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SUBSTANTIVE REPORT

EXPERT GROUP MEETING ON IMPLICATIONS OF GROUNDWATER REHABILITATION FOR WATER RESOURCES PROTECTION AND CONSERVATION BEIRUT, 14-17 NOVEMBER 2000

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ANNEXES

02-0009

I. INTRODUCTION

1. The Expert Group Meeting on Implications of Groundwater Rehabilitation for Water Resources Protection and Conservation, organized by the Economic and Social Commission for Western Asia (ESCWA) and the United Nations Environment Programme/Regional Office for West Asia (UNEP/ROWA), was held at United Nations House in Beirut from 14 to 17 November 2000 under the patronage of the Minister of Energy and Water in Lebanon. The Meeting was co-sponsored by the Federal Institute for Geosciences and Natural Resources of Germany (BGR) and the Ministry of Energy and Water in Lebanon. The Meeting constituted one of the activities planned within the framework of the 2000-2001-work programme for the Energy, Natural Resources, and Environment Division of ESCWA.

2. The aims of the Meeting were to review the status of groundwater pollution that may be taking place at the aquifers of the ESCWA member states, discuss the different techniques of groundwater rehabilitation and their application under different geological environments, review the results of application of groundwater remediation applied in some of the ESCWA countries or in areas of similar geological conditions, review the effort made in regard to groundwater in monitoring and protection, and promotion of public awareness on the pollution impact on health.

3. The Meeting documents included background papers prepared by the ESCWA secretariat; papers prepared by invited resource persons from UNEP/ROWA, BGR, and the Ministry of Energy and Water in Lebanon; country papers prepared by government-designated experts; and papers prepared by representatives from regional and international organizations and scientific institutions (see the list of documents in annex I). The presented papers briefly discussed the groundwater aquifer systems at national levels as well as the regional aquifers, degree of groundwater development and utilization and status of groundwater contamination level. In this sustentative report, only papers with significant contribution to the subject of the meeting have been selected that documented the status of groundwater pollution and discussed the techniques of groundwater rehabilitation and its application and groundwater protection measures.

4. The Meeting was attended by national water experts from ESCWA member states and invited national and international resources persons. Representatives from the following regional and international organizations and funding agencies also attended the Meeting: the Rome and Cairo offices of the Food and Agriculture Organization of the United Nations (FAO), World Bank, International Atomic Energy Agency (IAEA), Arab Academy for Science and Technology and Maritime Transport (AASTMT), Arab Center for the Study of Arid Zones and Dry Lands (ACSAD), Arab Organization for Agricultural Development (AOAD), Gulf Cooperation Council (GCC), International Center for Agricultural Research in the Dry Areas (ICARDA), Islamic Development Bank (IDB), Saudi Fund for Development, World Water Council, National Center for Remote Sensing in Lebanon, and academic institutions from different parts of Lebanon (see annex II for a list of participants).

5. The first part of this report will discuss the status of ground water utilization, the hydrogeological nature of aquifers in each ESCWA member states that may have been exposed to pollution or having a high risk of contamination from the different development activities. This background information is essential to the understandings of the pollution impact and the identification of appropriate groundwater rehabilitation techniques. The second part of the report briefly discusses the contents of the selected papers.

II. THE STATUS OF GROUNDWATER RESOURCES

6. Groundwater represents a vital source for all water consuming sectors especially in countries of the Arabian Peninsula region and Jordan. The magnitude of contribution of groundwater to the total supply varies not only from one country to another but also from sector to sector within the same country. Groundwater reserves in both renewable shallow and non-renewable deep aquifers are currently the main source of water in Jordan, the Syrian Arab Republic, Egypt, Yemen, the GCC countries, and Gaza, and have been exploited to meet

domestic, industrial and agricultural water requirements. Even in GCC countries where desalinated water is extensively utilized for domestic water supply, groundwater sources are used extensively in providing water for the rural areas, the irrigation sector and for mixing with desalinated water to increase the mineral content of the water. Groundwater utilization has been in excess of the safe yield of the aquifers. The magnitude of safe yield, representing the amount of water that replenish the aquifer annually and required to achieve sustainability groundwater, is estimated at 18.5 billion cubic meter (bcm). Groundwater utilization in the ESCWA region as of 2000 reached 29 bcm, compared to 18.5 bcm of groundwater recharge, which represent 67 per cent of withdrawal that been taking place in the GCC countries, Jordan and Yemen. In the countries of the Arabian Peninsula and part of Jordan where there are no major renewable surface water sources such as rivers, the depletion of groundwater has been extensive as demonstrated through the use of sustainability indicator shown in table (1). This indicator showed significant amount of groundwater is being withdrawn for the irrigation purpose and its sustainability has been threatened further by pollution from different groundwater resources in the ESCWA region.

7. In the ESCWA region groundwater quantity and quality has been threatened by increasing levels of depletion and pollution as a results of the various development activities and mismanagement practices. Groundwater over-exploitation from excessive and uncontrolled pumping has become a common observed features in many aquifers in Jordan, GCC countries, Gaza, the Syrian Arab Republic and Yemen. Groundwater quality is deteriorating from the dumping of domestic and industrial wastes and point and non-point irrigation sources into rivers and wadi beds and seawater intrusion into the coastal plains aquifers of countries of the Arabian Peninsula. As the quality of water deteriorates, its scope of uses diminished, thereby reducing groundwater supplies and intensifying the water shortages. All these factors have resulted in a progressive reduction in groundwater availability, increasing the pollution health risk and degradation of the environment.

TABLE 1. SUFFICIENCY OF RENEWABLE OF WATER RESOURCES IN THE ESCWA REGION

Country/area	Renewable water resources (mcm)			Annual water per capita** (cm)			Sustainability indicator*** (%)		
	Surface water	Groundwater Recharge	Total	1997	2015	2025	1997	2000	2025
Bahrain	0.2	100	100.2	137	131	99	309	349	608
Egypt	55 500	4 100	59 600	925	698	658	110	115	145
Iraq	70 370	2 000	72 370	2 963	1 832	1 359	68	88	118
Jordan	475	277	752	168	78	70	101	168	235
Kuwait	0.1	160	160.1	89	62	57	438	500	874
Lebanon	2 500	600	3 100	995	437	341	40	53	124
Oman	918	550	1 468	613	403	309	117	103	169
Qatar	1.4	85	86.4	98	70	60	345	580	943
Saudi Arabia	2 230	3 850	6 080	311	182	150	268	292	398
Syrian Arab Republic	16 375*	5 100	21 475	1 438	948	609	46	80	110
United Arab Emirates	185	130	315	137	103	67	388	692	1 015
W. Bank and Gaza Strip	30	185	215	-	-	-	205	230	600
Republic of Yemen	2 250	1 400	3 650	303	165	114	79	72	97
Total	152 335	18.5	169372	-	-	-	-	-	-

Source: Updating the assessment of water resources in ESCWA member countries E/ESCWA/ENR/1999/13.

* The flow of rivers can be reduces by upstream abstraction;

** Water barrier index. Renewable resources/population;

*** Sustainability indicator. Water use/renewable resource. Future sustainability is based on estimated 2000 and 2025 water demand

8. In regard to the occurrences of groundwater it has been found in numerous localized, national, and regional shallow alluvial and limestone, shallow and deep sedimentary and shared formations. Renewable groundwater is an essential water supply sources and is available in the shallow quaternary wadi, flood plain and rivers bed deposits located in the coastal plains and inland basins containing groundwater of good quality that is frequently recharged by perennial river flow and flood flow. The shallow aquifers receiving recharge and infiltration from application of water at the ground surface are the one that have been prone to pollution. The shallow aquifers in countries of the Arabian Peninsula, Lebanon, the Syrian Arab Republic, western Jordan, Iraq and Egypt's Nile delta hold groundwater reserves in the alluvial deposits and limestone formation can be prone to pollution due their shallow depth, rock fracture nature and solution opening. The ESCWA water resources that may have been exposed to pollution or having high risk of contamination due to natural location in regard to depth and rock types is shown in table 2.

TABLE 2. WATER SOURCES, QUALITY AND EXPOSURE TO CONTAMINATION SOURCES (AFTER JURDI 201)

Bahrain	Groundwater Desalinated sea water	Poor-fair Excellent	Excessive exploitation – Brackish water
Egypt	Surface water Groundwater	Good Fair	Municipal: overloaded sewerage disposal systems Industrial: discharge of untreated effluents Agriculture pesticides
Iraq	Surface water Groundwater	Good-fair	Excessive construction in neighboring countries Saline water intrusion Municipal: overloaded sewerage systems Industrial: discharge of treated effluents Agricultural: water drainage and run-offs sources
Jordan	Groundwater	Good-poor	Excessive exploitation – Brackish water, saline water intrusion Industrial: uncontrolled discharge of untreated effluents Agriculture: irrigation water drainage, pesticides and toxic materials
Kuwait	Groundwater Desalination	Poor Excellent	Excessive exploitation: Brackish water-saline water intrusion, transboundary underflow Industrial: oil spill
Lebanon	Groundwater Surface water	Good Excellent	Municipal: solid waste disposal, sewerage systems Silent trade: transboundary movement, dumping of hazardous industrial wastes

TABLE 2 (*continued*)

Oman	Surface water Groundwater	Good-poor Fair to poor	Excessive exploitation: Brackish water- saline water intrusion, transboundary underflow Industrial: oil pools
Qatar	Groundwater Desalination	Fair-very poor Excellent	Excessive exploitation: Brackish water- saline water intrusion
Saudi Arabia	Groundwater Surface water Desalination	Good-Poor Poor Excellent	Excessive exploitation: Brackish water- saline water intrusion
Syrian Arab Republic	Surface water Groundwater	Fair-good	Industrial: disposal of industrial and other types of waste water
United Arab Emirates	Surface water Groundwater	Fair-poor Fair-Very poor	Overdraft (Alluvial Aquifers) – saline water Industrial – oil spills and oil-sludge
Yemen	Groundwater Surface water	Fair-good Fair-poor	Overdraft (Alluvial Aquifers) – saline water Saline water Sewage disposal systems

Reference: United Nations Economic and Social Commission for Western Asia. 1995. "Assessment of Water on ESCWA Region". United Nations, New York, (E/ESCWA/ENR/1995/14). Chapter II & III.

9. Major aquifers are those located in relatively deep sedimentary and limestone formations of the Arabian Peninsula shelf, part of the Syrian Arab Republic, Jordan and Iraq, Lebanon and Egypt delta and Nubian sand stone. The Arabian Shelf covering two third of the Arabian Peninsula contains many major sedimentary carbonate and sandstone aquifers. Sandstone aquifers with age ranging from Paleozoic to Cretaceous cover the eastern part of: Saudi Arabia, southern Jordan, Rutbah area in Iraq. The Basalt aquifer shared between the Syrian Arab Republic and Jordan. The Disi-Saq sandstone aquifers are located between Jordan and Saudi Arabia. The Nubian aquifer, which is composed of thick sandstone, runs through Egypt, Libya and Sudan. Some of these aquifers usually are not at risk of pollution due to their large depth. The major water carbonate aquifers are known as the Eastern Mediterranean aquifers, which is composed of carbonate formations in Lebanon, the Syrian Arab Republic, and the highlands of Jordan, Java Al-Arab basaltic aquifers located in southeastern Syria, eastern Jordan and northern Saudi Arabia, and the Ezra tertiary limestone aquifers which are located in southern Turkey and the Syrian Arab Republic.

10. The major aquifers located in each ESCWA country are briefly discussed below.

11. *Lebanon*: Two main aquifers are recognized in Lebanon: the Jurassic limestone, with a thickness averaging 1200m and the Cenomanian-Turonian with a thickness ranging from 600 to 1000m. In addition the Neogene, Quaternary, and Carbonate aquifers is overlaying these two major aquifers. Recharge from precipitation is estimated at 2.5 bcm, and water quality ranges from 150 to 800 ppm.

12. *The Syrian Arab Republic*: Main groundwater aquifers are those of Anti-Lebanon, Alouite mountains, carbonate formations the Jurassic carbonate and the Cenomanian-Turonian limestone is 350m thick. Folding and faulting of the geological layers resulted in the mingling of the sub-aquifer systems. There are a number of springs discharging flow from this aquifer system, such as the Ari-Eyh, Barada, Anjar-Chamsine and Ras El-Ain. Recharge to this system occurs from intense precipitation in the mountainous regions, which infiltrates through the fractures and fissures of the karstified surface layer. The other significant aquifer system consists of the Damascus plain aquifers that extend from the Anti-Lebanon Mountains on the west to the volcanic

formations in the southern and eastern areas of the country. The aquifer system is composed of gravel and conglomerates with some clay, and is represented by riverbeds and alluvial fan deposits with a thickness of up to 400m. This aquifer system is composed of gravel and conglomerates with some clay. Recharge occurs from wadi and river flow, irrigation return, and leakage from the Cenomanian-Turonian aquifer was estimated at 410 mcm. Groundwater quality ranges from 500 to more than 5000 ppm.

13. The other major carbonate aquifer is the Haramoun mountain formation located between Lebanon and the Syrian Arab Republic. The main discharging springs are those of the Banias and Dan tributaries of the Jordan River basin. The average spring discharge from the Haramoun aquifer is estimated at 464 mcm with a recharge rate estimated at 320 mcm. Groundwater quality is estimated at 250 ppm. Other aquifers with limited potential are located in the desert areas. These consist of marl and chalky limestone of the Paleogene age. Recharge occurs mainly from flood flow. Water quality ranges from 500 to 5000 ppm depending on the source of recharge.

14. *Egypt*: Groundwater resources exist in the Nile valley and delta, the Nubian sandstone and alluvial aquifers. The Nile valley and delta are two distinct formations; the Quaternary and Tertiary sandstone and gravel of the upper formation are separated from the underlying Nubian sandstone formation by a layer of clay. The thickness of the Nile valley and delta aquifers averages 300 and 1000m, respectively depending on the location, with reasonable production capacity. Sources of recharge in the Nile valley are percolation form irrigation water and conveyance channels, while for the delta sources are irrigation percolation and river seepage. Recharge to the valley and delta aquifers are estimated at 6.2 and 2.6 bcm respectively. Water quality ranges from 170 to 1700 ppm and in some areas the concentration may reach more than 6000 ppm. Groundwater also occurs in the extensive Nubian sandstone aquifer that extends into the neighboring countries of Libya and Sudan. Aquifer thickness ranges form 100-800m, with large potential groundwater reserves of good water quality. Water bearing formations extend into the desert area of the Red Sea, and in the Sinai Peninsula.

15. *West Bank and Gaza Strip*: Groundwater resources occur mainly in the Cenomanian-Turonian mountain aquifers and coastal Pleistocene sand and sandstone aquifers. The mountain aquifers exist in the West Bank and consist of limestone and dolomite with thickness reaching 700m. In the mountain aquifer system, three groundwater provinces were identified in the western, northeastern, and eastern basins. These basins extend over most of the West Bank and discharge into the Yarkan River. The recharge magnitude is estimated 600 mcm. Sandstone aquifers exist in the Gaza strip with thickness ranged from 10 to 180m, with an estimated annual recharge volume of 70 mcm. Water quality ranges from 1200 to 3000 ppm.

16. *Iraq*: Groundwater aquifers consist of extensive alluvial deposits of the Tigris and Euphrates rivers, and are composed of Mesopotamian-clastic and carbonate formations. The alluvial aquifers have limited potential because of poor water quality. The Mesopotamina-clastic aquifers exist in the northwestern foothills consist of Fars, Bakhtiari and alluvial sediments. The Fars formation is made up of anhydrite and gypsum interbedded with limestone, and covers a large area of Iraq. The Bakhtiari and alluvial formations consist of a variety of material including silt, sand, gravel, conglomerate, and boulders, with thickness that may reach 6000m. Water quality ranges from 300 to 1000 ppm.

17. Another major aquifer system is contained in the carbonate layers of the Zagros Mountains. Two main aquifers can be found in the limestone and dolomite layers, as well as in the Quaternary alluvium deposits. The limestone aquifer contributes large volumes of water through a number of springs. The alluvial aquifers contain large volume reservoirs, and recharge is estimated at 620 mcm from direct infiltration of rainfall and surface runoff. Water quality is good, ranging from 150 to 1400 ppm.

18. *Jordan*: The major groundwater aquifers in Jordan are wadi El-Sir of the Turonian age, Amman of the Cempanian age, and the Disi formations. The wadi El-Sir and Amman formations consist of limestone, dolomite, chert and sandy limestone. One of these formation lays on top of the other throughout most of Jordan, with the exception of a mall area in the south. The other aquifer system is a deep sandstone aquifer in the Disi formation that extends into the northern region of Saudi Arabia. Recharge takes place directly by infiltration of rainfall

through fissures and karstified carbonate rocks, and from flood flow. Estimate recharge is 260 mcm. Base flow ad spring discharge is estimated at 540 mcm, with water quality ranging from 500 to 3500 ppm.

19. *Arabian Peninsula*: Groundwater reserves for some of the countries of the Arabian peninsula Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates, Oman and Yemen are found in the renewable shallow alluvial aquifers and non- renewable deep aquifers of sandstone and limestone formations. Alluvial deposits along the main wadi channels and flood plains of drainage basins in Kuwait, Saudi Arabia and the United Arab Emirates, Oman, Yemen and southern Jordan make up the shallow groundwater system in most of the southern ESCWA countries. Groundwater in the shallow aquifers is the only renewable water source. Groundwater from the shallow alluvial is used mainly for domestic and irrigation purposes. The alluvial aquifer is being contaminant from dumping of industrial and domestic wastewater.

20. The other main source of water for the countries of the Arabian Peninsula is the non-renewable fossil groundwater stored in the sedimentary deep aquifers. These aquifers store significant amounts of groundwater that is thousands of years old. The major aquifers are the Disi/Saq, Tabuk, Wajid, Minijur-Druma, Wasia-Biyadh, Tawilah and Amran sandstone aquifers and the Dammam, Um er-Radhuma, Neogene carbonate aquifers. Other aquifers are the Aruma, Jauf, Khuff, Jilh, Sakaka, the upper Jurassic, the lower Cretaceous, and Buwaib formations. These aquifers covering two-thirds the eastern parts of the Arabian Peninsula with large coverage of Saudi Arabia and some extending into Kuwait, Bahrain, Qatar, the United Arab Emirates, Oman, and Yemen, as well as into Jordan, the Syrian Arab Republic and Iraq. The following provide a brief discussion of groundwater resources of countries of the Arabian Peninsula.

21. *Saudi Arabia*: Major aquifer systems are the alluvial deposits, carbonate and sandstone formations. Deposits consist of mainly coarse-grained sand, gravel, silt and clay. The alluvial aquifers range in thickness from 10 to 250 m, and contain large groundwater reserves. Groundwater recharge occurs from rainfall and flood flow, and may reach 2000 mcm per year. Water quality ranges from 300 to 5000 ppm. The other main groundwater source is located in the deep carbonate and sandstone formations of the Saq, Tabuk, Minjur, Wasia, Wajid, Dammam, Khobar, Sakaka and Aruma aquifers. Vast amounts of groundwater stored in the deep aquifers serve as a dependable source of water for the central and northern regions of Saudi Arabia, and to a lesser extent, the other countries of the peninsula. Total dissolved solids range from 400 to 20,000 ppm. Good quality water is stored in only the Saq, Tabuk, Wajid, and Dammam aquifers.

22. *Kuwait*: Groundwater resources consist of water available from the Dibdiba, Far, Gar, Dammam, Rus and Umm er-Radhuma formations. The aquifer system is divided into two main groups: the Kuwait group which includes the Dibdiba composed of sand and gravel, Far of evaporite and Gar sand formations, and Hassa group represented by the Dammam limestone, Rus anhydrite and Umm er-Radhuma limestone formations. The main formations for groundwater utilization are the Kuwait group and the Dammam formation. Groundwater recharge is estimated at 160 mcm, with water quality ranging from 400 to 4000 ppm.

23. *Bahrain*: The main aquifers in Bahrain are the Neogene, Dammam, Rus and Umm er-Radhum. The Dammam and Umm er-Radhuma aquifers provide the majority of water for Bahrain but contain saline water. The subdivisions of the Dammam formation are to Khabor (dolomite) and the Alat (limestone) formations each containing major aquifers of average quality water which serve as an industrial and agricultural source for Bahrain. The Rus and Umm er-Radhuma aquifers contain either brackish or saline water unfit for consumption. Recharge is estimated at 100 mcm, occurs from leakage from other aquifers, as well as from underflow from the extensions of aquifers originating in Saudi Arabia. There are other aquifers such as the Aruma and Wasia that have high salinity. Groundwater quality in the Dammam formations ranges from 2000 to 4000 ppm, while for the Umm er-Radhuma it may reach 18,000 ppm.

24. *Qatar*: Aquifers in Qatar exist in the carbonate, Umm er-Radhuma, Rus, Dammam and Neogene formations. The Aruma and Wasia formations are also present in Qatar. Groundwater from the Dammam and Umm er-Radhuma, formations is used to provide water for use in all sectors. Water quality in some locations is

good, ranging from 400 to 2000 ppm, however for most of the aquifer water quality ranges from 2000 to 6000 ppm.

25. *Untied Arab Emirates*: Groundwater resources exist in the upper clastic and lower carbonate formations located in the Bajada region in the eastern part of the country. The aquifers consist of alluvial fan deposits, which form along the base of the Oman and Ras El-Khaymah mountains and extend over a large area. The upper aquifer is composed of gravel sand and silt, while the lower aquifer is composed of limestone, dolomite, and marl. Both aquifers range in thickness from 200 to 800m. In addition, the Dammam and Umm er-Radhama formation extend into the western desert areas, with thickness ranging from 500 to 1000 m. The Groundwater quality in the two aquifer system, particularly in the Bajada region, ranges from 600 to 2000 ppm. The Dammam and Umm er-Radhuma aquifers contain highly saline water.

26. *Oman*: the Batiniah alluvial and Bajada alluvial fan deposits, and the Umm er-Radhuma and the Rus tertiary carbonate formations represent some the major the aquifer system in Oman. The Baliniah alluvial aquifer is composed of gravel, conglomerate, medium and coarse sand, silt and clay. Thickness range from 240 to 600m. A large number of Aflajs were constructed to drain the mountain catchments into the Pediment zones. Water quality ranges from 800 to 6000 ppm. The alluvial fan aquifer of the Bajada region consists of Quaternary deposits and Fars group formations, with water quality ranging from 900 to 6000 ppm. The other aquifer is the tertiary carbonate aquifers is, represented by the Umm er-Radhuma, Rus and Dammam formations and having very poor water quality in excess of 4000 ppm.

27. *Yemen*: Groundwater resources are available in the Tihama and Gulf of Aden alluvial deposits. The Tihama alluvial aquifers represent an extensive system extending along the coastal plains, and ranging in thickness from 20 to 500m. The aquifers receive extensive recharge directly from rainfall and wadi flood flow. Water quality ranges from fair to good. The Gulf of Aden alluvial aquifers extend into the coastal area of the Gulf, with major wadis separated by intrusive rock, and thickness averaging 400m. Major aquifers are those in wadis and the Delta of Tuban, Abian, Ahwear and Meifa. Water quality varies from 600 to 2000 ppm.

28. The Hadramut aquifer system consists of sandstone and carbonate aquifers in the eastern Arabian Peninsula. The system consists of the Umm er-Radhuma limestone and Mukalla sandstone formations. The aquifer is overlain with thick alluvial deposits. Recharge from rainfall, runoff and intermittent flow is estimated at 160 mcm. Water quality from the Mukalla aquifer ranges from 440 to 1000 ppm. The other major groundwater source is contained in the highland aquifers located in the rugged volcanic and crystalline mountains in the central region of Yemen. They are located in the sub-basin and mountain plains of the center of the country. The main aquifers are in the alluvium, the volcanic formations, and the Taqilah, Amran, Kohlan and Wajid sandstone formations. Water Quality is generally goes

III. SELECTED PAPERS

29. This second part of the report of the selected papers addresses the three themes: groundwater pollution and its impact, groundwater rehabilitation techniques and groundwater protection as follow:

A. THEME I: GROUND AND WATER POLLUTION AND ITS IMPACT

30. This issue was addressed in a background paper presented by ESCWA-Natural Resources Section and other selected papers which focused on groundwater pollution resulting from irrigation practices, disposal of treated and untreated wastewater, intrusion of seawater into the coastal aquifer and impact of pollution on health and the environment.

1. *"Implication of groundwater rehabilitation in the ESCWA region"*

31. The paper stressed that groundwater represents as a vital water source for a large number of Western Asia countries in meeting various water demands and discussed the magnitude water quality deterioration that has resulted from increasing pollution level from domestic, industrial and agricultural activities. The paper reported that groundwater contribution to the total annual renewable water resources (i.e. surface water, groundwater recharge) was estimated at about 11 per cent at the region level. At country levels, however, the contribution of groundwater can be much more significant with dependency ratio varies from nearly 100 per cent in Kuwait to less than 3 per cent in Iraq where the contribution of groundwater at the regional level to total available annual renewable and non-conventional water resources was estimated at 16 per cent.

32. The socio-economic development activities in the western Asia region have resulted in a serious deterioration of groundwater quality of shallow aquifer. The paper pointed out that the largest user of water in the region is agriculture sector, however, rapid urbanization and improvement of the quality of life in terms of health, sanitation and social services, have resulted in a sharp increase in water demand for municipal purposes with large increases in pollution levels. The paper identified the pollution sources in the ESCWA region has been taking place from infiltration of domestic sewage from unsewered sanitation, leaking sewers or sewage oxidation lagoons having various degree of contamination to water supply wells, springs and aquifers. The paper discussed the most dominant pollution sources resulting from agro-chemicals such as residue of fertilizers and pesticides in irrigation return flow, organic components and heavy and trace metals, which are endangering the drinking water quality. Over-exploitation of fresh water aquifers has resulted in intrusion of brackish water contained in parts of the exploited aquifer and increased salinity due to salt-water intrusion.

33. The paper also indicated that the selection of ground water rehabilitation techniques depends on; the type of solid and its matrix, contaminant types, remediation objectives, current status of groundwater development, and location of polluted sites, time, and availability of funds and technologies to be used. The remediation techniques that can be applied to rehabilitate groundwater aquifer system include in situ physical or chemical treatment, biological treatment, and electro kinetics. Groundwater monitoring, data collection, vulnerability, and protection techniques were also discussed as a vital part in groundwater management measures. The made observation on the water situation and suggested some measures to combat pollution are indicated below:

(a) The lack of groundwater monitoring and data availability can be improved through increase investment in groundwater management capacity building, monitoring infrastructure, and research;

(b) There is a need for the implementation of integrated approaches to groundwater management with emphasis on regulatory, economic, technical and other measures;

(c) The need to involve communities in management of groundwater sources including the collection of groundwater information with the objective of stakeholder understanding of management measures;

(d) The need for promoting public awareness campaign, role of women, and the community participation towards preserving groundwater from pollution and depletion. Also there is a need to develop a strategic initiative that enhances awareness oriented toward decision makers and the public on the importance of groundwater resources, the emerging problems, and the practical solutions available to address such problems;

(e) Technology transfer, capacity building, and research development must take place to transfer this knowledge into the practical field level of restoring groundwater quality.

2. *Guidelines for groundwater protection and pollution control in the GCC countries*

34. The paper gave a brief account of groundwater resources and there present utilization in this arid and extremely arid region of the world where groundwater contribution is more than 91 per cent of freshwater requirements. The paper reported that the deterioration of groundwater quality was associated with to

overexploitation, anthropogenic activities, and salt-water intrusion along the eastern side of the Gulf. A water quality sampling of 388 wells done in 1989 in the six regions of Saudi Arabia revealed that elevated nitrate concentration in shallow aquifers located at a depth ranging from 30 to 50 meter ranged from 0.01 to 95 mg/l The ammonia level in 8 per cent of the wells reached more than 0.05 mg/l with some value as high as 5 mg/l.

35. The main sources of pollution were identified were the high levels of nitrates (in excess of 90 mg/l), ammonia (up to 5 mg/l) and faecal coliform; high levels of total dissolved solids from irrigation return flow; and problem associated with gasoline tank leakage and the injection of brine from oil operations. Fecal coliform bacteria were present in 21.4 per cent of the wells. The paper reviewed the management measures that had been implemented in the region and elaborated on the use of the geographic information system (GIS) and mathematical groundwater modeling to assess aquifer vulnerability for groundwater protection. The paper suggested guidelines for groundwater protection and pollution control in the GCC countries.

3. *"Groundwater pollution by irrigated agriculture: a case study"*

36. The paper evaluated the impact of pollution from irrigated practices on shallow and deep groundwater sources in eastern Saudi Arabia. The irrigated agriculture in this area started in 1985, with the min crops are alfalfa, wheat, barely, rod us, and vegetables. The study site soil texture is sandy (fine to medium sand) and becomes coarser in subsurface layers to depths of more than 150 cm. The organic matter contents are low. The cat ion exchange capacity of the soil is very low due to clay and organic matter content, the chemical analysis of the soil samples indicates that the soil of the study area is non-saline with ph ranging between 7.8-8.8. All sampled water from shallow and deep aquifers were checked for pesticides and herbicides pollution. The results of the study indicated that the quality of deep groundwater was not affected by the percolation of irrigation water because of the presence of a thick, impervious confining layer overlying the aquifer. However, nitrates and some trace metals such as boron as a result of the percolation of pollutants in excess irrigation water down to the shallow water table polluted unconfined aquifers.

37. Main pollution sources were nitrogen, phosphorus and potassium fertilizer and manure organic nitrogen. Pesticide and herbicide concentrations in the shallow aquifer were below the detection limit. The sampling of the shallow aquifer indicated high levels of nitrate, sulfate and trace elements of boron, iron, and copper. The nitrate values indicated seasonal variation with the highest values of 620 mg/l in the winter and 568 mg/l in the summer. The high sulfate values ranged from 7690 in the summer to 5990 mg/l in the winter while for boron it ranged from 18.7 in the summer to 24 mg/l in the winter The highest fluoride values also ranged from 5.4 in the summer to 15.4 mg/l in the winter.

38. To reduce the pollution levels in shallow groundwater, several measures were suggested to deal with each source of pollutant. It was clear from the study that the type and extent of groundwater pollution by fifteen years of intensive irrigation depends on management of fertilizers, pesticides, lands, crops and irrigation practices, and on the type of aquifer. The paper suggested that improvement of irrigation and cultivation practices and pest control can play an important role in minimizing the pollution impacts on shallow groundwater and these practices can be applied in other regions of Saudi Arabia in order to protect and sustain the groundwater resources.

4. *"Water and soil vulnerability to contamination in central Beqa'a plain – Lebanon"*

39. The paper focused on how irrigation practice through the reuse of wastewater and overuse of fertilizers, pesticides, and insecticides has contributed to increased groundwater pollution levels in the Beqa plain. The field study focused on a selected area in the Beqa'a plain covering an area of 127.5 square kilometers (km^2) and characterized by high clay content, pH values, and high action exchange capacity in the soil profile, in combination with a shallow water table ranging from 0.6 to 5 meters. The study showed that over-irrigation and a percolation rate of 200-300 millimeters (mm) per year had increased the salinity and nitrate levels in the

groundwater. The study a soil profile indicated varying degrees of groundwater pollution vulnerability. The residence time of percolating water in the soil above the aquifer varied, ranging from several months to 10 years.

40. The irrigation activities have resulted in elevated levels of nitrate and heavy metals such as chromium, nickel, cadmium, lead and zinc in soil profile and shallow groundwater aquifer. The aquifer is vulnerable to contamination, including heavy metal contamination, as its depth below the soil surface is in some locations close to less than 0.5 meter depth. The heavy metals concentration in the soil profile decreased with increasing depth with highest reported values of 0.28, 28.5, 93.6, 28, 72.8, 15.5 97.2 mg/l for cadmium, copper, chromium, cobalt, nickel, lead and zinc respectively. In the groundwater concentrations of 13.9, 6.4, 0.06, 115.2, 0.86 µg/l of Ni, Cr, Cd, Zn, and Pb respectively were found at a depth of 2 m, and similar levels of 12.5, 5, 0.03, 219.5, and 0.95 µg/l at a depth of 8 meters, while in the deep well of 70 meter concentrations were significantly lower with 5, 4, 0.02, 36.8 and 0.4 µg/l respective. Although these values indicate elevated levels of heavy metals, all concentrations are still well below the WHO drinking water quality standards. In contrast, nitrate concentration in the groundwater was sometimes above the WHO drinking water quality standard of 50 mg/l, reaching maximum values of more than 200 mg/l. The developed vulnerability maps developed in this study can serve as a planning tool to revert groundwater pollution.

5. *"Burman, underground removal of manganese from groundwater in Beheira Governorate"*

41. The presence of manganese and iron in the Nile Delta aquifer caused problems for both pipelines and consumers. A case study has been presented showing the effect of rehabilitation of groundwater through treatment process. A test was carried out on the groundwater extraction site of Kom Ramada. The Kom Hamada plant, is situated in the Nile Delta at 35 km southeast of Damanhur in Beheira governorate, Egypt. Because of its success, the method was named Burman "Beheira Underground Removal of Manganese" and is now being tested and implemented on the other sites as well. The aquifer is covered by a top-layer consisting of clay, loam, and sand about 6 m thick. The site has four production wells at 55 m deep and has a screen of 20 meter length at Kom Hamada with a production of 1.2 mcm in 1999. In the Kim Hamada and Itay al-Barud areas, the average concentration was found to be 0.41 and 1.1 milligrams per litre (mg/l) respectively. The problem has emerged in 1990 with the start of chlorination, mainly due to the precipitation of manganese oxides into the distribution systems of the study area.

42. The method used to remove manganese from groundwater is relatively cheap and it is characterized by the lack of utilization of chemicals, chemical like permanganate, and the use of facilities like sedimentation tanks and filters. The rehabilitation was based on the application of natural processes through the injection of aerated water. The subsurface removal of iron and manganese seeks to oxidize the two cations Fe+2 and Mn+2 in the subsoil. This is done by injection of a fixed volume of aerated water into a well, followed by water extraction this well and will continue until the iron and or manganese concentration rises to some fixed norm. The cycle of injection and extraction is repeated, after the first cycle, a substantial reduction of the concentration was obtained in addition to decreases in Fe+2 concentration. The manganese concentration was reduced further with each cycle. After the four cycles, it was almost completely removed. The paper showed that the Further evaluation of methodology program is planned.

6. *"Salt-water intrusion phenomena in the limestone aquifer of Hadeth"* near Beirut

43. One of the major groundwater pollution sources in Lebanon has been the salt-water intrusion phenomenon along the coastal zone from groundwater overpupming. The paper discussed the issue of salt-water intrusion into the coastal aquifer north of Beirut as a result of increased groundwater pumpage in excess of recharge. Salt-water intrusion was occurring in the Hadeth limestone aquifer near Beirut because the heavy pumpage of 17.5 mcm for the public water supply and un-controlled pumpage from more than 500 private wells exceeded annual recharge estimated at 14.5 mcm. The remedial approach of recharging well scheme utilized water from the

Dachouniye source and the Beirut River during the wet winter season. The advancement of seawater intrusion resulted chloride content increase from 250 mg/l in 1968, to 1200 in 1973 and later reached 2000 mg/l in 2000.

44. The salt-water intrusion phenomenon into shallow aquifers is being experienced in the coastal zones of Egypt, the Syrian Arab Republic, Lebanon, Gaza Strip and all countries of the Arabian Peninsula. In the eastern parts of Saudi Arabia salt-water intrusion was observed with reported values of 15000-21500 mg/l total dissolved solid. A similar situation was observed in Bahrain, United Arab Emirates, Oman and Yemen with high chloride content as a result of saltwater intrusion.

7. *"Environmental and health impact on groundwater pollution"*

45. The paper highlighted critical issues, including the need to update rules and regulations and to mobilize legislative and institutional bodies to implement pollution control measures and prevent environmental degradation, which would contribute to enhanced water availability and sustainability The paper examined environmental policies, regulations, and institutional framework applied in the region. The paper stressed that there is a need for community involvement through empowerment of women, the formation of youth groups, and the implementation of public awareness campaigns in order to promote public health protection and preservation of the ecosystems. Assessment of the regional profile of safe water coverage, and sanitation services in the Western Asia region was mentioned as a challenge to achieve unsustainable exploitation of water resources, mainly groundwater.

46. Development of a comprehensive health programs was recommended to reduce the socio-economic burden of water-related diseases especially toxic elements. Thus groundwater management in regard to combating pollution was identified as an essential component of the water resource assessment programs. The paper also stated that the health profile in the Western Asia region is mainly associated with: formulated and implemented national health plans, systemic immunization campaigns, and improvements in women's health and education. However, a more comprehensive approach should relate to exposure to environmental hazards associated with the state of development and inducing environmental factors. The paper reviewed different approaches for mobilizing the community, with particular emphasis given to the

B. THEME II: GROUNDWATER REHABILITATION TECHNIQUES

1. *"New approaches in groundwater rehabilitation"*

47. The paper provided an overview of the conventional and innovative remediation technologies available. It examined a variety of potential contaminants, listed their properties, and indicated where they most frequently occurred and their mode of movement. The paper described the characteristics of the contaminants and their associated risk. It indicated that contaminants could be classified as volatile organic compounds such as chlorinated compounds, ethyl benzene, and semi-volatile organic compounds such as pesticide, hydrocarbons, polychlorinated biphenyls, and metals and inorganic. The paper noted that contaminating substances such as chydrocarbons, benzene, toluene, ethyl benzene, xyclene, pesticides, polycyclic aromatic hydrocarbons, polychlorinated biphenyls and heavy metals were often found in soil and water samples taken from sites contaminated mainly through industrial and agricultural practices. Contaminants may also have been adsorbed onto soil particles, or be present in organic soil particles, such as plant material and humid substances, they may also be present as a solid or pure liquid phase in the pores of soil particles.

48. The physical state of contaminants is one of the factors determining the means of cleaning, they maybe present equal in size to, or smaller, or larger than the non-pollutant soil articles. The techniques of in-situ and ex-situ technologies for the remediation of contaminated soil and groundwater were discussed. These techniques include conventional civil engineering-based methods excavation, containment, and hydraulic measures, process-based methods and innovative concepts; treatment walls, bioremediation and monitored natural attenuation. The general applicability and the limitations of these methods were discussed.

49. The decision to treat contamination onsite or offsite depends on a number of factors, including the availability and cost of on and off-site facilities; available time scales; and site-specific factors, such as the location of the site relative to off-site treatment facilities; space available for on-site treatment, temporary storage and availability and capacity of local services, such as power, drainage, and water supply. Much of the current research on groundwater remediation has focused on the removal of contaminated water from the subsurface and treating it at the surface. While the removal of the contaminants is desirable, the costs are often prohibitive and rarely the contaminants concentrations are lowered to the required regulatory.

2. *"Implications of groundwater protection and conservation"*

50. The paper provided a comprehensive review of pollution control and groundwater rehabilitation techniques. The paper emphasized that a good basic knowledge of surface and subsurface soil profiles, aquifer characteristics and possible chemical reactions; aquifer hydrodynamics; and the physical, chemical and biological characteristics of pollutants and their behavior was required for the design of rehabilitation schemes as well as for the monitoring and protection of groundwater systems. The paper reflected on the reality that when groundwater became polluted, it was sometimes very difficult, if not impossible, to rehabilitate the aquifer. In addition, groundwater and contaminated-soil restoration measures could be extremely expensive, entailing large time, personnel, and financial commitments. The prevention of groundwater pollution through environmentally friendly measures, the establishment of an effective regulatory framework, and the application of simple but intelligent technical and other precautionary measures constituted a better option than the implementation of expensive and time-consuming remedial measures in the field. The paper outlined the concepts for the design of groundwater networks, the selection of observation points, and the maintenance and operation of the networks including groundwater sampling, data processing and quality control.

C. THEME III: "GROUNDWATER PROTECTION"

1. *"Solute transport models: an important tool for studies on groundwater protection or remediation"*

51. The paper focused on the application of models in the assessment, monitoring and protection of groundwater resources. The paper indicated flow and transport models are a useful tool in assessing the state of water quantity and quality as well as in evaluating alternative solutions including pollution movement and groundwater rehabilitation. Models can help in characterization of the system, identify gaps in the data and, e.g., locations for additional wells; addressing uncertainties, compare different scenarios, and indicate the best remediation or protection procedure under the given circumstances. The paper provided information on the basic equations and various methods used in transport modeling. There were many computer programmes available, ranging from simple flow models using particle tracking and analytical equations models to multiphase transport models and variable density models coupled with reaction models. Some examples of analytical and numerical models and their uses in real field situations were presented, with emphasis given to reactive transport and salt-water intrusion.

2. *"Groundwater vulnerability mapping: decision support in groundwater resources quality protection"*

52. The paper addressed different vulnerability assessment methodology of groundwater system stating that qualitative groundwater vulnerability mapping are a valuable tool in a variety of projects, which justifies their application on a regional scale especially when there is limited availability of data. When vulnerability mapping are prepared on a regional scale, it should always be kept in mind that they are only used for screening purposes and that they do not substitute the site-specific studies to predict groundwater pollution of certain land use. The paper examined different methodologies for assessing the vulnerability of groundwater systems, including

overlay and index, process-based and statistical methods. It was indicated that qualitative overlay and index methods were still used most frequently, as data availability limited the applicability of other methods. The paper demonstrated that the application of overlay and index methods in qualitative groundwater vulnerability mapping represented a valuable tool in groundwater protection for policy makers, regional planners and water resource managers.

3. *Groundwater protection in the ESCWA region*

53. The paper addressed the issue of delineating groundwater protection zones around major abstraction sites (well fields, springs) as an effective means of groundwater protection. Protection zones are aimed at regulating and limiting human activities and land uses with a high risk of releasing contaminants in the catchments area of groundwater abstraction. It is advisable to define protection zones for abstraction sites that produce water for public supply, other private potable supply including mineral and bottled water or for commercial food and drink production. The extent and shape of protection zones depend on the intended amount of abstraction, the hyrogeological and hydraulic characteristics of the exploited aquifer.

54. The long-term annual groundwater recharge within this zone should equal the abstraction rate to avoid over-abstraction. Protective zones may consist of an inner zone, an outer zone, and an abstraction catchments zone. The inner protection zone is the area in direct vicinity of the well field or spring. It usually extends several meters in diameter and is fenced off to prevent any kind of human activity, which might have an immediate effect upon the resource. The outer protection zone is based on the concept of 50-days travel time from any point below the groundwater table to the abstraction site. It is based on the assumption that a 50-days would allow enough time for biological contaminants such as bacteria or viruses to decay in an aquifer environment. It is an established standard used in many countries. Usually, the protective zone is not defined where the aquifer is confined beneath continuous covering stratum of very low permeability since in such cases infiltration is prevented.

55. The catchments area protection zone is designed to cover the complete catchments area of the groundwater abstraction site; all groundwater within the catchments area discharges to the abstraction site. Land use restrictions are also represent another mean of protection and enforcement measure. The extent of restrictions, interdictions, and prohibitions decreases from the inner zone I to the catchments zone. No human activity is allowed in the inner zone. The application of manure, artificial fertilizers and pesticides in agriculture or the existence of residential areas not equipped with a save means of waste water disposal should be tightly restricted. Precautionary groundwater protection measures need to be initiated and supported through legislative regulations and policies on the national, governorate and local levels.

4. *"Groundwater use and groundwater protection in Germany"*

56. Ground water sources provided more than 70 per cent drink water supply, and consequently protection of groundwater from pollution sources represents a priority issues in this country. The paper stated that according to an investigation conducted between 1992-1994, only 41 per cent of all measuring stations monitored was unaffected by anthropogenic influences. In 1995 the Joint Water Commission of the Federal Lander (LAWA) has prepared a report on the distribution of nitrogen concentrations in groundwater in Germany. According to this report, a total of 75 per cent of all measurements were below 25 mg/l. About one third of all measuring stations recorded a nitrate concentration less than 1 mg/l. About 25 per cent of the observed groundwater measuring points shows nitrate concentrations to be moderately to severely increasing mainly due to agriculture and figures of excess 50 mg/l are found in areas with special crops such as wine, vegetable, and fruit growing. Another problem of groundwater pollution is that produced by crop protection agents and the application of herbicides to uncultivated land and inputs from surface waters. Concentrations of crop protection agents lower than drinking water limit value of 0.1 microgram/l were detected at about 19 per cent of the stations monitored and the drinking water was exceeded in around 10 per cent of the cases. The substances most frequently detected in groundwater were herbicides and its degradation by product desthyl atrazine inspite of its ban.

57. The paper elaborated on the protective measures adopted in Germany which consisted of systematic and regular monitoring of groundwater and discussed the responsibility vested in the Federal States Monitoring permits installed for the purpose of early detection of pollution from hazards to groundwater sources, as well selection of appropriate measures to be implemented in adequate time frame. The ecological environment made it necessary the formulation and implementation of a comprehensive measure for protection of groundwater throughout the country. It was stressed that preventive measures must be taken to protect groundwater from inputs of harmful substances. To achieve this goal, the soil must be sufficiently protected with the objective of minimizing inputs of problematic substances in terms of quantity and quality from industry, services, traffic, agriculture and households. As far as quantity is concerned, a balance between abstraction and recharge of groundwater has to be ensured. For plants in which water-hazardous substances are produced, used, stored, or transported, the highest safety standards must be introduced. Land use by agriculture, pesticides, waste disposal, and sewer systems should all be regularly inspected.

IV. DISCUSSIONS

58. The papers presented at the Meeting and discussion that took place during the different sessions of the EGM addressed the threat the groundwater aquifer contaminatation that is taking place in many of the shallow aquifers in the ESCWA region as well as feasible means that can be applied to prevent or remove pollutants and its impact. Discussions revealed interest on the different techniques of rehabilitation and the interest of sharing constant information among member states regarding groundwater status and updating their monitoring and management techniques. Awareness about the potential risks of groundwater contamination and their consequences were identified as a prerequisite to careful handling and use of hazardous substances. The causes of pollution from development activities were identified. It was noted that groundwater degradation in the ESCWA region is taking place as a result of the following causes:

(a) The increase in discharge of untreated or inadequately treated domestic and industrial water in open areas, rivers and wadi channels;

(b) Discharges of agro-processing plants and a high level of agrochemicals into rivers, wadi channels and dumpsites;

(c) Discharge of hazardous and toxic industrial wastes in inadequate dumpsites;

(d) Infiltration of saline agricultural return flow drainage from large-scale irrigation into shallow aquifers;

(e) The migration of saline groundwater lenses and salt water intrusion due to heavy over groundwater extraction;

(f) The hydrodynamic disturbance cause by unmanaged pumping groundwater leading to mixing among multi-aquifers systems;

(g) Over use of fertilizers and pesticide material in the agriculture sector its easily migration to the shallow groundwater formation;

(h) Injection of oil brine water and hydrocarbon byproducts from oil production and refinery operation into aquifers for storage and pressure building;

(i) Naturally occurring pollutants such as Radium, Radon, and other radioactive elements.

59. These practices have resulted in different degree of pollution level was reported by the papers presented at the EGM. Pollutions were reported in Egypt Delta, in southern Iraq, in Jordan and in the Damascus basin in the Syrian Arab Republic. Discharging of industrial and domestic wastewater and irrigation return flow into the rivers are the main sources of contamination of aquifers in most of the ESCWA countries as a result of river-groundwater hydraulic interconnection. The development of major irrigation schemes and industrial and domestic wastewater facilities along the four major rivers, the Nile, Tigris, Euphrates, and Jordan, has lead to a deterioration of water quality in the connecting shallow aquifers. Fractured limestone aquifers in Lebanon and the Syrian Arab Republic are also prone to contamination, and the use of septic tanks in mountainous limestone areas represents a major pollution source.

60. Extensive agriculture activities in Saudi Arabia, Oman, United Arab Emirates, and Yemen and to a certain extent in the remaining countries have caused elevated nitrate and other fertilizer compound concentrations in the soil and the shallow groundwater sources. Fertilizer and pesticides leaching from irrigated fields often found in shallow alluvial aquifers of countries of the Arabian Peninsula. In addition the disposal of wastewater with low treatment level into dry wadi channels and its reuse in irrigation and landscaping represent another common pollution source in all countries of the Peninsula. Nitrogen is a major groundwater pollutant in the ESCWA region, which is being over used in the form of manure, sewage sludge, and chemical fertilizer. Nitrogen, as an essential plant nutrient, is an important fertilizer in agriculture, but high levels of nitrate in drinking water have a major health impact. Furthermore, too much nitrate in the soil leads to destruction of organic matter by its oxidation with the consequence of increasing amount of nitrate leached by infiltrating rain and decreasing self-purification capacity of the soil and the unsaturated zone near surface.

61. In many countries of the ESCWA region, pesticides are widely used for weed control in agriculture as well as controlling pests in industry. The use of synthetic organic pesticides expanded rapidly since the 1950s because they have a great benefit when it is used in conjunction with the use of fertilizers as it can lead to increases in crop yields. However, pesticides are a risk to human health. Some soluble pesticides can move fast through the unsaturated zone, but their progress may be delayed by adsorption and biological degradation processes. High risk exists with regard to rapid flow in fractured aquifers.

V. CONCLUSION

62. Economic and social development during the last two decades have lead to improved provision and extending coverage of water supply and sewerage network, improvement in the standard of living, expansion of irrigated areas and industrial activities with consequence increases in water consumption specially from groundwater sources, increases in pollution levels and resources depletion in all ESCWA countries. In regard to groundwater pollution, different pollution levels are encountered depending on the extent of natural protection of the water resources and other influencing factors. The vulnerability of groundwater aquifers in the region to quantity- and quality degradation problems caused by overexploitation and pollution, which further reduced the already scarce supplies available in the member countries, and called for effective measures to protect groundwater resources and rationalize their use. The groundwater issue that has received some attention is salt-water intrusion, which has resulted from excessive pumping of coastal aquifers. Even though pollution levels are increasing, only locale limited protection and rehabilitation programs have been formulated and implemented on a limited scale.

63. Lack of systematic monitoring of groundwater quantity and quality and the absence of comprehensive legislation and regulations and their enforcement has resulted in a continuing degradation of water quality. The geology of shallow porous alluvial and fissured and kartisified limestone aquifers, which are typical aquifers in the ESCWA region, allows pollutants to move fast from their sources and accumulate in the groundwater system. Major pollutants in the ESCWA region are fecal bacteria, viruses, nitrate, phosphate and heavy metals from partially treated or untreated domestic and industrial wastewater, and organic contaminants from industrial and medical toxic wastes and contaminated sites. The vulnerability of many aquifers in the region to pollution necessitates that special attention be given to the development of appropriate policies and regulations for their

protection, and to the implementation of effective measure to rehabilitate the soil profile and underlying aquifers. Removal of contaminants from the aquifers may be very costly or impossible, so that the polluted resource has to be condemned.

64. Many methods of soil and groundwater remediation are available and much tested, however, application of groundwater remediation was very limited to few cases in any of the ESCWA which may be attributed to the lack of awareness and commitment by decision makers to address this critical water issue as well as lack of experience and financial resources.

65. It was noted that because aquifers in the region were vulnerable to pollution, special attention should be given to the formulation and adoption of effective policies for their protection. Preventive measures were often more cost-effective than rehabilitative or remedial solutions. In view of the above, the adopted EGM the recommendations are mentioned below.

VI. RECOMMENDATIONS

A. RECOMMENDATIONS TO MEMBER STATES

66. It is recommended that member States consider the following:

(a) Formulating practical, integrated groundwater management policies appropriate to each country's situation. Such policies should enable the concerned authorities to guard against water depletion and degradation, deal effectively with diffuse pollution, and prevent further water contamination, especially by hazardous substances, in order to protect public health and the environment and deal with accidental pollution. This may be achieved through various means, including the following:

(i) Adopting appropriate instruments and measures for the implementation of groundwater management policies, updating and reforming regulatory frameworks (regulations and by-laws), and developing and implementing enforcement mechanisms that clearly define the responsibilities of the various agencies concerned. Involving stakeholders in enforcement is a practical option that should be considered by member States;

(ii) Developing and adopting sound agricultural policies and irrigation practices suitable for arid lands. Adequate attention should be given to the application of decision support systems to ensure an optimal match between water quality, crop, soil and climate to optimize productivity, and to minimize the qualitative and quantitative impact of agricultural activities on groundwater aquifers.

(b) Enhancing the capabilities of groundwater protection departments in member States through the following:

(i) Developing and strengthening groundwater quantity and quality monitoring systems. Particular attention should be given to the development of reliable and comprehensive databases that can be used to facilitate efforts to assess and prevent pollution and design appropriate rehabilitation measures;

(ii) Preparing groundwater vulnerability maps and integrating them into geographic information systems to facilitate analysis. This information may be used in decision-making processes, with emphasis given to the delineation of "wellhead protection areas" around municipal water wells and the control of groundwater-polluting activities within such areas.

(c) Encouraging research and studies to develop and update standards for the assessment and monitoring of groundwater quantity and quality; and preparing guidelines for the implementation of those standards;

(d) Implementing programmes to increase the awareness of local communities and encourage their participation in the monitoring, management, conservation of groundwater aquifers and their protection against all types of pollution;

(e) Encouraging the adoption of protective measures, including those based on the Polluter Pays Principle, and carrying out environmental impact assessments for development projects that may pollute water resources;

(f) Focusing special attention on building capacities in groundwater modelling and the use of GIS and other special techniques for the assessment of groundwater aquifer vulnerability;

(g) Working to increasing groundwater use efficiency in the various sectors, and giving priority to rehabilitating and protecting groundwater by organizing workshops and training courses to disseminate relevant information.

B. RECOMMENDATIONS TO THE ESCWA SECRETARIAT, UNEP/ROWA AND OTHER REGIONAL AND INTERNATIONAL ORGANIZATIONS

67. International and regional organizations, and ESCWA in particular, are called upon to enhance cooperation in areas of common interest relevant to groundwater rehabilitation, protection and management, and to enter into discussion so that agreement may be reached on effective measures to support efforts by member States to implement the recommendations of this Meeting.

68. ESCWA and other United Nations entities should engage in a cooperative effort to launch a regional project in member States to develop and strengthen the capacities of departments involved in groundwater protection, primarily through the organization and support of training workshops and seminars and the provision of technical assistance relating to groundwater rehabilitation, protection and conservation; and should exchange data and information on various phenomena relating to environmental degradation, in particular those adversely affecting the quality of groundwater in member States.

Annex I

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Annex II

LIST OF DOCUMENTS

Symbol	Title
E/ESCWA/ENR/2000/WG.3/L.1	Provisional Agenda
E/ESCWA/ENR/2000/WG.3/L.2	Proposed organization of work
E/ESCWA/ENR/2000/WG.3/3	Implication of groundwater protection and conservation
E/ESCWA/ENR/2000/WG.3/4	Groundwater vulnerability mapping: decision support in groundwater resources quality protection
E/ESCWA/ENR/2000/WG.3/5	Pollution of groundwater from irrigation practices in the Arab countries
E/ESCWA/ENR/2000/WG.3/6	Groundwater use and groundwater protection in Germany
E/ESCWA/ENR/2000/WG.3/7	New approaches in groundwater rehabilitation
E/ESCWA/ENR/2000/WG.3/8	Water and soil vulnerability to contamination in central Beqa'a Plain-Lebanon
E/ESCWA/ENR/2000/WG.3/9	Evaluating the potentials of submarine springs: An unconventional groundwater source for coastal area
E/ESCWA/ENR/2000/WG.3/10	Salt water intrusion in Hadeth aquifer: Groundwater rehabilitation techniques
E/ESCWA/ENR/2000/WG.3/11	Groundwater pollution control measures in Lebanon
E/ESCWA/ENR/2000/WG.3/12	Guidelines for groundwater protection and pollution control in the GCC countries
E/ESCWA/ENR/2000/WG.3/13	Groundwater pollution by irrigated agriculture: A case study
E/ESCWA/ENR/2000/WG.3/14	قضايا هامة بالنسبة لإعادة تأهيل مصادر المياه الجوفية في منطقة الإسكوا
E/ESCWA/ENR/2000/WG.3/15	Implications of groundwater rehabilitation in ESCWA region
E/ESCWA/ENR/2000/WG.3/16	Groundwater pollution: Environmental health impacts
E/ESCWA/ENR/2000/WG.3/17	Burman, underground removal of manganese from groundwater in Beheira governorate, Egypt
E/ESCWA/ENR/2000/WG.3/18	Solute transport Models: An important tool for studies on groundwater protection or remediation
E/ESCWA/ENR/2000/WG.3/19	Isotope studies for groundwater protection and pollution control
E/ESCWA/ENR/2000/WG.3/20	MENA/MED water initiative proceedings of the regional workshop on sustainable groundwater management in the Middle East and North Africa
E/ESCWA/ENR/2000/WG.3/CP.1	ورقة قطرية – الجمهورية اللبنانية
E/ESCWA/ENR/2000/WG.3/CP.2	ورقة قطرية – المملكة الأردنية الهاشمية
E/ESCWA/ENR/2000/WG.3/CP.3	ورقة قطرية – الجمهورية العربية السورية

Annex III

TITLE OF THE SELECTED PAPERS AND THEIR PRINCIPLE AUTHORS

A. THEME I. GROUNDWATER POLLUTION AND ITS IMPACT

1. Implication of groundwater rehabilitation in ESCWA Region (Ms. Rawya Kansoh/ESCWA).
2. Guidelines for groundwater protection and pollution control in the GCC countries (Walid Al-Zubari).
3. Groundwater pollution by irrigated agriculture: A case study (Walid Abdulrahman).
4. Groundwater vulnerability to contamination in Central Beqa'a Plain (Talal Darwish/NCRS).
5. Burman, Underground Removal of Managese from Groundwater in Beheira Governorate, Egypt (Hassan Warda).
6. Saltwater intrusion in Hadeth aquifer of Beirut (Bernard Massaad/MEW).
7. Groundwater pollution: Environmental and Health Impact (May Al-Jurdi).

B. THEME II. GROUNDWATER REHABILITATION TECHNIQUE

8. New approach to groundwater rehabilitation (Weingram/BGR).
9. Implication of groundwater protection and conservation (B. Tussaint/BGR).

C. THEME III. GROUNDWATER PROTECTION

10. Flow and transport modeling (Mr. Klaus Schelkes/BGR).
11. Groundwater vulnerability mapping: decisions.
12. Groundwater use and protection in Germany (Mr. Kessler/BGR).
13. Issues in Groundwater Rehabilitation Projects.