ESCWA UNEP BGR (MEW)

Distr.
LIMITED
E/ESCWA/ENR/2000/WG.3/5
6 November 2000
ORIGINAL: ENGLISH

ECONOMIC AND SOCIAL COMMISSION FOR WESTERN ASIA

Expert Group Meeting on Implications of Groundwater Rehabilitation
for Water Resources Protection and Conservation
Beirut, 14–17 November 2000

POLLUTION OF GROUNDWATER FROM IRRIGATION PRACTICES IN THE ARAB COUNTRIES

00-0627

Pollution Of Groundwater from Irrigation Practices in the Arab Countries

Background

It is evident that the Arab Countries are facing blooming water crises. The estimated per capita share of water in the Arab countries in general is less than 1000 cubic meters/year and it is less than 400 in most of the Gulf Arab countries, compared with 7650 cubic meters annual per capita water share in the world in general. Another critical aspect of the water resources in the Arab countries is the high percentage of the present utilization of the resources to the total available. It is estimated that total utilization of water resources in the Arab countries is as high as 80%, compared to only 8% the world wide. The utilization reaches more than 100% in some Arab Countries as shall be discussed later. In addition to that the Arab Countries lie in the driest hottest belt in this world with unbalanced water budget and very high water requirement in all aspects of life. This shows clearly the severe water situation in the Arab Countries which imposes great concern towards its protection, conservation and sustainability.

2- The Relative Importance of Groundwater in the Arab Countries

The water resources in the Arab region are mainly the conventional sources, namely surface and ground water. Due to the limitation in these conventional resources and their inability to meet the growing demand for water in the region, nonconventional resources are gaining a continuous accelerated momentum. The non-conventional resources in the Arab region comprise, the reuse of agricultural, domestical and industrial drainage, in addition to increasing use of desalination of salted water.

Groundwater resources represent a very small percentage of the total available Arab water resources, in general. It is in the range of 14% but it represents almost 100% of the water resources of certain Arab Countries. It is estimated that the total fossil fresh water storage in the Arab Countries is in the magnitude of 7734 milliard cubic meters, while the annual recharge is only 42 milliard and only 35 milliard are available for use. Its regional distribution is as follows :-

Table No (1)
Ground Water Distribution in the Arab Countries

Regions	Fossil		Recharge(annual)		Usable (annual)	
	10^9 m^3	%	10^9 m^3	%	10^9 m^3	%
Eastern Region	13.3	0.2	8.5	20.2	6.58	18.7
Arabian Peninsula	361.6	4.7	4.8	11.5	4.71	13.5
Central Region	6439.0	83.2	11.2	26.8	8.75	25
Western Region	920.0	11.9	17.4	41.5	15.0	42.8
Total	7733.9	100	41.9	100	35.04	100

Source: AOAD sources and studies

There are many schools of thought and approaches regarding the use of groundwater, one of these approaches advocates for the use of fossil water, which is being collected over millions of years and is being recharged in very slow limited process. AOAD advocates that the use of groundwater shall not exceed the rechargeable portion. This shall be discussed in details later. Within the rechargeable portion a limited portion is available for use, due to geographical, quality or any other reasons.

Table No (1) shows that the fossil ground water which is mainly concentrated in the Central Region with 83 % while only 0.2% is in the Eastern Region. These percentages greatly differ when considering the usable groundwater in the Arab Region, increasing to 18.7% in the Eastern Region and going down to 25% in Central Region, and with the highest percentage of usable groundwater, (42.8%) in the Western Region.

Table No (2) shows that the overall relative importance of groundwater in the Arab Countries regarding water availability is in the range of 14% as mentioned above. This percentage ranges from about 8 to 9% in the Eastern and Central regions to 27-28% in the Arabian Peninsula and Western region.

Volume wise, groundwater relative importance in the Arab Countries wide ranges from about 4% in Sudan to 97% in Bahrain and 91% in Qatar and 73% in Saudi Arabia 60% in Mauritania.

The relative importance of the groundwater cannot only be judged from volume point of view. For example in Sudan where its percentage to the total available water resources is less than 4%, it has a very high relative importance reaching 100% in certain parts of Sudan where it is the only available source of water specially in Western parts of Sudan far from the Nile Valley . Almost more than 60% of the population in Sudan rely on groundwater for their domestic water use and more than 80% of the animal watering is from groundwater resources.

Table No (2)
The Relative Importance of the Groundwater in the Different Arab Region

Region	Groundwater (usable)		Surfacewater		nonconventional		10^9 m^3/y %	
	10^9 m^3/y	%	10^9 m^3/y	%	10^9 m^3/y	%		
Eastern	6.6	8.9	67.2	91	0.04	0.01	73.84	100
Arabian Peninsula	4.7	27.8	9.9	58.6	2.3	13.6	16.9	100
Central	8.7	8.6	87.4	86.5	4.9	4.9	1.1	100
Western	15	27.1	40	72.2	0.36	07	55.36	100
Total	35	14.1	204.5	82.8	7.6	3.1	247.1	100

Source: computed from AOAD reports & studies.

It is clear that groundwater plays a major role in the water resources utilization in the Arab Countries and it has a very high relative importance in many of these countries.

3- The Main General Sources of Pollution of the Groundwater in the Arab Countries

It is evident that the effective use of groundwater or any water depends on the extent of its quality. The groundwater quality differs from aquifer to aquifer and from region to another depending on the types of rocks and stratum it passes through and the overlaying types of soils. The sources of groundwater pollution are either natural or due to unbalanced human activities.

The natural groundwater pollution is mainly due to the natural interaction of this water through its hydrological and hydrogeological cycles. These interactions are governed by the chemical and physiological natural laws.

Salinity is the main natural pollution of the groundwater. It is due to the chemical interaction of water when it passes through rocks with high salt contents.

The aquifer vulnerability is another natural source of pollution. This depends on the aquifer permeability, the extent of the cracks in the overlaying strata groundwater level, and the composition of the strata, of the aquifer.

The chemical properties of the overlaying soil, through which the recharge of the groundwater takes place are effective potential sources of pollution of groundwater. It is known that groundwater recharge is mainly from the part of rainfall that finds its way to the groundwater. So all the recharged portion passes the overlaying soil before reaching the groundwater. Here the pollution may take place. These soils may contain some organic materials which could be carried to the groundwater thus polluting it.

Also the physical properties of these overlaying strata affect to large extent the rate of infiltration of the water recharging ground water. The slower the rate of flow the more the possibility of pollution.

The geographical location is another source of groundwater pollution, aquifer near to the sea or any other large salt-water bodies are subject to pollution if the hydrostatic balance is disturbed for any reason. Sea intrusion into fresh water aquifer is experienced in the coastal aquifers.

Rainfall is the main source of groundwater recharge in the Arab Countries, its variation definitely, has impact on the groundwater quality. Drought and reduction on the normal average of rainfall lead, no doubt, to the reduction of the recharge rates, this means in many cases of confined aquifers increasing the saturation of salts and other minerals.

The Arab Countries have witnessed in the last three decades various activities in all aspects of life. One of these activities is the accelerated development including the agricultural sector. The unbalanced, nonrational development specially of water resources, has some foot prints on the quality of the water resources. These include the following:

Many Arab Countries have extensive urbanization and industrialization programs, which has lead to huge displacement of population towards the large cities leading to disturbance in the

demography of urban and rural population. One of the unavoidable consequences of this disturbance of demography is the stress on the water supply networks, which are not designed to meet this continuously increasing demand. The results are the repeated breaks of the systems with large leakage of water which will find its way to higher groundwater levels, carrying with it all pollutants material on its way. Another element of urbanization is the production of large domestic wastewater, which is another potential source of pollution to groundwater, as rainfall shall carry all soluble and decomposed parts of this waste to the groundwater. Domestic wastewater treatment plants also face the same stresses,this coupled with the lack of proper maintenance and modernization lead to large leakage of untreated wastewater which eventually goes to the groundwater polluting it. Another important element of the random people displacement is that most of these displaced people have little or no sanitation facilities. This shall definitely lead as uncontrolled pollution to the environment and eventually polluting the groundwater.

Another problem of industrialization which traversed the Arab Countries, is that most of these industries and specially the many scattered small industries are not well planned.They produce many polluted waste material(including wastewater) contaminated with chemicals, minerals and some time toxic heavy minerals. Due to its unplanned nature and being small enterprises, it is almost impossible to impose on it the obligation of the treatment of this wastewater. One of the consequences is definitely the pollution of the groundwater. Even the large planned industry in the Arab Countries, in many cases, behaves the same. As mentioned earlier, industry produces polluted wastewater, which contains many chemical even heavy metals. Certain industry like leather industry produces large amount of such wastewater. The industry usually tries to dispose of this polluted water with the least cost, one of the means is injecting it into the groundwater through boreholes specially constructed for this purpose. This is an unaccepted practice as it is a direct pollution to the groundwater resources. In certain cases limited treatment is being conducted prior to this injection, but still it is unacceptable practice and most of the countries national laws prohibit it.

The production of groundwater associated with the mining of petrol may be source of groundwater pollution. Huge amount of polluted water is sometimes produced with the production of oil. The disposal of such water may eventually constitute a source of groundwater pollution . This is very common in many Arab Petroleum producing Countries .

4- Irrigation Practices as Sources of Groundwater Pollution

In addition to the above main sources of groundwater pollution, there are other sources of such pollution. This is the focal points of this paper. Certain nonrational irrigation practices are considered as the most effective pollution sources for groundwater. Sometimes rational controlled irrigation practices ultimately lead to some sort of groundwater pollution. These are inevitable irrigation practices.

The irrigation practices that lead to groundwater pollution include :

4-1 The Reuse of waste water in irrigation

As mentioned before most of the Arab Countries are facing serious water shortage due to many complicated interconnected reasons, the most important of it is the limited conventional resources. One of the available obvious options is the use of nonconventional water resources.

Reuse of the treated wastewater is in the top of these options. Such reuse has a dual objective; safe disposal of this environmental pollution and bridging the water shortage gap.

The wastewater in general include sewage, which is domestic disposal, industrial disposal and agricultural drained water . It is evident that prior to the reuse of any of those types of wastewater proper treatment is prerequisite.

Proper treatment can be done easily when the wastewater is being properly collected through controlled organized wastewater drainage network. After treatment most of organic and inorganic materials are decomposed and all solid and toxic materials are taken away from the wastewater making it more acceptable for reuse in irrigation, but still the treatment can never produce totally pollutant free water. It is inevitable that the reuse of such water shall eventually go down to the groundwater polluting it .

4-1-1 Reuse of domestic wastewater in Irrigation

It is true that the effect of the controlled sewage disposal of urban centers on the pollution of groundwater is very much reduced through proper treatment. But most of the Arab population; do not have controlled organized sewage disposal network systems due to economical reasons. They use different ways and means to dispose of their natural human discharges. These are mainly isolated units with limited treatment or no treatment at all and as such they represent effective source of pollution of groundwater. These isolated units include:

- Bucket latrine

This primitive system was in use in many rural and even urban centers in some Arab Countries some time ago and may be still going on in certain remote areas. But in general it is been largely abundant and replaced by other systems. In this system, the discharges take place directly on small metal buckets. These puckets are emptied daily by night into large tankers. The collected material is then placed into large open spaces to dry naturally by sun. Through this process a substantial portion of the liquid part infiltrates to the groundwater. During the rain season the amount of infiltration increases as the rainfall carries a large amount of soluble materials to the groundwater. The dry sludge is commonly used as fertilizer manure, causing groundwater pollution.

- Pit latrine

This system is still the most common system of disposal of human discharges in the rural areas and even in the suburb of some urban areas in the Arab Countries.

The human discharge takes place directly on the open well which connected to the subsoil groundwater. This untreated discharge is definitely a direct pollution to the subsoil water system and it may reach the main groundwater system. In many cases the wastewater in these pits are pumped when the well are full due to bad connection with the subsoil. This pumped untreated wastewater is mainly use to irrigate green lawns and forests. This practice definitely shall lead to groundwater pollution.

- Soakaway pit latrine

This system is in use in certain up graded rural areas. The unit is composed of two components, three chambers septic tank and a soakaway pit filled with porous material like sand stone or broken red bricks. The discharge takes place directly in the septic tank, where preliminary

natural treatment takes place. The solid material is allowed to decompose and its residue rests on the bottom of first chamber. In the second chamber more decomposition and settlement of the solid material take place. The third chamber receives almost clear water and then it flows into the soakaway pit . The material of the soakaway pit is changed from time to time . It may take ten years to change this material if the soil around the soakaway pit is porous and allows the water to infiltrate. This infiltration definitely reaches the groundwater in the long run.

- Syphon system

This is the common use till now in many urban Arab centers and cities which lack adequate organized controlled sewage network system. It is an isolated system for a house or a group of houses or buildings. The disposal is collected by a small in house system of pipes and manholes.

The disposal then flows into a septic tank where a similar process of the above soakaway pit system takes place. The clear water then flows into an open well connected to the subsoil water (same as pit latrine). Although some natural treatment takes place, but still the discharged water into the open well is considered a pollutant to the ground water. In addition to that it may face the same situation mentioned in the pit latrine where excessive wastewater is pumped and used in some sort of irrigation which eventually pollute the groundwater.

4-1-2 Reuse of Industrial wastewater in Irrigation

The industrial wastewater is generally the most toxic wastewater. It contains many mineral, heavy materials and dangerous chemical like the dyes and leather tanning. Usually industry is obliged to treat their disposed wastewater before discharging them in natural or man made system. Reuse of such water in irrigation is not very much recommended but sometimes it is being used for irrigating green lawns and nonproductive agriculture. Such practice may eventually lead to the pollution of the groundwater.

4-1-3 Reuse of Agricultural drainage in irrigation

It is common practice to reuse agricultural drainage water back in the irrigation system. This agricultural drainage is full of the residue of the chemical fertilizers, insecticides, pesticides and weed control materials. This type of wastewater is reused without any treatment. It is either being added to fresh water or used in irrigation at intervals between fresh water usage. This type of practice reduce the concentration of these chemicals in the water. But still some of these chemicals shall infiltrate down to the groundwater polluting it.

4-2 The Overutilization of groundwater

To meet the growing demand for food, many Arab Countries with limited surface resources have expanded their irrigated sectors utilizing the groundwater. Their ambition was above the capability of their groundwater. Over use of the groundwater has resulted in devastating conditions. The groundwater salinity has increased beyond the permissible limits for use. In many cases the groundwater leveled was lowered beyond the economical depths of abstraction . Table No(3) shows the increasing pattern of the agricultural water use in the countries of the Arab Gulf Cooperation Council (GCC) in the last two decades.

Table (3)
The Pattern of the Growing Utilization
Of Water for Agriculture in the GCC Countries

Million cubic meter /year

Country	1980	1985	1990	2000
Emirates	450	600	800	1200
Bahrain	70	80	100	120
Saudi Arabia	1860	7430	1400	20000
Sultanat Oman	650	750	880	1200
Qatar	65	70	75	85
Kuwait	-	65	80	110

Source : AOAD paper on Appropriate Technologies for Water Resources Development.
Arab Ministerial Conference on Water – Cairo 1997.

This shows clearly the fast growing water use pattern especially in Saudi Arabia where the utilization was increased to more than ten folds in two decades. It is known that these countries have very limited or almost no surface water resources .This expansion is almost relied on the over utilization of groundwater.

The over utilization of the groundwater is considered to be the most serious and effective source of pollution of this vulnerable resources. It is considered that any utilization above the annual rechargeable portion of the groundwater is over utilization. The balanced rational utilization must be within the annual rechargeable limits. The direct consequences of such utilization are of economical, environmental and social impacts. This type of utilization shall definitely lead to the reduction of groundwater levels in the concerned aquifers. Economically this means an increase in the cost of pumping this water which shall be reflected on the cost of the production. Environmentally it shall lead to the deterioration of the quality of the groundwater and the increase of its salinity due to the intrusion of salt water from sea or any near by salt water bodies and aquifers. These economic and environmental impacts shall have adverse effect socially.

The groundwater depth in Gafara plains in Libya increased by 24 meters in less than 20 years , due to over-utilization.This has resulted in the pollution of the main source of domestic water for many coastal cities in Libya including Tripoli. The same situation is also noticed in Tunisia where the over use of groundwater has increased the water depth from 6 meters to more than 30 meters below sea level. This has resulted in the continuous deterioration of groundwater quality in coastal cities of Tabia and Makneen. In Mauritania the intrusion of sea water to the groundwater has resulted in the abandon of the boreholes that feed the capital with domestic water. The intrusion of salt sea water into the coastal aquifers in Qatar is a recorded unhappy experience. These serious situations confirm that over utilization is the main source of groundwater pollution.

In Syria it was reported that there are more than 124000 boreholes in Damascus aquifers to meet the growing demand for water for agriculture, industry and urbanization development. The utilization was much more than the recharge, with the consequence of the reduction of groundwater levels increasing the cost of the water use and deteriorating its quality.

In Sudan the use of groundwater is mainly for the supply of drinking water for human and the large animal resources. The over utilization of groundwater specially by the animals in droughts periods that the Sudan has witnessed during the late seventies, has lead to the saltinization or drying up of many of these boreholes.

4-3 The leaching of the soil

In certain soils where the salinity is high, the soil is leached to wash away these salts. This contaminated water eventually infiltrate to the groundwater polluting it.

4-4 The use of saline water in irrigation

Due to the limitation of water resources in certain Arab Countries, there is a growing toward the use of saline water in irrigation. There is extensive research and study in this respect. This includes the following: -

- Breeding of certain crop varieties that can sustain saline water;
- The study of the effect of such practice on the soils;
- The most suitable irrigation systems;
- The irrigation sechdule when using such water.

Definitely this practice may be a real break through in finding solutions for the shortage of water resources in the Arab Countries , and it must be encourage. But one of its main disadvantage is the possible pollution of the groundwater.

4-5 Other Irrigation practices

One of human activities which has direct adverse impact on groundwater quality is the continuous growing chemical fertilization in the irrigated agriculture in the Arab countries. To meet the growing demand for food and to balance the economy of the irrigated sector, chemical fertilization is used for boosting production. In addition to that insecticides, pesticides and chemical weeding are largely used in Arab irrigated sector. The residue of all this chemicals may find its way to groundwater polluting it specially in the sandy porous soils in may Arab Countries.

One of the obvious examples is Nile Delta in Egypt, where the infiltration from the agricultural land in addition to sea intrusion has resulted in increasing the groundwater salinity to up to 6000 mile gram/litre.

In a study in Tadla plains in Morocco, it was reported that due to the use of chemical fertilizers, the groundwater was heavily polluted.

In Algeria the pollution of groundwater from agricultural activities was noticed in Mitidja plains and Sidi Bel -Abbes area.

In Jordan the Amman – Zarga aquifer has witnessed groundwater pollution and reduction in its water level by 30 meters, due to both over use and the chemicals application in agriculture.

5-Water Protection Measures (Constraints and Solutions)

By its nature the groundwater protection is a long-term process. . Its effect is slow and matches with the slowness of the pollution process itself. It is subject to the hydrogeological rules that govern the water movement and its interaction with the pollutant.

In the Arab Countries the main orientation was toward the development of the water resources while the protection of this vulnerable natural resources receives little attention.

Recently with the blooming crisis of water and the rising attitude towards the environment, the attention to the protection and conservation of the water resources has greatly risen in the Arab Countries. One of the most obvious actions is the creation of special Ministries for the Environment in many Arab Countries during the last two decades. Arab regional specialized agencies, one of which is the Arab Organization for Agricultural Development (AOAD), have intensified their efforts towards the issues of the rational use, protection, conservation and maintenance of the Arab scarce water resources. More efforts from all concerned, is still very much needed.

The main responsibility of the protection conservation and maintenance of all natural resources hinge on the countries national programs, which must be the spear head for any regional programs.

The measures of the groundwater pollution include the following:

5-1 Provision of Basic Data on the Groundwater Resources

It is evident that prior to the identification of any protection to any system, full information, and data about that system must be known. The collection of information and data about the groundwater and its interaction, is both time and cost consuming, and for that reason, there is a general tendency to relax on this important issue. Nowadays, there are advanced remote sensing systems for preliminary evaluation of the groundwater potential. This type of preliminary information and data is essential for any planning of the development or protection of these resources. The more the detailed the information, the more the effective the measure of protection. The basic needed data and information may include, the recharge amount, its system and sources, the type of the aquifer. These basic preliminary data are very useful but it is not a replacement for detailed ground investigation regarding, water quality, pumping test to determine aquifer capabilities and physical features, which is needed for actual utilization stage.

The preparation of hydrogeological maps for the groundwater is very helpful tool for the balanced utilization of the resource and identifying the source of pollution and the needed measures of its protection.

There are new advanced systems for the preparation of the hydrogeological maps based on the risk analysis. The UNESCO is promoting a system which shows the vulnerability of the aquifer.

These types of maps are most useful for the identification of appropriate protection measures. The analysis, upkeep and dissemination of the data, information and mapping are complementary to its collection.

5-2 The Balanced Utilization of the Resources

The groundwater storage is composed of two main parts. The fossil storage which took millions of years to be collected in the aquifers and as mentioned before, the volume of this fossil water in the Arab Countries is about 7734 milliards cubic meters. The other part is the annual recharge and that is the annual addition to the storage from annual rainfall or other sources and this is estimated as 42 x 10^9 m^3. As mentioned above there are two schools of thought for the utilization of the groundwater. The first advocates the use of the fossil water being a huge amount of water that may help in bridging the water gap in the world. The second school of thought calls for the limitation of the utilization to the annual recharge due to the many adverse effects of the first school, most important of which are the short life time of the utilization and the increasing cost from such utilization due to the continuous lowering of the groundwater levels and the environmental , pollution and social hazards associated with such utilization. AOAD is for the second school of utilization of the groundwater, for sustainable agricultural development. Balanced utilization within the allowable limits of the annual recharge is very effective measure for the protection of these resources

5-3 Proper Treatment of Wastewater

As mentioned above wastewater is one of the main pollutants of groundwater. Proper treatment of this wastewater for reuse or for discharging it is the natural water resources bodies, proved to be an effective measure for the protection of groundwater.

Therefore, wastewater, from domestic, industry or agriculture must be subjected to proper treatment before reuse in any field. Specific standards for treatment water must be clear according to the concern of each country. Generally, the process of proper planning wastewater treatment involves the following major steps:

- Determine the flow of wastewater.
- Determine the composition of such wastewater.
- Determine to standard for the disposed or reusable effluent.
- Identify objectives and alternatives process for treating effluent before disposal or reuse.
- Determine the quantity and quality of expected sludge.
- Determine standard of disposed or reusable sludge.
- Identify alternative sites for treating for disposing or reusing effluent and sludge .
- Determine the need for pilot studies and industrial pretreatment programs.
- Evaluate the technical , economical, social and environmental feasibility of each alternative and select the most attractive.

5-4 Legal Measures

Legal and constitutional protection measures are mainly concerned with issuing of specifications and laws to protect the resources. This may include :

- Water Resources Zone Protection, which is the physical protection of the water wells and aquifers.
- Laws identifying the responsibilities, duties and functions of all water concerned bodies.
- System of the authorization for the utilization of the resources.

- Treatment disposal of the solid and liquid wastes.
- The penalties for noncompliance with the laws.
- The mechanism for enforcing the laws.

5-5 Institutional Measures

The institutional setup is the focal point for the success of any measures. The effective organization being assigned with the protection measure is crucial point. The organizations must have able man power, technical ability and lastly and not leastly the willingness to be effective. The authority of such organization must expand beyond the protection limits. It must include the precautional measures which may include the right to object to any development, procedure, law, or any proposed action that may in the end lead to the pollution of the resources.

These precautional measures may prove to more cost effective than any other measures.

5-6 Capacity Building

The availability of trained staff is a prerequisite condition for the success of any measures to protect the resources. Capacity building of the staff assigned the job is the key for the success of the assignment. Continuous training in job is one of the effective easy means for partial capacity building. Advanced qualification and training is equally needed.

5-7 Public Awareness

The above discussion shows clearly that human activities are the main sources of groundwater pollution. Most of the people in the Arab Countries are not aware of this fact. They are not aware that their normal unquestionable life rhythm is one of the main sources of pollution of groundwater, which they need for drinking or use in agriculture or any other use. They need to know this and to be told how to improve their life rhythms in accordance with the protection requirement, the end result being improving the standard of their life.

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Figure (2)
The Groundwater Behavior in the Last
Two Decades in Gafara Plain in Libya

Figure (1)
Saline Groundwater Extent in the Arab Countries