

Groundwater Management

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Abstract-Groundwater plays a major life support to humanity. It is the major source to meet the domestic, irrigation and industrial demands. The discussion in this research paper begins with the definition of management as a general, and its importance to be applied to water resources. Then the ground water and ground water resources classifications are presented. Major threats to ground water resources are discussed in the following section. Also then the importance of ground water contamination and groundwater restoration as two of the vital elements in regard to groundwater managements are discussed. This discussion is followed by the protection of groundwater reservoirs under two topics. These topics cover the tools to manage and monitor the surface groundwater along with groundwater, with respect to their quantities and qualities. Recommendations and scientific suggestions throughout the paper are presented to save, properly used and protect the groundwater, and ground water basins.

I. INTRODUCTION

Before discussing groundwater management, it is essential to have a definition for management, which acts as a tool to handle the groundwater preservation and its related subjects. In general, management is the process of planning, handling, and controlling the use of resources to accomplish performances goals. The basic skills for managements are:

- Diagnostic: Visualizing the sources of problem
- Communication: To exchange information and ideas affecting the problem with others
- Decision making: The ability to recognize and define problems and opportunities correctly and then select an appropriate

course of action to solve the problems.

Now, after management is being defined, it is time to continue with what ground water importance to human is and how it can be managed to fulfil our demand for future generations. Actually, ground water plays a major life support to human being including all other living species. It is the major source to meet the domestic, irrigation (or agriculture) and industrials demands. Ground water represents the worlds largest freshwater storage and occurs in wide range of rock types and usually requires little or no treatment. Therefore, it is often the cheapest and simplest water supply option .It is not too far from reality to say that ground water is the most misunderstood and mismanaged resources available.

Ground water needs adequate protection and management. The role of ground water supply in total use of water is been increasingly rapid and with the rising of standard living will be more increased. It is estimated that there is four million cubic kilometres of ground water are stored in earth crust to a depth of 800 meters. As times goes on, the ground water reservoirs are considered for purposes other than water supply such as use of deep wells for waste disposals and use of aquifers as a storage space. Therefore, such activities tend to affect the quality of groundwater. Actual objective of ground water management is to make sure that groundwater resources will be available in appropriate time with acceptable quantity and quality for the need of the society. The most important purpose of groundwater management is to reserve it for drinking supply, and then for other usages. Drinking water quality includes water used for all usual domestic purposes, including consumption, bathing and food usage. Fig. 1 shows the ground water usual distribution.

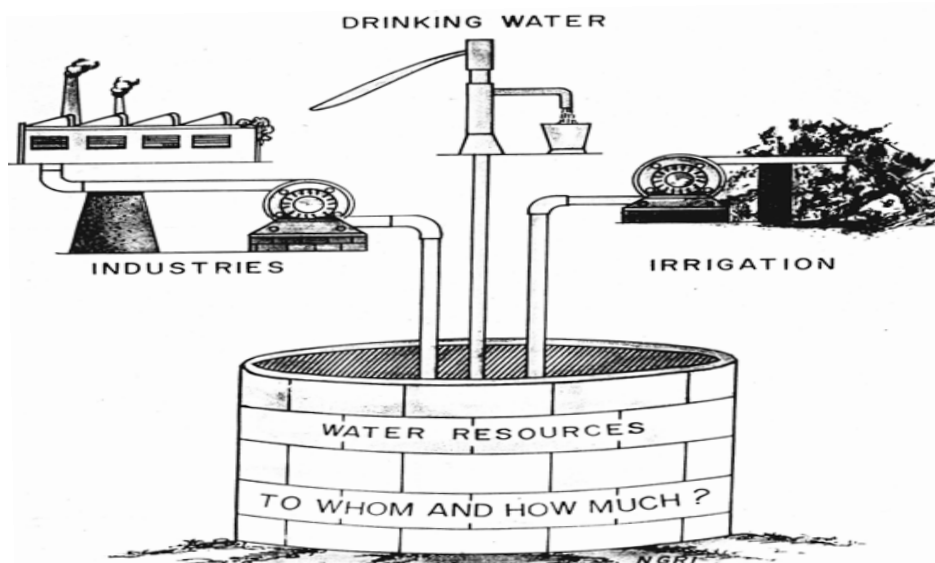


Fig. 1 Groundwater distribution

II. GROUNDWATER-GROUNDWATER RESOURCES

Water beneath the land surface in the saturated zone is hidden natural resources. Most of earth groundwater exists in reservoirs beneath the ground, which are called aquifers. Underground body made of layers of porous sand, gravel or fractured rocks that are saturated with water from above or from structures slopping toward it, and is capable of supplying useful quantities of water to a well or spring. Water in unconfined aquifers may have been collected recently by percolating in to the land surface, so they have young age. The top layers of unconfined aquifers are the ground water table. Unconfined aquifer often extends to the surface of land as river or lake. The source of groundwater (recharge) is through precipitation or surface water that percolates downward to the earth crest. Groundwater is part of the earth hydrological cycle that is the movement of water through the atmosphere, ocean, surface channels, and underground aquifers. Generally, ground water moves very slowly, typically from a few centimetres to about a meter per year depending on the intake or recharging amount of water in to the ground and also the soil type and texture. At one time, ground waters and its purity and availability were taken as for granted, but as with today's demand and scarcity of clean water, the contamination and availability of ground water are serious issues to consider.

In general, groundwater reservoirs that are the main source of water supplies are classified in four different groups, in these categories ground water reservoirs may be used or abused as are stated below.

- Natural uses
- Extraction of existing resources
- Land uses
- Subsurface uses

1) Natural Uses

Usually groundwater resources in their natural states are used for groundwater springs and base-flow contribution to surface water.

2) Extraction Of Existing Resources

Extraction of existing resources can be divided in to four different groups that are, extraction of water for purposes other than water supply, extraction of other naturally occurring fluids and also extraction of other natural resources.

3) Land Uses

Groundwater resources can be used as a host for specific uses conducted on land overlying the reservoir. This part may be the largest division of all classified uses of groundwater resources. These divisions are general construction, highways and roads, urban development, agriculture, excavation dewatering, drainage, solid waste disposals, salt or waste piling, agricultural developments, recreational development, incidental spills of harmful liquids, disposal of liquid waste by irrigation, waste retention ponds and lagoons, septic tanks, animal feed lots, and accidental breakage of sewers or pipelines.

4) Subsurface Uses

Also, ground water resources can be used as a host for specific uses inside the reservoir such as, artificial recharge, storage of fresh water in saline aquifers, natural gas storage, storage of storm run off and heat storage.

III. THREATS TO GROUNDWATER

Threats to groundwater resources can be divided to two different groups; the first is the threat to quantity and second the threats to quality of groundwater resources. These two are discussed with details in the followings.

1) Threats To Quantity

An increase quantity of groundwater withdrawn from underground reservoirs for domestic purposes could be considered threats because the associated problem caused by this action may include overdraft, drawdown and subsidence. Overdraft occurs when groundwater is removed faster than recharge can replace it. This can result in:

- A permanent loss of a portion of its storage capacity
- A change that can cause water of unusual quality to contaminate good water

• In coastal basins, salt-water intrusion can occur Generally, any withdrawal in excess of safe yield (the amount that can be withdrawn without producing an undesirable result) is an overdraft.

Drawdown differs significantly from overdraft. Since, it results in a temporary lowered water table generally caused by pumping. In this situation, the water table recovers when supply is stopped. Subsidence is one of the dramatic results from overpumping. As the water table declines, water pressure reduced. This causes the fine particles that held water to become compacted, and also permeability is reduced and so the soil will be consolidated under loads. Therefore the land above the aquifer can sink (from a few centimetres up to even a few meters) and causing a sinkhole. This can damage property and the field.

2) Threats To Quality

Inorganic compounds*, pathogens and organic compounds**, can harm water quality affecting the health of humans, and other living species as well.

IV. GROUNDWATER CONTAMINATION OR POLLUTION

Even, groundwater is in many regions a renewable resources, it may be locally limited. Therefore is vulnerable to damage, which in many cases, the damage may be irreversible, or if not irreversible, it may be very hard to restore the original conditions for it.

The man made contamination of groundwater is an undesirable phenomenon, whether it is groundwater contamination by a

newly created, environmentally hazardous object or past and existing groundwater pollution by mismanagement of hazardous wastes, leakage, and emergency spills of chemicals. In many cases, once groundwater contamination has occurred, remediation of an aquifer would be expensive and technically difficult or infeasible. When estimating the importance of a groundwater contamination problem and developing water protection measures, it is helpful to be guided by at least two criteria. These criteria's are, risk to human health and threats to environments or so-called ecological risks. The most serious situation requiring intervention occurs when groundwater contamination is a source of risk to human health. Because the unconfined aquifers is hydraulically connected to the confined aquifers, the contaminated unconfined aquifer is a potential source of contamination of the confined aquifer below. The migration of the contaminated groundwater in the unconfined aquifer also carries radionuclide to the receiving rivers and surface waters. Thus, the three problem mentioned above are interconnected. The source of groundwater contamination is many and contaminants are numerous in developing countries. Common industrial solvents such as tri chloro-ethylene and carbon tetra chloride found in wide spread areas. Suburban areas usually have ground water with high levels of nitrate due to the use of lawn fertilizers found in groundwater. Landfills are known sources of contamination. Some of the more common contaminant transport in to groundwater includes; Accidental spills, Surface impoundments, Underground storage, Above ground tanks, Pipelines, Injection wells, Land application of waste and pesticides, Septic tanks, Radio active waste disposal, Salt water intrusion and acid mine drainage.

V. GROUNDWATER RESTORATION

As was stated before studies have shown that once ground water has been contaminated, it may take many years to remove the contaminants through natural process from an aquifer after the source of contamination has been eliminated. There are two broad categories of remedial measures for this problem. First, the source of contamination must be removed or isolated and second the groundwater has to be pumped or treated.

VI. PROTECTION OF GROUNDWATER RESERVOIRS

The protection of groundwater should include both its quantity as well as its quality. The quantity aspect of ground water protection is to regulate groundwater withdrawals in such a proper and calculated way that the water supply sources would not influence each other and that groundwater would not be permanently overdrawn. The quality aspect of groundwater protection is to eliminate or at least to minimize the wide range of contaminants and pollutions in to the groundwater reservoirs. Both of the mentioned parameters are interconnected and must be managed properly. In the following sections quantity aspect of ground water resources as well as its quality aspects with respect to managerial dimensions is being discussed. The emphasis is being put on water quality than the quantity, but their important relation is being taken to account and discussed. Fig 2 shows the groundwater resources distributed of the world

1) Groundwater Quantity Management

Water demand includes industrial, domestic and agricultural. The studies show that the consumption of water will increase in the future due to growth of population, industry and agriculture. In some regions, the available water resources may not be adequate to meet the demands during short time period. Therefore; problem of water scarcity will exist in those areas. A suitable strategy for the problem is to be adopted for the long term water supply augmentation to ensure groundwater recharge. Usually a small part of surface run off is stored in the form of streams and utilized as consumptive used, and most of the quantity of rainwater is being lost. Therefore, this heavy quantity surface runoff water should be stored properly for utilization by implementation of effective groundwater recharge techniques. Some of the programs that may be used in order to conserve rain water and facilitate additional recharge to the groundwater reservoirs and help to overcome the possible scarcity of ground water during dry seasons may include:

- Construction of retaining structures (to recharge aquifers artificially from rainfall waters)
- Water conservation (construction of retaining structures for percolation of water in to the ground from huge rain runoff water that is usually lost otherwise. This method is called artificially recharging aquifers)
- Irrigation efficiency project (improving the irrigation technology and engineering structures in the irrigation system)
- Water reclamation (recycling the water and reuse it for industries and possible plant watering and also recharging it to the underground resources)

One of the approaches to manage surface water in order to save groundwater from excessive discharge is called "the water shed management approach". In the following section, this type of approach is briefly being discussed.

2) Water Shed Management

The most critical components to water shed management approach is the involvement of all key stakeholders at each step of the process, the key components are:

- Assess natural resources (soil, surface and ground water, air, plants, animals, and peoples)
- Prioritizing the problem
- Developing strategies for reaching objectives
- Implement strategies and assess the result

3) Groundwater Quality Management

Groundwater pollution by human activities cannot be completely eliminated, but it can be minimized. The fact that pollution (in any form) is the price that the civilized world must pay to exist has to be admitted. On the other hand, it is essential that the problem should be countered by selecting effective and reasonable solutions for reducing groundwater pollution to an absolute minimum. Control of ground water pollution necessarily begins with the development of strategies and guidelines to prevent future groundwater pollution and to maintain existing groundwater quality at the highest degree practicable. Strategies must include all aspects involved in the mechanism for achieving the objectives of the strategy. It may

*include all compounds that do not contain carbon, and those compounds that contain metals

**include volatile organic compound such as benzene, and some semivolatileslike pesticides

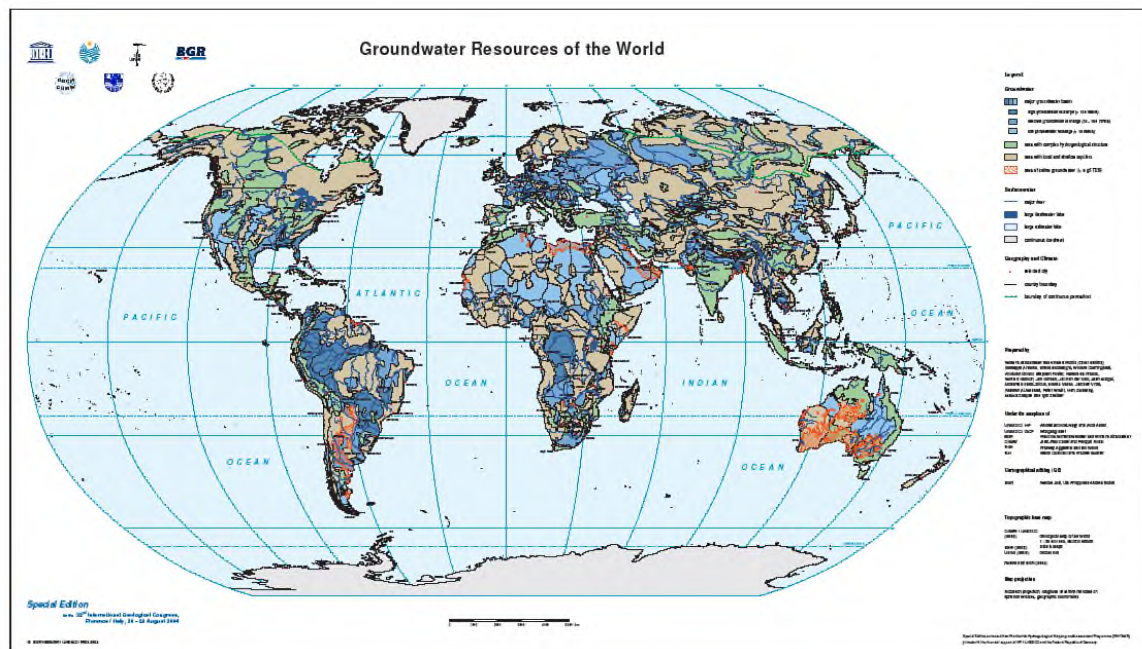


Fig. 2 Groundwater reservoirs of earth

be very difficult to find good solutions that would be accepted to all interest groups affected by the mechanism. Therefore, any strategy would include a compromise between what is theoretically desirable and what is practically can be achieved. Table 7.1 lists some of the methods available for achieving the objectives of a groundwater quality program. When groundwater is polluted, certain natural protection is provided by soil which water passes through. Pollutants in groundwater tend to be removed or reduced in concentration with time and distance travelled. Purification occurs in filtering action of earth materials and in chemical and biological process. However, the cleaning process by earth ability is not complete and has to be complemented by protective measures. In general, there are two basic approaches in dealing with groundwater quality problems. The first is handling existing cases of pollution, and the second is preventing new incidents to happen. The most common approach toward existing problem is to start corrective action only after an occurrence of pollution is discovered. A major effort should be directed, by the responsible organizations toward defining extent and degree of severity of the groundwater-polluted area. Equally pressing as the need to develop methods and strategies for dealing with existing problems of groundwater pollutions is the need to establish a program to prevent future problems. One part of the program would be an inventory of all possible sources of pollution and evaluation of their potential hazards. Groundwater protection can then be based on the same factors as surface quality water control. Therefore reducing the pollution potential of source and eliminating some of those activities or uses of groundwater

reservoirs that have the highest potential for introducing pollutants in to the groundwater. Another part of the prevention program is to evaluate the environment for accepting the degree of pollution, and identifying the most critical areas where the physical environment has the least capacity to protect groundwater from pollution. There are many alternatives for protective measures such as: setting groundwater standards, enforcing land use restrictions in critical areas, imposing limits on individual uses of groundwater reservoirs that may lead to pollution, and determining the protective zones for where there are intake water wells. Monitoring process can not be considered as a protective measure for groundwater pollutions, rather it is just a detective measure of the groundwater quality problem. Monitoring is usually applied when there is need to determine groundwater quality at a particular location and its changes with time or it is necessary to determine if designed protective measures are working. One of the measures which is been practiced by most of European countries to limit pollution areas is called the "protective zone". The concept of protecting zone around the source of water supplies applies mostly to where there is a populated region. The boundary of the zones may be set up considering the operational depression of water level, continuing of withdrawal and duration of exploitation. The protected area consists of several regions. Usually two or three and depending on the groundwater condition. These zones can be described briefly as follows:

Zone I: Minimum zone protection that is confined to the immediate environment of the well or intake area includes protection against all kinds of influences. It is generally surrounded by barriers or fencing.

Table1 Groundwater protection alternatives

Natural protection
Purification
Preventive actions (preventing pollution from occurring)
Inventory of pollution sources
Location of existing sources
Identifying the potential sources
Evaluation of potential hazards
Land suitability studies
Control pollutions sources
Design and operation requirements
Management and inspection practices
Eliminating the dangerous sources
Protective measures
Groundwater standards
Regulation of groundwater uses
Land use controls
Groundwater zoning
Law regulation enforcement
Protection of water supply sources
Water- well construction
Sealing of abandoned wells
Protective zones
Corrective measures (handling pollution after it occurs)
Soil removal Interception trenches
Pumping the affected area
Monitoring the progress

Zone II: This zone has the maximum boundary of the protected area and includes protection against wider reaching effects such as waste disposal pollution. Certain use of the area is allowed. For example, low capacity water supply, light housing development or small industries developments are allowed in this zone.

Zone III: All kind of uses in this zone are regulated and limited to a permit. In addition, an intermediate zone of protection may be established within this zone.

Another method to manage groundwater quality is called "regional groundwater quality management that also can be used in any of the mentioned protective zones.

In this method, procedures are to be taken for ensuring the sustainable and hazard free water resources for drinking, agriculture and industries. The following procedure also can be considered for any regional ground water basin:

- Remediation
- Planning to stop it from happening again or getting worst (prevention is far better than cure)
- Some of the possible remedial measures may be considered as follows:
- Treatment of pollutants
- Improving lining of flow channels and discharge the wastes liquids in low permeability zones.
- Pumping of polluted groundwater, treating and

recharging in to the system.

- Use of treated or partially treated groundwater in industry or agricultural sectors.

4) *Management Plan To Protect Aquifer And Well Fields*

Since groundwater resources are so vital in life cycle on earth, it is important to protect them from being polluted. Some of the procedures in this regard that are to be considered are listed below:

- Occurrence and distribution of pollutant sources
- Knowledge about pollutant sources
- Knowledge about hydrodynamics of aquifer system
- Knowledge about the behaviour of pollutants
- Data network and monitoring
- Regulation to limit and treat pollutants

It has been proven that industries are one of the main sources of pollutants for groundwater resources. Therefore, industries with out-dated technologies should be closed down and be replaced with eco-friendly technologies. Also it is found very difficult to remediate the aquifer, it is preferred to relocate the industries after studying the vulnerability of the area to the contaminants.

5) Solid Waste Management

The garbage generated in the urban areas including the industrial solid wastes disposed on the land surface also gives rise to groundwater pollutions. The most serious risk occur when sanitary landfill is practiced and where hazardous industrial waste including liquid effluents are disposed off at inappropriate sites. The municipal solid wastes are usually disposed in low-lying ground without any record or quantity and quality of wastes. Even the disposal is stopped, the site will represent a potential hazard to groundwater for future decades. Researches show that the solid wastes in developing countries generally are less toxic, having a high content of water and decaying vegetable matter, compared to typical solid waste from different types of metals (lead, mercury) and synthetic organic compounds (solvents, phenol). Municipal wastes usually contain small quantities of hazardous materials, but the plume from the refuse site to the down gradient site will contaminate the drinking water and therefore a serious health hazard may be produced. Municipal towns will contaminate to grow rapidly and this in turn will impose enhanced stress on groundwater resources.

The rapid development of industry, often small scale units and highly dispersed, is likely to produce wide spread contamination of groundwater by metals and chemicals. These types of contaminants from industries disposal to the ground or to surface water channels, where it may directly pollute the groundwater. Solution to this problem is the collection, treatment, and proper disposal of such solid wastes and liquid effluents

VII. SUMMARY AND CONCLUSION

Groundwater occurs in a wide range of rock types and usually requires little or no treatment; therefore, it is often the cheapest and simplest water supply option and is the main reserve of fresh water and a valuable natural resource. Therefore, it deserves all the care and attention that human can offer. How long human generation will enjoy the benefit of groundwater depends on the degree that these vital reservoirs are well managed and used. The space groundwater occupies underground, is susceptible to pollution, if improperly managed or protected. If this resource is polluted, cleanup process may be of long and expensive procedures.

One of the most important concerns is the contamination of underground waters by the industrial agriculture and domestic pollutants. Therefore, it is the responsibility of the governments to have an effective management plan to regulate, monitor and control the outcome of each sector wastes. Groundwater and surface water are fundamentally interconnected. It is often difficult to separate the two; because they feed each other. This is why one can contaminate the other, and if one is less available, the other will be in intense use. It is also important to understand that surface water management

should be considered as a part of groundwater management in order to have an effective plan to use and to save this priceless reserve for ourselves and for the future generations.

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