves water that are useable, only fresh water is important as saline water contains high salt amount and requires desalination before consumption and other activities (WHO, 2011)

As such, surface water which is water found naturally above ground surface such as in rivers, lakes and ponds has long since been used as the main water source for daily needs; as seen in early civilizations that are usually built near rivers, oasis or lakes. Being more readily available for abstraction as compared to other fresh water resources, surface water has thus remained as the main water resources in many places where surface water is in abundance. The total freshwater consumption of the world is 1240 m^3/cap/year and Malaysia is one of the country with high freshwater consumption (Hoekstra and Chapagain, 2007).

Notwithstanding the availability of surface water on earth, water distribution around the globe is uneven and varies greatly. Inhabitants in parts of the globe where surface water is scarce may need to resort to other means of water resources such as the underground reservoir of water

1.2 Background of Study

1.2.1 Water Scarcity

The earth was in fact never short of water. However what is in shortage is the supply of cheap, clean, and potable water that is available to people. Only fresh water is potable and most other demands for water are concerning fresh water only, not to mention albeit the earth is rich in water, the distribution of water on earth is unfortunately not uniform. Fresh water can be abstracted from many places or produced but the energy consumption and its cost limits water abstraction to places where fresh water is readily available. Thus to be precisely said, water shortage refers to the shortage of cheap, clean water (Hoffman, 2001).

Although water is a renewable resource in the hydrological cycle and recharges via precipitation, water scarcity has become an increasingly alarming issue in the recent year in conjunction with the growth spurge of the world's population which places a huge amount of demand on water resource. More water is consumed and used by people and even more water is needed for the production of food for the growing population. World population is expected to reach 8.3 billion, i.e. a 50 % increase in global energy and food demand and a 30 % increase in the demand for fresh drinking water—a resource that is already in short supply for one third of world population (West, 2009). As the available water resources do not increase in number albeit renewable, the growing human population and demand for water thus steadily outgrows the available water resource for everyone.

The scarcity of water is further worsened by pollution of surface water which is caused by human activities and as the world's population continue to increase, water pollution only become more severe. In many region of the world water scarcity has become a main issue and it is estimated that 3.575 million people die each year from water-related disease (Prüss-Üstün et al., 2008). Countries with little rainfall have thus relied heavily on groundwater and countries with abundance of rainfall have also started to explore the possibility of incorporating groundwater into water supply system as contingency plans.

1.2.2 Groundwater

Groundwater is defined as water that is stored under the ground surface and in saturated zone. When water percolates into the ground and stays in soil interstitial place or geological stratum, a reservoir of groundwater is formed. Being stored underground, groundwater is relatively less polluted and uniform in their physical properties and thus, is of great potential to be used as water resource. The area saturated with water is called the saturated zone and the area directly above it is the water table which sets the boundary between the saturated and the unsaturated zone (Freeze and Cherry, 1979). Water can be abstracted from the saturated zone for many purposes such as drinking, irrigation, and industrial purpose. The chemical properties of the water however, depend on the geological structure which holds the water as minerals from the structure dissolves in the groundwater.

Groundwater application has been increasingly important in many parts of the world recently due to the increased water scarcity all over the globe. The intense sustained withdrawal of groundwater has eventually leaded to groundwater depletion in many places such as in Asia and Africa as groundwater abstraction exceeds the capacity of the groundwater storage (Molden, 2007). As such, alternatives to conventional abstraction of groundwater are needed. Notwithstanding the advancement in treatment processes in meeting the demands for water, most available high-tech methods are either too expensive or too complicated and produce hazardous by-products (Shamrukh and Abdel-Wahab, 2008).

1.2.3 Riverbank filtration (RBF)

Riverbank filtration method, a variant to the conventional groundwater abstraction method, draws water from shallow aquifers and aquifer is recharged with the aid of nearby river water that filters through the riverbank before mixing with the shallow aquifer water. It is a natural water treatment process that is both inexpensive and efficient in mass producing large amount of treated water. Nonetheless, its effectiveness is subjective to many factors which are to be examined in this study. The compatibility of particular constraints on quality of water recovered from bank filtration scheme is examined, especially heavy metal ions present in all bank filtration water.

RBF has been used as a pre-treated method to improve drinking water quality for more than 100 years in Europe and China (Wu et al., 2007). There are also other countries which utilize such technology such as in Kuihe, China, along Nile River in Egypt and Yamuna in India. RBF has been applied at a large-scale as mentioned in the investigation of a full-scale RBF plant located in Upper-Egypt at a section of Nile valley by Shamrukh and Abdel-Wahab (2008). The pilot plant was constructed in 2004 to supply portable water for Sidfa city (30 000 residents), Assiut Governorate. Successful application of RBF has also been outlined in the studies by Lee et al. (2009) which characterize the riverbank-filtered water and river water qualities at a site in lower Nakadong River basin, Republic of Korea and the water after riverbank filtration are generally found to be of lower contamination as compared to raw Nakadong River water.

Hydrochemistry of groundwater in a region is largely determined by both the natural process, such as precipitation, wet and dry dispositions of atmospheric salts, evapo-transpiration, soil/rock-water interactions and the anthropogenic activities, which can alter these systems by contaminating them or by modifying the hydrological cycle. Understanding of the factors responsible for influencing the groundwater hydrochemistry is very essential for protection and sounds management of the groundwater resources in a region (Singh et al., 2007). In this research, the suitability of RBF in relation with the distance of borehole from river bank is tested by observing the change in quality of water after being filtered by river bank and flows into the shallow aquifer to recharge the groundwater for different distances between borehole and riverbank. From the findings of the research conducted, it can be determined if RBF is suitable for drinking and irrigation purpose.

1.2.4 Malaysia and its Water Needs

Located near the equator, Malaysia experiences a tropical rainforest climate where it is warm and humid throughout the year. Heavy rainfalls are received with an average annual precipitation level range of 1787 to 4159 mm a year and its distribution varies with the land topography and monsoon season (Malaysian Meteorological Department, 2010). Two significant monsoon winds contributes in the heavy rainfall, namely the South-West Monsoon which brings rain to the west coast of Peninsular Malaysia in the month of May – August while in the month of November – March, the North-East Monsoon brings rain to the east coast of Peninsular Malaysia and East Malaysia. Thus with the heavy rainfall throughout the year, Malaysia is abundant with surface water and also groundwater.

According to Chu (2004), the use of groundwater has been on the rise due to depletion of surface water during the dry season in area such as Kedah, Perlis and Melaka, increased in demand due to population, agriculture and industrial growth and the lack of viable surface water source site such as dams and lakes in new development areas.

1.2.5 Area of Research

The area of research is located in Alor Pongsu, a part of the Kerian Irrigation Scheme which is an irrigation scheme for the national granary located in the North West corner of the state of Perak, covering an area of 23 359 hectares of land. This scheme consists of 8 compartments and is generally divided into Kerian Laut and Kerian Darat based on its location relative to the sea. Alor Pongsu is one of the areas covered by Kerian Laut and Sungai Samagagah; a tributary of Sungai Kerian, flows through it, providing the means of water supply for irrigation. The location of the site is as shown in Figure 1.1.

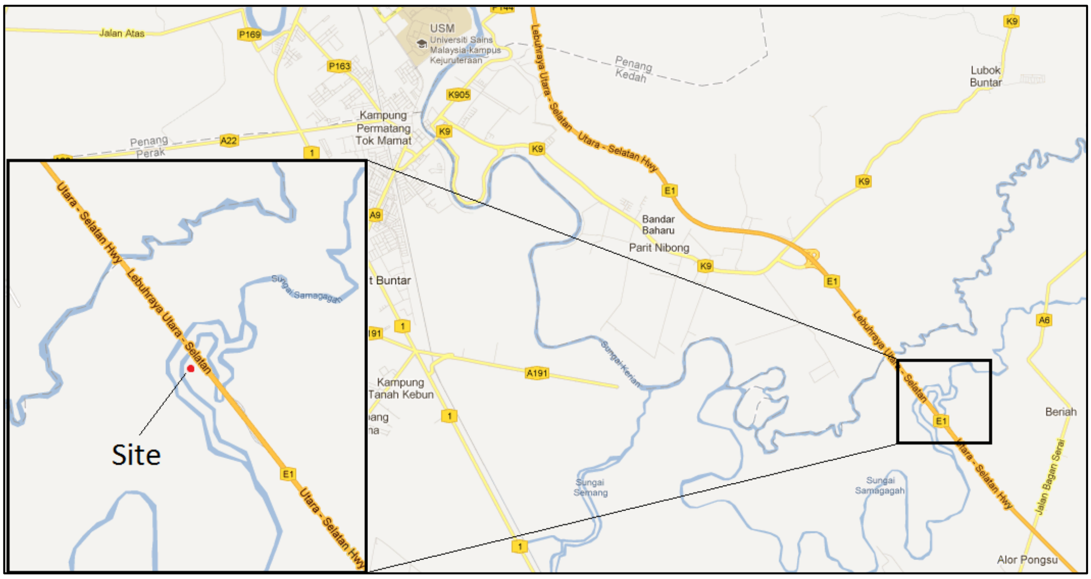

Figure 1.1 Location of Study Area

1.3 Problem Statement

With the growing population and the thriving economy and development in the water abundant Malaysia, the highly unlikely situation of water scarcity has become a concern at certain places of the country especially in dry seasons and where agricultural activities are most active. The switch to relying on groundwater as a supplementary water resource has not been an inviting solution as intense sustained abstraction of water from the groundwater well places great stress on the aquifer and eventually will lead to abstraction of water well beyond its capacity. Since water is needed in mass quantity in a short time, the possible solution was to apply the riverbank filtration pretreatment technique in order to meet the demands for water.

However, riverbank filtration (RBF) has rarely been practiced in Malaysia yet and since the factors of a functional RBF varies according to geographical factors, thus there is a need to determine what are the settings that are most suited for a functional RBF application at its maximum functional capacity. Therefore in this research, the relation of distance of well from the river and its effectiveness of water filtration is tested based on certain selected parameters and the best functional setting of an RBF well is determined.

1.4 Objectives

The objectives of this research are as follows:

1. To investigate subsurface condition using geophysical method in order to determine suitability for Riverbank Filtration.
2. To determine the physical characteristics of aquifer near the riverbank in the research area.

3. To determine the suitability of shallow groundwater in area of research as potable water, agriculture and industrial usage.
4. To evaluate and verify the potential of riverbank filtration water for water resource exploration.

1.5 Scope of Work

To determine the best settings and conditions where RBF will function effectively, the study has to be carried out based on the topography and layout of the site i.e. the establishment of a functional RBF site at an available shallow groundwater nearby a river. Thus the project is generally divided into 3 main stages i.e. the site identification and well establishment phase, the sampling, testing and monitoring phase and finally the data analysis and interpretation phase.

The first phase, site identification and well establishment requires locating a suitable site that can provide for river water filtrating into an shallow aquifer and since groundwater is hidden from plain sight and boring is an expensive method, Earth Resistivity Image Profiling (RIP) is used to identify and locate the location of the aquifer before boring process. RIP was carried out to determine the earth resistivity of chosen site with possible existence of groundwater and based on the resistivity value obtained through RIP test, the location of aquifer can easily be identified without random boring. Once the suitable location for the well is decided, boring is carried out according to the required number of well and its distance from the river.

Following the well construction phase, samplings can be carried out in a consistent interval of time period and field tests are carried out also. Modified pumping tests are also carried out to determine the pumping capacity supported by the well and finally when all required sampling is done, tracer test is carried out to determine its water parameter. With the collected samples, hydrochemistry analysis is performed to determine its chemical composition and the ions present in the water. Bacteria enumerations as well as isotope tests are carried out to determine the effectiveness of filtration from riverbank and percentage of water mixture between river and aquifer. All of these samples are analyzed in the laboratory.

With the gathered data from various testing, the results are organized into tables and charts for analysis and comparisons. Based from these interpretations, deductions are made regarding the research and conclusion for the best setting of RBF is made from these deductions.

1.6 Justification of Research

The understanding of the factors which directly affects the potential of RBF is crucial in determining the effective setting of an RBF system. The setting mention in this section is the placement of the well apart from the river edge and also its location such that RBF actively occur and the resulting riverbank filtrate is useable for drinking, domestic, agriculture or industrial purposes. Since RBF is an adaptation of the naturally occurring formations, its effectiveness is highly dependent on its surrounding environment and thus, it is needed to determine the condition in which it can best perform. Although researches of RBF and its application is not foreign in many countries, Malaysia is not properly exposed to this RBF technology as surface water is still relatively abundant as compared to neighboring countries and also the common misconception that water scarcity will never strike the country. However as of today, such misconception can no longer be neglected as water scarcity has struck at some places in the country during dry seasons and also where pollution is highly possible. The result of the research is significant in providing sets of database on RBF work in

Malaysia where the RBF is carried out in environments and climate that is suited to our country's and this data are vital in further in-depth exploration of RBF in the future.

1.7 Thesis Outline

This thesis is written in five major components or chapters in a proper and simplest order to allow an easy comprehension of the research carried out; namely the Introduction, Literature Review, Methodology, Discussion of Results and finally the Conclusions and Recommendations. A general outline of the contents of each chapter can be found in the following notes.

Chapter 1 – Introduction, introduces the water element as a simple resource yet being the most vital element for everyone in this world to survive. The chapters gradually unfolds itself into the scarcity of water and the problem faced in securing a proper water resource that can meet the increasing demands for clean water supply over the world and finally leads to the search for the possible alternatives and water supplementary systems or techniques. The chapter then outlines the importance of the study followed by a brief description of its background and the problems faced. The objectives are also clearly stated as well as the scope of research work. Chapter 1 gives an overall understanding of the research conducted.

Chapter 2 – Literature review, meanwhile provides an extensive review of literature backgrounds and critically examines the existing knowledge and research carried out in the past on the topic of Riverbank Filtration and its past exploits and attempts in supplementing the existing water resources. The pooling of the data acquired by other researchers in the past enables the establishment of a clear direction of this research and identifying the main objectives along with the expected outcomes to be achieved.

Chapter 3 – Methodology, describes the methods and procedures employed in the research in order to fulfill the objectives. Some methods are standards commonly used internationally while some are customized or modified according to the needs of the research and in order for the smooth flow of the research progress without running into setbacks and dead ends. Details procedures are given for the custom methods while only brief descriptions are given for standard methods.

Chapter 4 – Discussion of results, analyses the collected data from the entire research, organize and presents it the simplest and easiest way for interpretation and finally discusses it at length and in details. Comparisons and deductions are made from the results obtained. Graphics are used whenever needed to aid the interpretation of results and to make deductions easier. Standards and guidelines available were also used as references when analyzing the results.

Chapter 5- Conclusion and Recommendations considers all the deductions made in the previous chapter and valid conclusions are drawn for the entire research. Conclusions made are also based on the objectives of the research and recommendations of further research that can be conducted on the topic were given.

CHAPTER 2

LITERATURE REVIEW

2.1 Water Concerns

With water scarcity becoming an increasingly alarming issue globally, effort in securing sustainable water resources has suddenly become a global interest. After thousands of years of human evolution in which water has been a plentiful resource in most areas, amounting virtually to a free good, the situation is now changing abruptly to the point where, particularly in the more arid regions of the world, water scarcity has become the single greatest threat to food security, human health and natural environment. The International Water Management Institute (IWMI) study identifies the water demand and supply situation of 118 countries over the 1990 - 2025 periods. The 118 countries included in the study have been classified into two broad groups excluding China and according to the nature and degree of their projected water scarcity in 2025 i.e. Absolute Water Scarcity group and Economic Water Scarcity group (Seckler et al., 1999). The major concerns sparked from this water crisis are mainly on producing sufficient amount of water to meet its demands and at the same time, being able to sustain its production in continuously meeting the demands for water in the future. Thus various cutting edge water filtration technologies have been applied to produce clean water in mass quantity. However these methods have each their setbacks and its practicability is highly questionable with the limitation of various factors; cost being the main limitation factor.

2.2 Current Treatment Technology for Potable Water

As the current demands are for mass amount of water in a short period of time, conventional water treatment system are no longer sufficient in meeting these demands. Conventional methods used by typical water treatment plants like precipitation are unfavorable especially when dealing with large volumes of matter which contains heavy metal ions in low concentration. Precipitation is accompanied by flocculation or coagulation, and one major problem is the formation of large amounts of sediments containing heavy metal ions. For effective precipitation suitable pH conditions and temperature are required and in addition suitable concentration of metal ions and controlled stirring intensity. Frequently after final filtration, concentration of heavy metal ions in the filtrate still remains on the level of a few mg dm^{-3} (Dabrowski et al., 2004).

There are some advance water treatment technologies available to meet these demands such as the ion exchange method which uses ion exchange resins. Compared with other usual methods, ion exchange provides advantages. By ion exchange, either all ions can be removed from a solution or substances are separated. Therefore, selective removal of ionic contamination and completed ionization can be distinguished. The choice of between both depends mainly on the composition of the solution and on the extent of decontamination required (Dabrowski et al., 2004). The process has some disadvantages in that there are substances occurring in some water(such as organic matter or Fe^{3+} ions) which can foul the resin (Alchin, 2008). This condition is called the poisoning of ion exchange resin and the efficiency of ion exchange will lessen gradually till it is not functional.

Another type of advance filtration technology is the membrane filtration technology. A membrane is a thin of semi-permeable layer that separates substances when certain driving force is applied across the membrane and is used for removal of bacteria, microorganisms, particulates, and natural organic material. Membrane filtration is a common process in water treatment and is gaining increasing importance nowadays. The filtration efficiency usually depends on the materials used for filter (Sang et al., 2008). The membrane treatment scenario does not remove substantial levels of natural organic matter (Jacangelo et al., 1997).

Adsorption technology is also another type of advance water treatment technology which promotes the adhesion of pollutant to a certain surface and removes the film of adsorbed particles for pollutant removal. It is universal in nature as it can be applied for the removal of soluble and insoluble contaminants and biological pollutants with removal efficiency of 90–99%. Its efficiency is reduced by presence of suspended particles, oils and pre-filtration is usually required. Adsorption is affected by factors such as temperature, nature of the adsorbate and adsorbent and the presence of other pollutants. It is also affected by atmospheric and experimental conditions such as pH, concentration of pollutants, contact time and particle size of the adsorbent (Ali and Gupta, 2007).

Meanwhile, Soil Aquifer Treatment (SAT) is also an advance water treatment method. The sum of water quality benefits derived during percolation of reclaimed water through vadose zone (unsaturated zone) sediments and subsequent groundwater storage are collectively known as soil SAT (Quanrud et al., 2003). In Israel, the approach to wastewater reuse using SAT was to exchange the use of reclaimed wastewater for irrigation with the use of fresh water for potable purposes (Idelovitch, 2003). According to Quanrud et al. (2003), the public resisted the indirect potable reuse of these reclaimed water due to the fear of its safety of use.

All of the mentioned and many other advance technologies for treating water are effective in producing clean water but most of them have their shortcomings. While some treatment technologies are specific in pollutant type removal, others are simply inefficient towards particular pollutant species. In the long run, most of these technologies are costly and requires high maintenance work. Technologies such as reverse osmosis, ion exchange, electrodialysis and electrolysis are costly technologies with a 10–450 US$ per million liter cost for treated water. The cost of treated water by adsorption varies from10 to 200 US$ per million liters (Ali and Gupta, 2007).

2.3 Reliance on Groundwater

While surface water has gradually become scarce and polluted in countries which were once abundant with clean surface water, the focus on surface water has slowly shifted to groundwater for a reliable and sustainable water resource. Groundwater generally has the advantage of a good hygienic and consistent quality as compared to surface water (De Vet et al., 2010). Since groundwater is stored in a closed space underground, its water is less exposed to contamination. The flow of water through layers of porous media also enables filtration of water before it reaches the aquifer storage. Thus, groundwater is a reliable and convenient water resource and it has long been used in many parts of the world.

Groundwater is widely applied in India. In India, the population is growing fast and thus generates a huge demand for fresh water due to water consumption and also intense agricultural activities. Land use for agricultural purpose in Jaipur City has increased alarmingly during last 10 years. Extensive studies on groundwater quality has thus been carried out (Tank and Chandel, 2010). Tank and Chandel (2010) has carried out the research to understand the spatial distribution of hydrochemical constituents of groundwater related to its suitability for agriculture and domestic use.

Groundwater has equally been widely practiced in Australia. Owing to limited rainfall, scarcity of surface waters and high rates of evaporation, much of central Australia is dependent on groundwater for its primary water. Much of the water extracted from aquifers in the North Territory is from deeply weathered Pre-Cambrian or Cretaceous/Tertiary sediments including extensive evaporate deposits (Kinsela et al., 2012). In their research, Kinsela et al. (2012) determines what causes scale formation and also scale formation possibilities in North Territory of Central Australia. An assessment of possible low cost treatment to counter the scale formation was also carried out.

In China, groundwater has been widely applied too. The Hetao Plain (HP), also known as the Great Bend, is located in the Inner Mongolia Autonomous Region of the People Republic of China. The fertile plain is known to be one of China’s oldest crop-producing areas, based on an ancient and widespread artificial irrigation system extracting water from the Yellow River. Due to increased operating costs, some famers decided to shift from irrigation with river water to groundwater abstracted from local shallow aquifers (Neidhardt et al., 2012). Neidhardt et al. (2012) studies the impact of flood irrigation with high Arsenic content groundwater on soil and crops in HP.

In Iran, groundwater has been increasingly practiced and exploited recently. Iran is a predominantly arid country with low and highly variable rainfall. Recently, Iran’s agriculture has become increasingly reliant on groundwater resources to produce food. Population growth, industrial development, and irrigated agriculture expansion have increased demand for water in Iran. To keep pace with this rising demand, there has been a sharp increase in use of groundwater. Groundwater use for irrigated agriculture in Iran has increased vastly over the last three decades (Karimi et al., 2012). In the paper, Karimi et al. (2012) explores water management that can help in reducing groundwater abstraction and also limiting energy consumption and carbon footprint of groundwater economy.

2.4 Groundwater Stress

As the demand for water gradually increases with the growth of population, more water is needed with a higher production rate. Since groundwater are stored in large quantity underground, the reliance on surface water for water supply has been shift to groundwater resources to meet this growing demand for water and by doing so, an immense pressure is place on the aquifer with large scale abstraction of water from the aquifer. Since water is needed in mass amount, continuous abstractions of groundwater were carried out and a large drawdown of hydraulic head is formed over the area of abstraction. Uncontrolled over-abstraction of water from aquifer eventually causes the depletion of groundwater at the area of abstraction. The resulting lowering of groundwater levels can have devastating effects on natural stream flow, groundwater fed wetlands and related ecosystems. Also, in deltaic areas, groundwater depletion may lead to land subsidence and saltwater intrusion (Wada et al., 2010).

In Punjab, India for example, the green revolution ushered in a major technological transformation in Indian agriculture, which was assisted with a technology intensive agricultural pricing policy. It simultaneously led to the extensive use of groundwater for irrigation and a shift to water-intensive cropping pattern. Role of irrigation shifted from a risk reducing agency to a production augmenting technology (Sarkar, 2012). Sarkar (2012) further reported that rich farmers build more abstraction well to irrigate their farm and causes an inequity of water distribution between the rich and the poor community in the place and the government has to interfere and introduce proper water abstraction management to avoid groundwater depletion.

According to Calow et al. (2010) in the paper of Groundwater Management in Drought-prone areas of Africa, groundwater is the only perennial source of water supply in the dry land regions and its importance is clearly seen via the early settlements patterns that were determined by the proximity to water resources. While it is assumed that failure of wells and boreholes are due to overexploitation it could also be due to low permeability of aquifer where groundwater are not quick enough to replenish the water abstracted and the cone of depression restricts the inflow of water. Increased stress on groundwater source also causes failure of pump due to the strain placed on the pump through prolonged pumping throughout the day, leading to breakdown. All in all, Calow et al. (2010) reports the importance the groundwater droughts in Africa and the needs to identify the cause for the drought and also elaborate plans for groundwater managements and to face groundwater droughts when it strikes.

Meanwhile in China, groundwater overexploitation can be seen in North China Plan (NCP) with 17 950 ha of land consumes more than 70% of the water supply system and is in shortage of water with the rapid urban and industrial development and expansion of irrigated land, leading to overexploitation of both surface and groundwater resources, particularly north of the Yellow River (Changming et al., 2001). It is also reported that a general increase in depth of groundwater level of more than 4 cm over a decade was observed and subsequently resulting in land subsidence and saline water intrusion due to hydraulic gradient difference. Considering NCP is one of the most important social, economic, and agricultural regions of china, remedial measures were suggested such as better groundwater management, raising water use efficiency and relocation of water abstraction points in a different area.

It can therefore be said that reckless over-abstraction of groundwater will place stress on the aquifer and eventually lead to depletion of groundwater and other subsequential problems such as land subsidence and saline water intrusion that increases the land salinity and thus rendering the land infertile. While groundwater management can elevate the problem and demand for mass water supply by just a little, alternative water treatment methods that can mass produce are still in need to meet the growing demand for clean water supply in par with the population growth and also the rapid economic development.

2.5 Riverbank Filtration and Application

RBF is a water pre-treatment technology that offers water filtration process for mass amount of water without needing to construct any high end structures or inducing high installation and maintenance cost as it naturally exists and only needs slight adaptation and modification to suit surrounding environment features. While its filtration does not provided ultrapure filtration standards, it does however offers pre-treatment process of water that allows the cost-cutting in following water treatments and as said, in large quantity of water.

The quality of surface water changes when it flows through porous medium. Due to natural attenuation processes such as filtration, sorption, acid-base reaction, oxidation, reduction, hydrolysis, biochemical reactions etc., RBF is able to filter potential contaminants (Dash et al., 2010). In the report of River bank filtration in Haridwar, India: removal of turbidity, organics and bacteria, Dash et al. (2010) studies the improvement in quality of river water after filtration through a layer of 17-m thick sand-gravel unconfined aquifer at a production well surrounded by surface-water bodies, in Haridwar (India). The chosen site for the study is located at the bank or River Ganga which is approximately 300 km away from the Gangotri glacier. The results showed that the RBF facility is found to be efficient in removing turbidity, coliform bacteria and more than 70% of Organic substance.

In Mathura, India, the river Yamuna was polluted with distinct disagreeable colour. The dissolved carbon content was 4.0 – 6.8 mg/L and the colour was as high as 40-64 colour units. Singh et al. (2010) compared the efficiency of RBF and chlorine as pre-treatment to river water. The process for both methods is as shown in Figure 2.1.

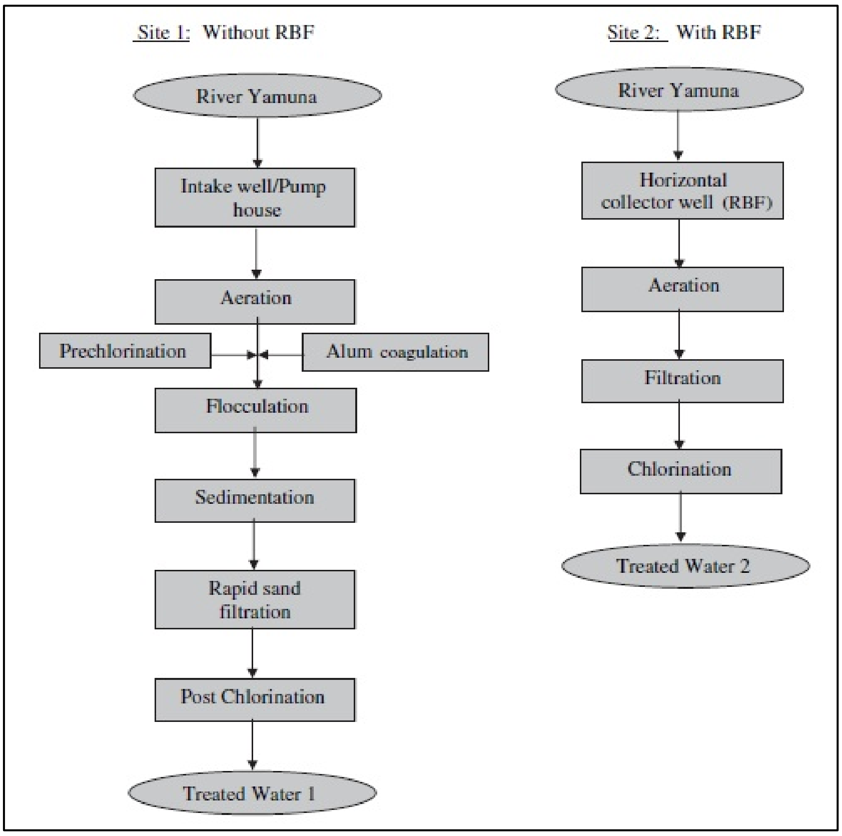

Figure 2.1 Process comparisons for both treatment methods (Singh et al., 2010)

The findings were that RBF was found to be more effective to enhance the quality of water as compared to direct pumping of river water. The color, coliform bacteria, UV-absorbance and organic contaminants were reduced by half in the riverbank filtrate. For production of potable water from riverbank filtrate, the dosage of ozone used and the time of ozonation were also reduced.

In Australia, Dillon et al. (2002) examines the compatibility of two constraints on the quality of water recovered from bank filtration schemes; (1) removal of cyanobacterial toxins is adequate; and (2) salinity is acceptable for drinking water supplies. The site chosen is at 2 semi-arid places adjacent to the River Murray in South Eastern Australia where the ambient groundwater of unconfined aquifer alongside some part of the river is saline. Thus the RBF facility would need to be designed for removal of cyanobacterial toxin as well as limit the portion of brackish water recovered in well water abstraction. Dillon et al. (2002) reported that in order to sufficiently remove the cyanobacteria, the distance of production well from the riverbank must be sufficient to allow adequate time for biodegradation. But on the other hand, the further the well is from the riverbank, the less proportion of river water is being uptake in the recovered water. Thus a balance of cyanobacteria removal and river water uptake is needed and a well 50m from the riverbank was found to be adequate in fulfilling both criteria.

The use of artificial neural networks to evaluate the effectiveness of riverbank filtration were also demonstrated by Sahoo et al. (2005) where they developed and applied 3 types of artificial neural network (ANN) to predict and estimate the effectiveness of 2 RBF facilities in Louisville KY, and Santa Rosa SA, US. The 3 type of ANN used are the feed-forward back-propagation network (BPN), radial basis function network (RBFN) and, the fuzzy inference system network (FISN).

In Changwon, Korea, riverbank filtrate water was used in cooling down the Daesan water treatment plant facility building during summer and heating up the plant during winter. Geothermal energy was initially used but as a measure of cost saving, riverbank filtrate was used. Shin et al. (2010) reported that water from riverbank filtrate have the property of being cooler than surface water during summer and warmer during winter. However it is necessary to predict the range of temperature of RBF water at the Daesan RBF site by using numerical modeling in order to assess the efficiency and applicability of geothermal energy utilization through the RBF facility under various conditions. It was found that with the increase of pumping rate, the proportion of river-originated water passing through the coldest zone will increase while the temperature of groundwater drawn will still be maintained. There were plans to build 6 more wells at the site which is predicted to decrease the temperature of RBF water by 2^oC and this temperature variation is to be taken into account for design and operation purpose.

2.6 Earth Resistivity Imaging

Among the many geophysical techniques available for detecting subsurface condition, earth resistivity imaging is the most suitable technique that can be used for hydrogeological studies. The principle of earth resistivity imaging is that it detects the horizontal and vertical discontinuities in the electrical properties of the ground and also the 3-D bodies of anomalous electrical conductivity (Wightman et al., 2003). The ground is injected with artificially-generated electric currents and the electrical signal is collected and analyzed. The potential between one electrode pair is measured while direct current is being transmitted between another electrode pair. The difference in resulting potential is compared with the injected current. A known set of potential difference expected of a homogeneous ground is used as a comparison with the obtained potential difference and the deviation from the expected values signifies the heterogeneity of the sub-surface layers. The separation distance of electrodes determines the depth of penetration and both parameters is proportional in homogeneous grounds. By varying the electrode separation, information of ground stratification can be obtained.

Earth resistivity imaging has been widely used in hydrogeological and geophysical studies due to the reason that electrical properties, geological formation and also the fluid contained in the substructures are often co-related. For most of the substructure formations and minerals, they are natural insulators and thus electricity can only be conducted through pore water that is found among them. It can also be said that the resistivity signifies the porosity of the rocks which conducts electricity through means of electrolytic process. The variation of porosity of rock underground signifies the rock location (Wightman et al., 2003).

Low frequency alternating current was used in most of the available earth resistivity meters nowadays to avoid electrolytic polarization and to overcome the telluric effect. If direct current is used, anion and cation will build up at its respective electrode and overtime inhibits the further arrival of more ions. When alternating current is however used, there will not be building up of ions at its respective electrodes. Telluric current is the subsurface occurrence of natural electric current which flows parallel to earth's surface and causes regional potential gradients. This effect is countered if the results of several cycles of increased and decreased potential difference by equal amount are summed up (Chavalier, 2007).

The conventional method used for analyzing substructures is the point sampling i.e. borehole sampling. Boreholes sampling is accurate but its accuracy holds true only to the point of sampling. Apart from its inconvenience of having much work involved in a single borehole, boring is an intrusive process that disturbs the sample. According to Granato and Smith (1999), point sampling approach is expensive as well as not representative of the whole site area as it is only informatively accurate at the sampling point only. Intrusive processes are dangerous and may not truly representative of the complex subsurface geology. Therefore, noninvasive methods such as earth resistivity imaging are alternatives that have been used to groundwater studies not to replace borehole sampling but to supplement it in order to be cost-effective.

Current uses of geophysical methods include the feasibility study of transient electromagnetic method (TDEM) for groundwater exploration by Fitterman and Stewart (1986) on four specific problems i.e. (1) mapping of alluvial fill and gravel zones over bedrock; (2) mapping of sand and gravel lenses in till; (3)detection of salt or brackish water interfaces in freshwater aquifers; and (4) determination of hydrostratigraphy. It was found the method has great sensitivity and excels at mapping conductive targets but it is rather difficulty to detect fresh-water saturated substructure layers.

Karlık and Kaya (2001) study the extent of contamination induced by the Isparta open waste-disposal site using direct current (DC) resistivity geo-electrical sounding and very-low-frequency electromagnetic (VLF-EM) technique. These methods proved to be fast, inexpensive and accurate data collection method and there exist a good correlation between both geophysical technique used.

In Purulia district (West Bengal), India, Sharma and Baranwal (2005) successfully carried out integrated electrical and electromagnetic surveys for delineation of groundwater-bearing zones for construction of deep tube-wells for large amounts of water. Very low frequency (VLF) electromagnetic surveys were used and the entire area was surveyed in a relatively short time by the combined use of resistivity and electromagnetic surveys.