

Environmental Management of Groundwater in Egypt via Artificial Recharge Extending the Practice to Soil Aquifer Treatment (SAT)

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Abstract

The economic development in Egypt and the rapid growth rate in various development sectors are dependent on the availability of water resources. Egypt has turned to use the groundwater to satisfy the growing demand, at the expense of exceeding the safe yield and overexploiting the aquifer systems in some areas such as western Nile Delta and along the desert fringes in the Nile Valley. Shortage of irrigation water sources in Egypt bring out the issue of using non-conventional water resources. As a part from the environmental management of groundwater resources, Egypt launched a program to examine the feasibility of artificial recharge for the augmentation of groundwater supply. Through this program a detailed study has been carried out for the investigation and potential site selection for carrying out an artificial recharge experiment using treated wastewater.

The aquifer artificial recharge by treated sewage water is a new tool can be applied in Egypt for using the sewage water safely compared with the direct use. Through the aquifer soil (unsaturated zone), advanced sewage treatment stage will be added by which most of the biological load will be removed and partially reduction in concentrations of some chemicals can be found.

This paper presents the preliminary hydrogeological investigation and tested scenarios for the aquifer storage which used to evaluate the technical environmental, consideration in Abu Rawash farm as a case study. In addition to applying environmental impact assessment (EIA) of artificial recharge experiment to assess the feasibility guidelines for the future recharge projects. Results indicated that artificial recharge for groundwater aquifer using treated wastewater is promising whoever it needs more detailed study to assess the aquifer feature influences the mechanism of recharge with treated wastewater. The health risk due to changes in the physical and chemical conditions prevailing in the aquifer or due to limited adsorption capacities as well as the microorganisms survive and toxic pollutants degradation.

Keywords: *Groundwater; Artificial recharge; treated wastewater, Hydrogeological Investigation*

1. General Background

Groundwater is considered as one of the main sources for both rural and agriculture water supplies in many areas in Egypt especially in the desert regions. Over recent years, increasing abstraction to meet rising demand for domestic supplies and expansion in reclamation in desert fringes has raised concerns for the sustainability of

the groundwater resource and the livelihoods it supports. Shortage of irrigation water sources in Egypt bring out the issue of using non-conventional water resources. Non-conventional water resources include agricultural drainage water, desalinization of brackish groundwater and municipal wastewater. Egypt has already started

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reusing particularly treated sewage water for direct irrigation of 3000 fed. At El Gabal El Asfar. But the main concern must be how to mitigate the expected negative environmental impacts. This challenge has pushed the researchers to improve the tools or technologies by which the non-conventional water can be recycled safely.

Recharging aquifers with reclaimed water appears to be a viable option. Conventional surface disposal of wastewater can cause significant river water quality deterioration. Direct disposal of reclaimed water into rivers and drains often leads to eutrophication due to the presence of contaminants, such as nitrate and phosphate (Horn and Goldman, 1994). A common indicator of eutrophication is increased phytoplankton density resulting in green turbid and foulsmelling water. After such a bloom, the algal biomass is broken down both chemically and biologically, resulting in greater chemical and biological oxygen demands (COD, BOD). Alleviating such a situation requires a reduction in water-borne nitrate, phosphate and pathogenic bacteria in the river or drain water.

As a part from the Environmental Management of Groundwater Resources (EMGR), Egypt launched a program to examine the feasibility of artificial recharge for the augmentation of groundwater supply with cooperation between Dutch and Egypt governorate. Through this program a detailed study has been carried out for the investigation and potential site selection for carrying out an artificial recharge experiment using treated wastewater. Abu Rawash area is a pilot area where RIGW studied reuse of treated sewage water and its Environmental impacts on Groundwater by funding from the Academy of Scientific Research and Technology (ASRT)

The aquifer artificial recharge by treated sewage water is a new tool can be applied in Egypt for using the sewage water safely compared with the direct use. Through the aquifer soil (unsaturated zone), advanced sewage treatment stage will be added by which most of the biological load will be removed and partially reduction in concentrations of some chemicals can be found.

The paper presents also presents also environmental impact assessment (EIA) of artificial recharge experimental for groundwater aquifer in Abu Rawash farm as a tool to develop initial assessment criteria for applying such technique to be quantitative feasibility guidelines for the future recharge projects by sewage water.

2. Water Resource and Groundwater in Egypt

Egypt's main water resource is the Nile River. The Nile agreement with Sudan allocates 55.5 BCM/yr. to Egypt, which amount is secured by the multi-year regulatory capacity provided by the Aswan High Dam. The second water source is groundwater in the Western Desert region and in Sinai in non-renewable aquifer systems. The annual extraction from the main aquifer in these areas, the Nubian Sandstone aquifer system, is about 0.5 BCM/yr. Rainfall in the coastal zones of Egypt reaches about 1.5 BCM/yr but is a rather unreliable source due to its spatial and temporal variability.

Groundwater in the Nile aquifer system and desert fringes is not a resource in itself as it is replenished from the river Nile by seepage from canals and deep percolation from irrigation application. The annual groundwater abstraction in the Nile aquifer system and fringes is about 4.6 billion m³. Another 0.5 billion m³ is abstracted from the desert aquifers and the coastal areas. Groundwater abstraction is expected to increase considerably to 11.4 billion m³ – in the forthcoming years, thus increasing the relative importance of groundwater in the national water resources management. The larger quantitative role of groundwater and the further application of integrated water management are posing specific challenges to the institutions dealing with groundwater research and management.

2.1. Groundwater Framework in Egypt

The hydrogeological framework of Egypt comprises six aquifer systems (RIGW, 1999), as shown in Figure 1:

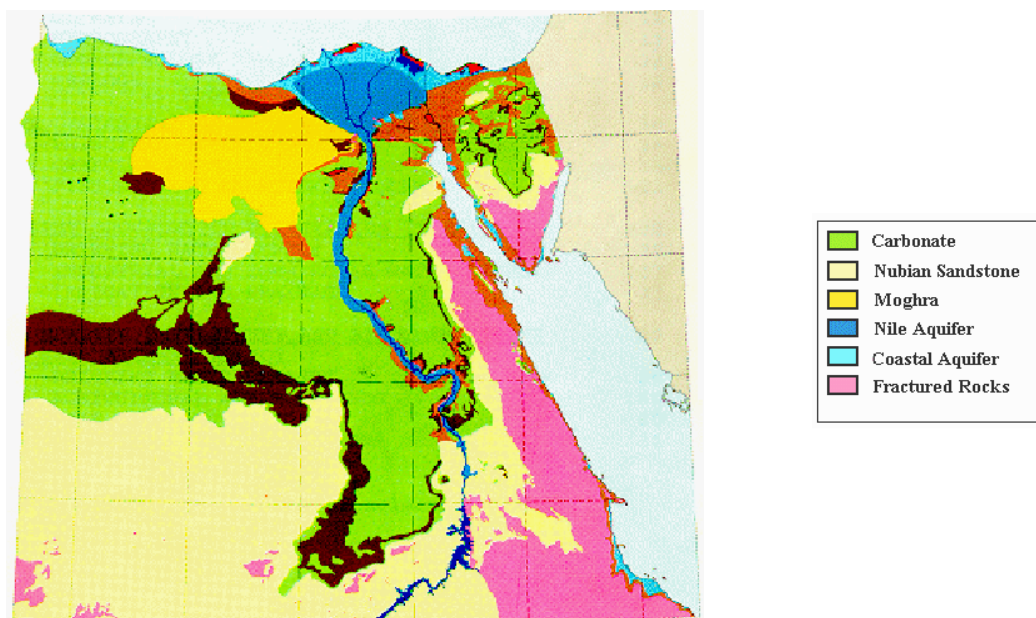


Figure 1: Aquifer systems in Egypt

- 1) **The Nile aquifer system**, assigned to the Quaternary and Late Tertiary, occupies the Nile flood plain and desert fringes;
- 2) **The Nubian Sandstone aquifer system**, assigned to the Paleozoic-Mesozoic, occupies a large area in the Western Desert, and parts of the Eastern Desert and Sinai;
- 3) **The Moghra aquifer system**, assigned to the Lower Miocene, occupies mainly the western edge of the Delta;
- 4) **The Coastal aquifer systems**, assigned to the Quaternary and Late Tertiary, occupy the north western and eastern coasts;
- 5) **The karstified carbonate aquifer system**, assigned to the Eocene and to the Upper Cretaceous, predominates essentially in the north and middle parts of the Western Desert;
- 6) **The fissured and weathered hard rock aquifer system**, assigned to the Pre-Cambrian, predominates in the Eastern Desert and Sinai

2.2. Key Challenge for Groundwater Resources Management in Arid Areas

Groundwater differs from surface water because of contrasting physical and chemical environment in which it occurs. Key challenge for groundwater resources management has to deal with balancing

the exploitation of a complex resource (in terms of quantity, quality, and surface water interactions) with the increasing demands of water and land users (who can pose a threat to resource availability and quality). Calls for groundwater management do not usually arise until a decline in well yields and / or quality affects one of the stakeholders groups. If further uncontrolled pumping is allowed, a vicious circle may develop and damage to the resource as a whole may result, with serious groundwater level decline, and in some cases aquifer saline intrusion (or even land subsidence). To transform this "vicious circle" into a "virtuous circle" it is essential to recognize that managing groundwater is as much about managing people (water and land users) as it is about managing water (aquifer resources). In practical terms it will be necessary to set possible management interventions in the context of the normal evolution of groundwater development.

Groundwater management strategies needed to stabilize heavily stressed aquifers are generally sub-divided into demand side management interventions and the supply side engineering measures.

It is always essential to address the issue of constraining demand for groundwater abstraction, since this will normally contribute more to achieving the groundwater balance, and in the more arid and densely-populated areas, such as the

Arab region, will always be required in the longer run. Complementary local supply-side measures, such as rainwater harvesting, aquifer recharge enhancement (with excess surface run-off or other sources of water such as desalination and treated wastewater, or even through Soil Aquifer Treatment techniques (SAT), and urban wastewater reuse should always be encouraged, especially where conditions are favorable. They are often important in terms of building better relationships with groundwater users and can provide an initial focus for their participation in aquifer management.

2.3. Supply Management of Groundwater Resources in the Arid and Densely Populated Areas

Supply management can be implemented simultaneously with demand in management to increase water supply availability and augment water supplies by such means as desalination, reuse of treated wastewater, recycling, weather modification, artificial recharge, water importation and the use of marginal quality water. Those supply management measures with the greatest potential to increase water resource availability in this region and desalination, reuse of treated water, and artificial recharge.

Aquifer storage augmentation can be made through the use of surface spreading basins, injection wells, or the artificial modification of natural channels by means of dams and dikes.

Aquifer recharge enhancement and manipulation of subsurface storage will allow increased long-term average rates of groundwater abstraction benefiting all users. Seasonal storage may be participated to take advantage of the availability of excess water during the wet season. Recovery of stored water can contribute to deferring expansion of water facilities or to their downsizing. Such practice may be beneficial for the storage of floodwater occurring over a short period in many parts of the Arab region. Long term storage can be utilized in situations where desalination production is in excess of water demand. Emergency storage is of significance in building up strategic reserves of groundwater to meet demand when primary water sources are unavailable as a result of contamination, warfare or natural disasters.

Other advantages of artificial recharge schemes include restoration of groundwater levels, and water quality improvement (Pyne, 1995). Increasing the rate of recharge, possibly eliminating the effect of over-pumping can reduce the rate of groundwater mining. Increasing pumpage from confined aquifers located near the surface usually results in land subsidence. A remedial solution may be to increase the magnitude of recharge in order to maintain pressure. Furthermore artificial recharge is considered one of the more effective means of combating salt water intrusion along coastal zones. In many Arab countries pumpage exceeds natural recharge, and withdrawal from alluvial and limestone aquifers is accelerating the advancement of the saltwater front. The same methods can be used to control the movement of contaminant plumes.

The other important aspect of artificial recharge is the storage of reclaimed wastewater. High-quality treated water may be stored seasonally, to be recovered later for irrigation and industrial uses. Large volumes of treated wastewater are allowed to flow into the sea in a number of Arab countries especially in Gulf region. Treated wastewaters are being disposed of along coastal zones or in wadi channels in most of these countries could be used to recharge the alluvial aquifers. However, the quality of treated effluent must be taken into consideration in order to avoid groundwater pollution and the consequent diminution of water supply availability. Treated effluent must meet certain water quality standards. Treated effluent used for recharge may entail further treatment flowing conventional secondary treatment in order to comply with health regulations concerning stable organism, heavy metals and the presence of pathogenic organisms.

Sandy soil and alluvial material, characteristic of large areas of the Arab region provide favorable conditions for the storage excess treated wastewater and the enhancement of its quality. The technique known as Soil Aquifer Treatment (SAT) can improve the quality of treated wastewater (Bouwer, 1985) this method involves recharging shallow aquifers through infiltration basins at the ground surface and takes advantage of ability of the underlying unsaturated soil profile to accomplish in situ biodegradation and filtration of

wastewater. The use of the SAT scheme with secondary effluent in arid regions of Arizona, in the United States, resulted in groundwater quality that met chemical and aesthetic requirements for unrestricted irrigation (Bouwer, 1985). Implementation of the SAT scheme in wadi channels and flood plains can increase the magnitude of recharge and improve the chemical and biological characteristics of the wastewater. SAT schemes are site-specific, however, and must be experimented with to determine the influencing factors of infiltration, percolation, and chemical and biological processes. Currently this technique is being experimented in Kuwait (KISR) Saudi Arabia (KFUPM) and Egypt.

Managing natural groundwater recharge and enhancing the magnitude by artificial means represents an excellent option for increasing water supply availability for all countries of the Arab region.

3. Artificial Recharge Technologies

The increasing demand for water has increased awareness towards the use of artificial recharge for augmentation of groundwater supplies all over the world. Stated simply, artificial recharge is a process by which excess surface water is directed into the ground to replenish as aquifer either by spreading on the surface in basins, by using

recharge wells, or by altering natural conditions to increase infiltration (Asano, 1985).

It is the technique of infiltrating or injecting water in an aquifer through surface systems like basins, canals or streambeds or by injection wells. (Figure 2)

It refers to the movement of water through man-made systems from the surface of the earth to underground water-bearing strata where it may be stored for future use. Artificial recharge (sometimes called planned recharge) is a way to store water underground in times of water surplus to meet demand in times of shortage.

Controlled artificial recharge is applied to serve one or more of the following objectives:

- Storage of water, aiming at improved water management where availability of water in time does not coincide with the water demands in time.
- Retaining salt water intrusion or up-coning, e.g. along coasts.
- Improvement of the water quality due to the purification capacity of the subsoil (reuse of wastewater).
- Restoring of groundwater levels in depleted aquifers.

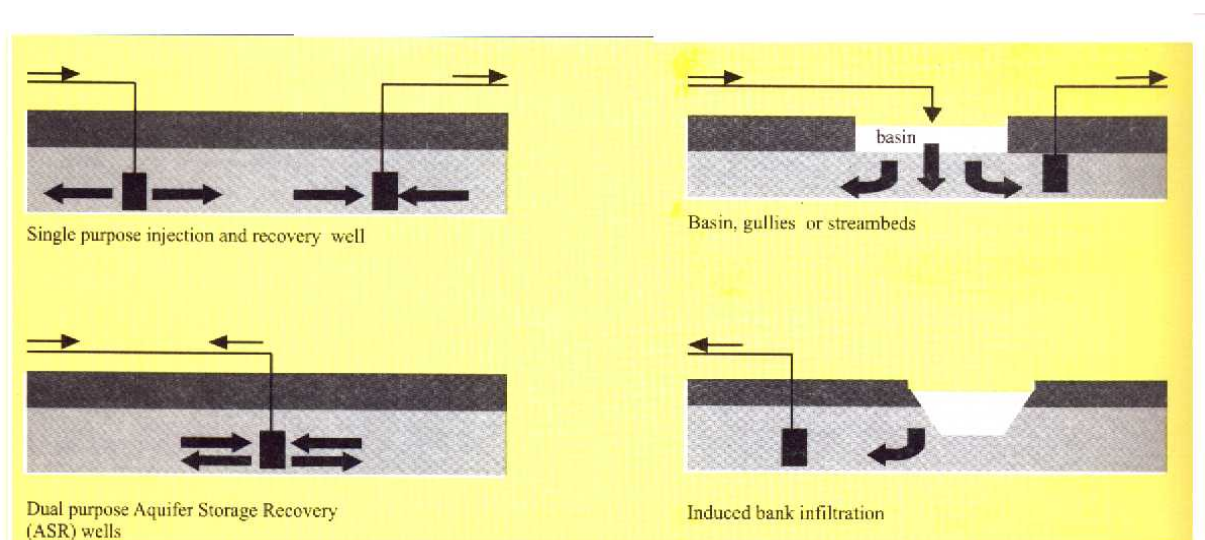


Figure 2: Artificial recharge techniques

Recharging basins are still the most common method of recharge and provide excellent versatility for water resources planning. However, the high cost of land in some urban areas has provided the motivation for the development of vadose zone injection wells. The problem of vadose zone injection wells is that once they are clogged, they are very difficult to redevelop since

there is no technique to backwash the well or to rapidly dry them. A combination of low technologies can be used to accomplish groundwater recharge with reclaimed water or other poor quality water sources. Table 1 summarizes the major characteristics for various technologies used for artificial recharge.

Table 1

Major characteristics of aquifer recharge methodologies

Parameter	Recharge Basin	Vadose Zone Injection Wells	Direct Injection Wells
Aquifer Type	Unconfined	Unconfined	Confined/Unconfined
Pre-Treatment Requirements	Low Technology	Removal of Solids	High Technology
Capacity	1000-20,000 m ³ /ha/day	1000-3000 m ³ /well/day	2000-6000 m ³ /well/day
Maintenance Requirements	Drying and Scraping	Drying and Disinfection	Disinfection and Flow Recovery
Soil-Aquifer Treatment	Vadose Zone and Saturated Zone	Vadose Zone and Saturated Zone	Saturated Zone

3.1 Experiences of Artificial Recharge in Egypt by Nile flood Water

Aquifers can be used as storage reservoirs for water by applying artificial recharge. In addition the underground passage and storage of water often results in improving the quality of the water. Artificial recharge can also be used to counteract salt water intrusion. Experiments on artificially recharging groundwater via basin infiltration and injection wells have been executed in the period between 1994 and 1999. The experiments have shown that basin infiltration is technically feasible in the western delta fringes with infiltration rates between 0.1 and 0.4 m/day. The realized infiltration rates will depend on the location of the basin and the mode of operation. Higher infiltration rates will be observed in case the basin is regularly cleaned and if the basin contains deeper gullies for the settlement of fine particles. Higher infiltration rates can be expected in the eastern delta fringes and the fringes of the Nile

valley. A preliminary financial evaluation was positive for the case that the recovered water would be used for agriculture. Reuse for industrial or public water supply purposes will increase the feasibility.

Tests with injection wells have indicated that artificial recharge by injection wells in a promising technique. Injection rates between 7 and 25 m³/hrs were realized for a period of a week in the western fringes of the Nile delta and the coastal area west of Alexandria. The tests were too short to make a final assessment. Longer tests are foreseen in the existing experimental sites and at a new pilot project in Toshka area, in the south of Egypt.

Artificial recharge of groundwater is an important technique for Egypt's water policy in which water conservation and reuse of water has high priority. This holds especially for schemes aiming at reuse of treated wastewater. Studies on existing schemes, like the el Gabal el Asfar farm, and column tests

have resulted in understanding and predicting the bio-chemical processes in the saturated and unsaturated zone and its effects on the groundwater quality. The results have been used in recommendations on using the soils as remediation environment for partially treated sewage water.

RIGW executed different artificial recharge experiments such as: El-Bustan, Bahig and Touthka using Nile water flood.

a)- Basin Experiments in El Bustan Extension Area

The subsurface in the El Bustan Extension Area is dominated by fluvial sand and gravel with thin interbeds of clay and silt, deposited during the Quaternary. The water in this aquifer exists under semi-confined or phreatic conditions. The site selection for the basin consisted of two phases:

- Regional drilling and geo-electrical investigations
- Local investigations. The experimental results illustrated in figure 3.

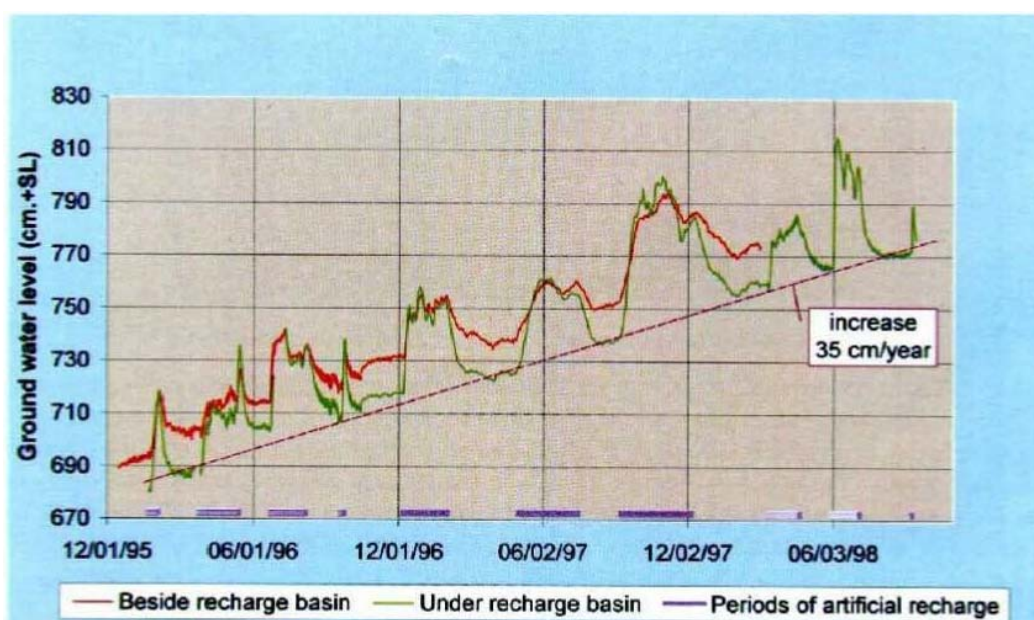


Figure 3: Experiment results

b) The Experimental in South Khoure Touthka

In Touthka area the largest reclamation project in Egypt is being executed. Part of the agricultural lands will be irrigated by groundwater. The option of artificially recharging part of the flood water before it is spilled into Touthka depression has been investigated to:

- Identify the most suitable recharge techniques (recharge basin, injection wells & gravity

wells) that can be applicable for the implementation of a large scale artificial recharge in Touthka.

- Assist of the technical and economical feasibility of applying such project in Touthka area. Figure 4 shows the results of the experiment.

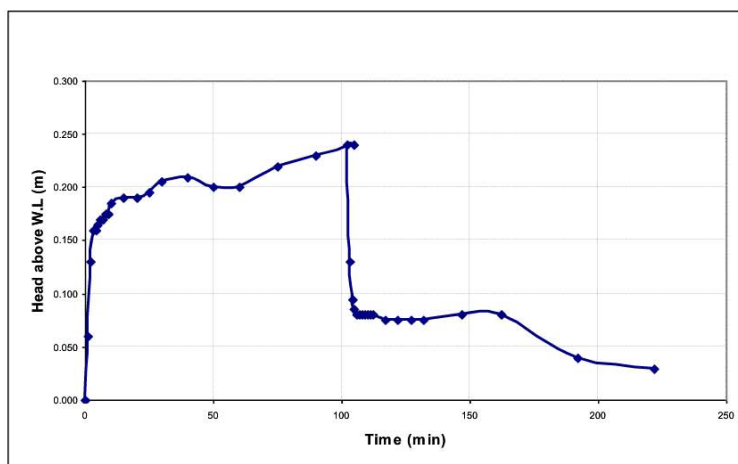


Figure 4: Increasing and decreasing head above groundwater levels after stopping recharge

4. Artificial Recharge Using Treated Wastewater in Egypt

4.1. Wastewater in Egypt

Historical in Egypt reuse of sewage, after primary treatment, in agriculture has been in practice since 1911 (Gabal Al Asfar farm: 3000 feddans). Yet, experience of large scale, planned and regulated reuse project is still Limited. At present there some large scale pilot projects (167 thousands feddans) namely East Cairo, Abu Rawash, Sadat City, Luxor, and Ismailia. In the mean time most of the sewage water drained to the agricultural drains is actually reused in one way or another. The total wastewater production from the main cities in Egypt is about 3.93 in 2009 as shown in Table 2.

Table 2

Wastewater production at major cities

City	Treated Wastewater Production (Billion m ³ /y)	
	2000	2009
Cairo	1.40	1.50
Alexandria	0.60	0.63
Other areas	1.60	1.80
Total	3.60	3.93

Agricultural drainage water and sewage water are reused nowadays in Egypt but the main concern must be how to mitigate the expected negative environmental impacts. This challenge has pushed the researchers to improve the tools or technologies by which the no conventional water can be recycled safely.

Sewage as a source for increasing water supplies, have been used in Egypt since 50 years. Normally, raw or treated sewage is used directly for irrigation. The aquifer artificial recharge by treated sewage water is a new tool can be applied in Egypt for using the sewage water safety compared with the direct use. Through the aquifer soil (unsaturated zone), advanced sewage treatment stage will be added by which most of the biological load will be removed and partially reduction in concentrations of some chemicals can be found.

4.2. Wastewater Quality

In Egypt, the domestic wastewater in the rural areas is concentrated with a COD (chemical oxygen demand) as high as 1100 mg/l, which is almost two times of that in the urban areas (Elmitwalli et. al., 2002). El-Sherbiney et al. (2001) determined the maximum aerobic biodegradability of the Egyptian domestic wastewater. They found that the minimum aerobiceffluent COD concentration of rural areas was almost similar to the Egyptian effluent standards for COD, while the minimum aerobic effluent COD concentration of urban areas was

significantly lower than that of the Egyptian effluent standards for COD. Ibrahim (1995) evaluated the applied different technologies for domestic wastewater treatment in rural areas of Egypt. He also found that the effluent of these systems did not comply with Egyptian effluent standards for COD. Most of developed countries have the effluent standards for treated municipal wastewater in Classes. Egypt had only one effluent standard for the treated domestic wastewater.

The Egyptian effluent standards for COD are even lower than some classes in developed countries. Moreover, this value is higher than that in most of developing countries. Based on the effluent standards in many developed and developing countries. The Egyptian effluent standards for treated domestic sewage are recommended to be divided in the four classes.

- First class: for the effluent of the wastewater treatment plants in the cities. The domestic wastewater of the Egyptian cities, which

represents the major part of the Egyptian domestic wastewater, is less concentrated as compared to that of villages and, therefore, it is possible to achieve a high quality effluent, if these wastewater treatment plants are operated properly.

- Second class: for the effluent from wastewater treatment plants in villages and this class can have a lower effluent quality as compared to that in class 1.
- Third class: for the effluent of on-site treatment systems for remote houses or communities, which will be installed in any area without any sanitation? This means that any new houses or communities should have pre-treatment facilities.
- Fourth class: for the existing houses in the rural areas without any sanitation.

Table 3

Recommended Maximum permissible-Concentration for COD, BOD5 and pathogen

Parameter	Class 1	Class 2	Class 3	Class 4
COD (mg/L)	100	200	350	350
BOD5 (mg/L)	40	80	200	200
Pathogen (FC/100 mL)	1000	5000	10000	10000
Recommended treatment System	Pre-treatment (sedimentation or Anaerobic treatment) followed by aerobic treatment + disinfection	Pre-treatment (sedimentation or anaerobic treatment) followed by aerobic treatment + disinfection	Sedimentation tank, septic tank or anaerobic treatment + filter, wetland or pond	Sedimentation tank, septic tank or anaerobic treatment + filter, wetland or pond

These mentioned-classes have to upgraded and modified stepwise, in each phase, until achieving the targeted effluent standards. The adaptation and implementation of such classes and recommendations in this paper will result in a control and a reduction of the pollution from domestic wastewater in a short period and will

reduce the illegal discharge of untreated wastewater to the canals and drains in Egypt.

Using treated wastewater in groundwater aquifer recharge can play an important role in managing these resources and enhancing the groundwater quality and quantity. Applying of such projects for

recharging aquifer with treated wastewater is restricted by the regulation of the Egyptian Environmental EEAA, Authority of tourist, development and irrigation laws. Applying this system will be a solution in wastewater sanitation

in the small new communities if it is environmentally safe. The project will provide Ministry of Water Resources and Irrigation with a set of guidelines in applying the obtained results of the controlled artificial recharge technique.

Table 4

Major characteristics of aquifer recharge methodologies

Parameter	Recharge Basin	Vadose Zone Injection Wells	Direct Injection Wells
Aquifer Type	Unconfined	Unconfined	Confined/Unconfined
Pre-Treatment Requirements	Low Technology	Removal of Solids	High Technology
Capacity	1000-20,000 m ³ /ha/day	1000-3000 m ³ /well/day	2000-6000 m ³ /well/day
Maintenance Requirements	Drying and Scraping	Drying and Disinfection	Disinfection and Flow Recovery
Soil-Aquifer Treatment	Vadose Zone and Saturated Zone	Vadose Zone and Saturated Zone	Saturated Zone

Where sewage effluent is to be used for potable purposes, recharge and recovery breaks the toilet-to-tap connection of water reuse and enables blending with natural groundwater. Combined with soil-aquifer treatment, these aspects enhance the aesthetics and public acceptance of potable water reuse. Water reuse and storage of surplus water for use in times of water shortage also must be increasingly relied upon to cope with uncertainties in future climates and their effect on surface and groundwater supplies. Design and management of artificial recharge systems involves geological, geochemical, hydrological, and engineering aspects.

Figures 5, 6 present the locations of treatment plants in the Nile delta and valley. The total expected rate of treated wastewater representing 9% of Egypt's share from Nile.

4.3. Experience of RIGW in Artificial Recharge Using Treated Waste Water

• Selection Criteria and Preliminary Investigation

To delineate the suitable areas for applying the artificial recharge technique over Egypt, a regional study for the factors affecting the feasibility of the artificial recharge has been carried out. The analysis was carried out for the entire Egypt using the Geological Information System (GIS) as well as extensive field data. A GIS based method is found to be very useful in suitability analysis for artificial recharge sites (Saraf and Choudhury, 1998).

The factors affecting the feasibility of the artificial recharge in Egypt have been classified as include: (i) hydrogeological set up; (ii) depth to groundwater; (iii) hydraulic parameters; and (iv) the prevailing treatment stages. Another important factor is that groundwater in and near the experimental site is not of high value, e.g., is not a main source of drinking water. This will reduce the risks associated with possible pollution of groundwater. Other factors of importance in facilitating operations include: (i) the accessibility of the site; (ii) the distance to the treatment/collection facility; and the distance to the laboratory. (Figure 7)

El Gabal El Asfar, Abu Rawash and Helwan.



Figure 5: Location map of sewage treatment plants in Nile Delta

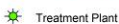


Figure 6: Location map of sewage treatment plants in Nile valley

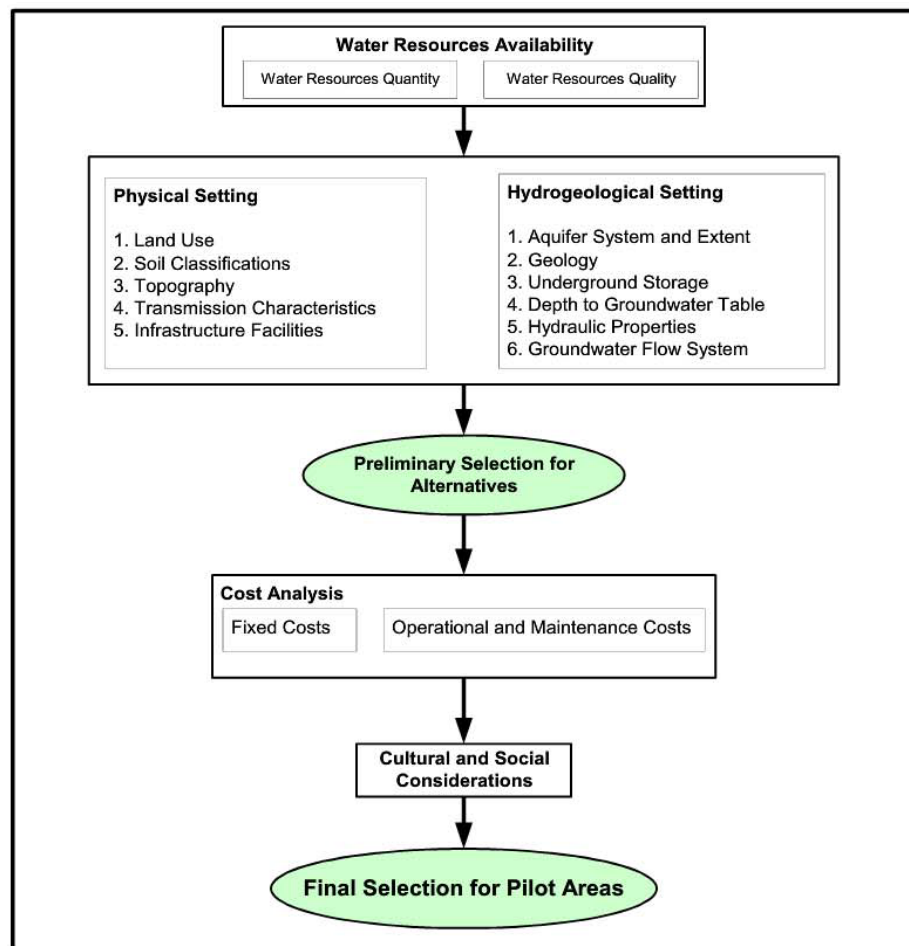


Figure 7: Schematic diagram of the selection process

a) Column Experiments

- Artificial recharge of treated sewage water is considered a promising technique to increase the usable for water resources.
- As a part of the artificial Recharge program column experiments have been executed to simulate infiltration with partially treated sewage water in Abu Rawash.
- The main objectives of the study are:
 - o Assessment of the vulnerability of the aquifer for various polluting constituents of sewage water.
 - o Assessment of the chemical process during infiltration of partially untreated sewage water.

b) Abu Rawash experiment (Basins method)

The selected area for applying the reuse of treated sewage water based on the hydrogeological conditions and vulnerability to pollution of the groundwater aquifers is Abu Rawash treatment plant. Where, the raw wastewater from greater Cairo is collected to Abu Rawash wastewater treatment plant at the desert fringes northwest of Cairo. Then the treated wastewater is disposed to a line canal then to Al Rahawy Drain. To investigate and quantify the aquifer recharge by treated wastewater under different hydraulic load conditions using recharge basin or injection well, a square basin with length of about 50 m was constructed.

• Physical and Hydrogeological Settings

The recharge site is located 30 km northwest of Cairo City and east of Cairo-Alexandria desert road. The surface is almost flat and the ground elevation is about 15.0 m (amsl). Detailed hydrogeological investigation for the site has been carried out including topographical surveying, soil classification, and geo-electrical resistivity survey. It was assessed that it is one layer aquifer system which comprises of coarse sand with fine gravel and intercalation of silt and clay thin layers which promised good prospects for the groundwater recharge. The depth to groundwater ranges from 4 m to 7 m below the ground surface. The pumping test data analysis indicating that the saturated hydraulic conductivity for the study area ranges from 15 to 30 m/day. The average effective porosity ranges from 15% to 25%.

• Groundwater Quality Evaluation

To evaluate the effect of using pretreated wastewater for recharging the aquifer on the groundwater quality, the chemical and bacteriological constituents of the wastewater and groundwater was tested. Total Nitrogen, Phosphorus, BOD and Fecal Coliform were tested as indicators for soil aquifer treatment efficiency.

The Biological Oxygen Demand (BOD) and Suspended Solids (SS) were measured before and after the pretreatment process to assess its efficiency as shown in Table 5. The efficiency of suspended solid removal is about 41% while it is about 25% for decreasing the bacteriological load table 5.

Table 5

Measured BOD and SS for wastewater before and after the pretreatment process

Parameter	Average Concentration (mg/l)	
	Raw Wastewater	Pretreated Wastewater
SS	2800 – 2000	1500 – 1300
BOD	400 – 300	300 – 200

• Role of Aquifer-Soil in Waste Water Treatment

- The artificial recharge with waste water is depending on the exchange impacts of soil on water and the impact of water on soil. The exchange impacts play an important roles in purification process of the recharge contaminated water.
- The organic loads which are expressed by COD and BOD in the waste water are considered the main problems and pollutants in the recharged water. These organic loads causes the following:

- o Increasing the organic matter content in the soil.
- o Decreasing the infiltration rate of the soil by time.

4.4. Experiment Results

The organic matter % of surface and subsurface soil were studied in addition to the determination of BOD of the sewage water during the time of recharging that sewage water to the G.W which was extended to about one year. The samples were collected on monthly and management of these parameters are represented in Figures (8, 9, 10)

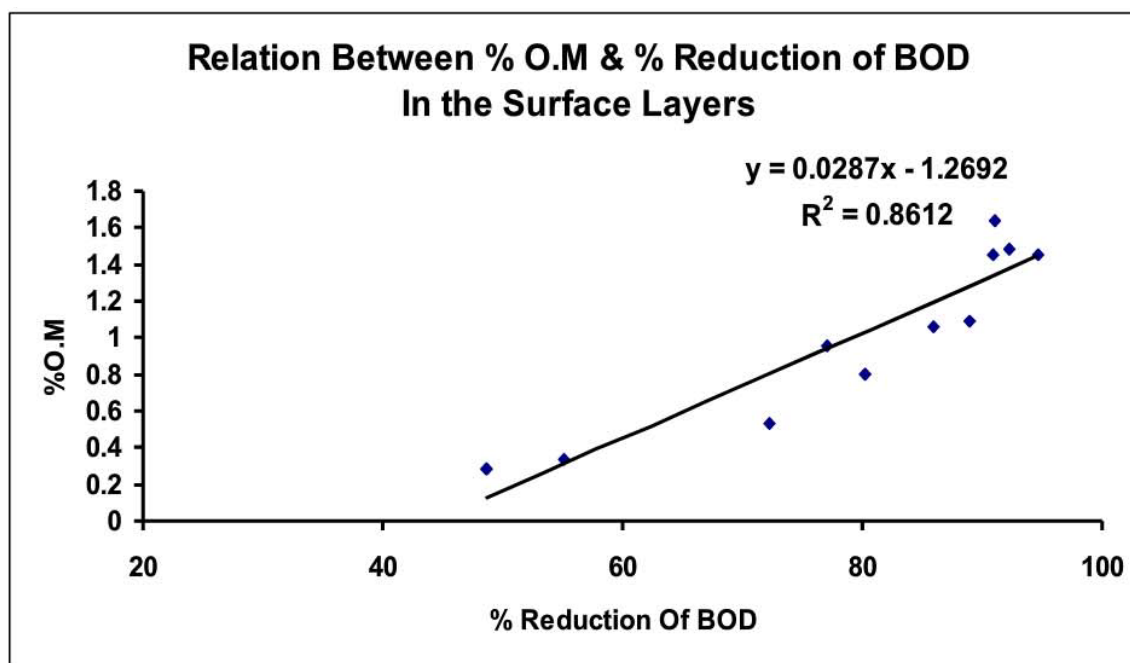


Figure 8: The linear correlation between the reduction of BOD and organic matter in the surface layers

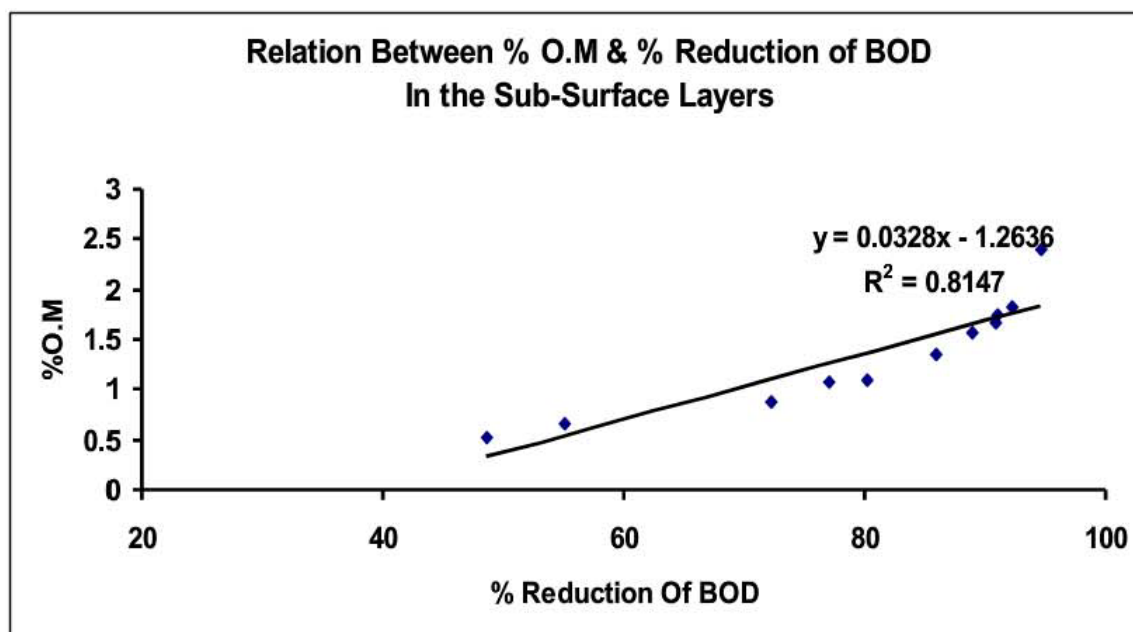


Figure 9: The linear correlation between the reduction of BOD and organic matter in the sub-surface layers

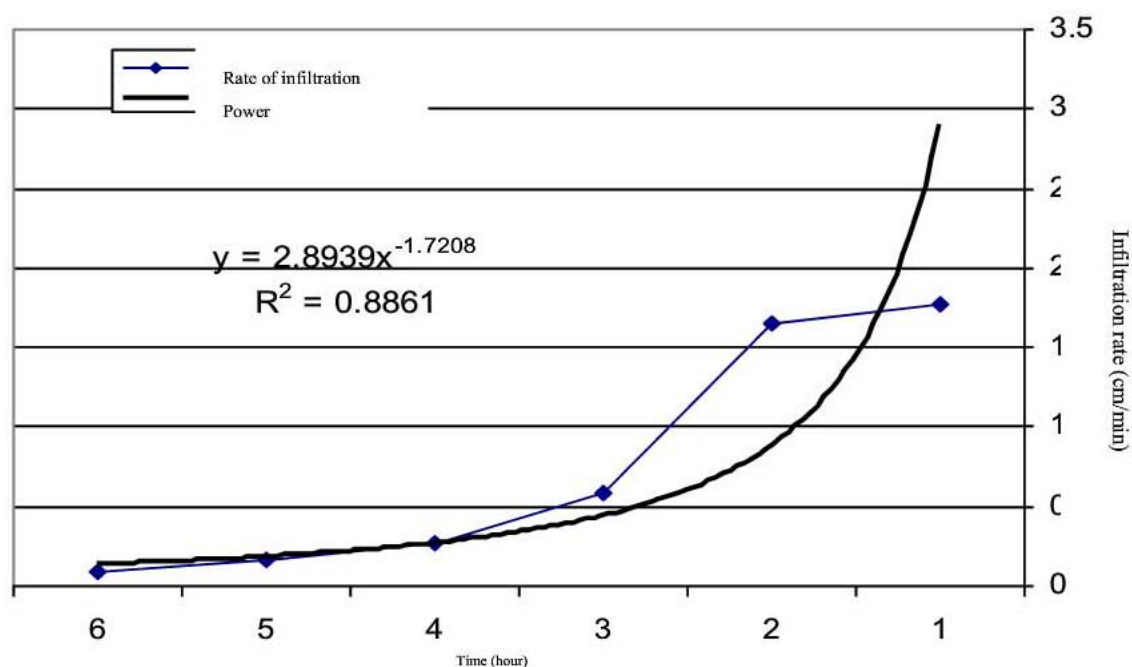


Figure 10: The results of the experiments

The previous Figures presents the relation between the organic matter content of both surface and subsurface soil layers and reduction of biological oxidation demand of the sewage water that recharged artificially to groundwater at Abu Rawash area. The relations followed linear regression with the following equations $y=0.0287x-1.2892$ and $y=0.0328x-1.2636$ for surface and subsurface soils respectively. The relations were strongly significant were R^2 values were 0.8612 and 0.8147.

The results clear that the soil played an important role in treating the sewage water. The soil prevented organic compounds that exist in the sewage water to pass through the soil to groundwater.

• Conclusions of Abu Rawash Experiment

- The soil can play an important role in treating waste water.
- The infiltration rate will be decreased by continuous recharging waste water.
- The infiltration rate will decrease gradually to reach the clayey soil infiltration rate value at

this time the top layer of the basin should be removed to permit waste water infiltration.

5. Application of ICID Check-List Method

Application of ICID check-list can be an efficient tool in performing such steps. The check-list is used to collect and present extensive knowledge and information about the project in the straight forward way. The output of this application is a decision on the most significant impacts and the shortage of data (FAO, 1995).

Approach of assessment of the potential impacts and identification of environmental setting based on evaluation results obtained from operation artificial recharge experiment fro groundwater aquifer in Abu Rawash. Typical EIA matrix for drainage and irrigation has been developed to qualify the base line of environmental and hydrogeological setting and the potential impacts before and after experiment operation which was based on simple qualitative. Figure (11) shows the expected percentage of negative and positive impacts.

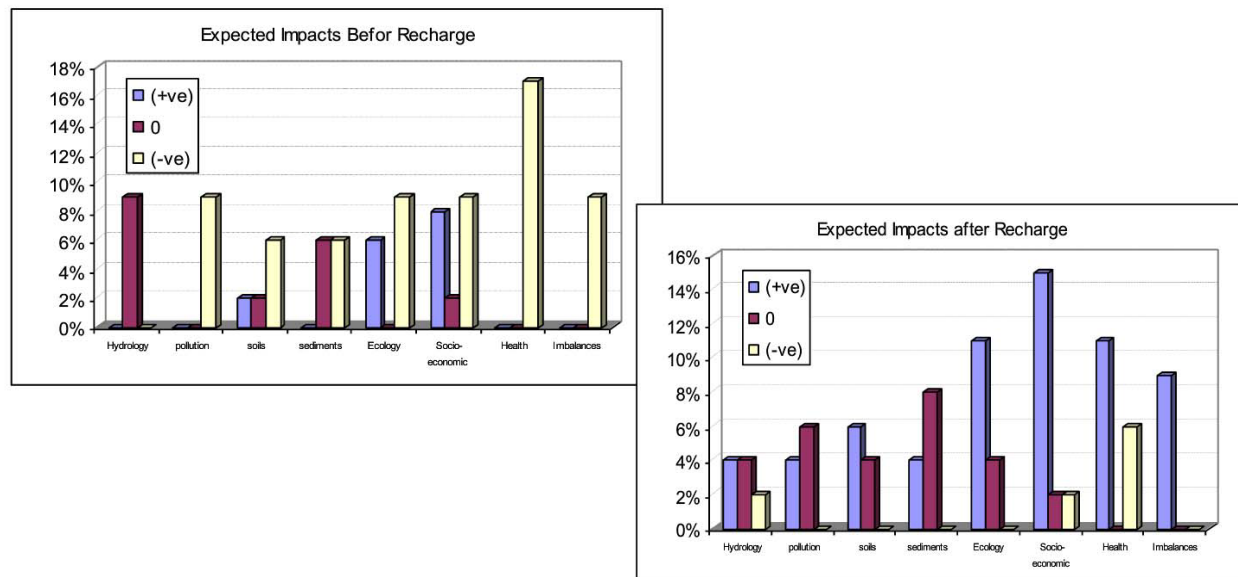


Figure 11: Expected percentage of negative and positive impacts

6. Summary and Conclusions

Increasing demand for water in Egypt particularly in the areas suffering from shortage of surface water has shown that the extended groundwater reservoirs formed by aquifers are invaluable for water supply and storage. Natural replenishment of this vast supply of groundwater is very slow. Artificial recharge as a means to boost the natural supply of groundwater aquifers is becoming increasingly important in groundwater management particularly in non-potable water reuse.

The objective of this study is to present the preliminary hydrogeological investigation and tested scenarios for the aquifer storage which used to evaluate the technical environmental, consideration in Abu Rawash farm as a case study. In addition to applying environmental impact assessment (EIA) of artificial recharge experiment to assess the feasibility guidelines for the future recharge projects.

Recharging the aquifer with constant hydraulic load increased the recharge rate by about 40%. In case of using the pretreated wastewater, the soil efficiency in removing the pollutants is decreasing due to the changes in its chemical balance and physical properties. It is recommended to carry out detailed study about the effect of leaching the soil by fresh water or adding some chemicals in the recharging basin to activate pollutants removal.

The ICID checklist is very simple layout of sheet enables an overview of impacts to be presented clearly which is enormous value for scoping the process and data shortage can be easily seen.

A well designed active recovery system for the recharged pretreated wastewater can be considered as a protection system that prevent the contaminants from migration and extend. Also a good designed monitoring system is a must to evaluate the effect of recharge process on the groundwater in terms of quantity and quality.

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