Evaluation of Spatial and Temporal Variation in North East Jabal Al Hasawnah Wellfields Water Quality, Libya

Fathi M. Sanok, M. Ekhwan b. Toriman, and Mazlin Mokhtar

***Abstract*—**this study was conducted in order to evaluate insufficient of data availability on water quality in Libyan groundwater status. The assessment of ground water can help to recognize and improving estimates of contaminant fate and transport in groundwater systems. The Libyan People mainly depends on ground water which is the major source of drinking and agricultural purposes. Multivariate statistical techniques were applied for evaluation of temporal spatial variations and have been determined by Pearson correlation coefficients and Factor analysis to the data set of North East Jabal al Hasawnah wellfields (NEJH), northern and southern. The groundwater quality was examined and compared with (WHO) standard. Total of 16 parameters of water quality were monitored during 12 months in 2009 at 150 sites, 71samples at (NEJHn) and 79 samples at(NEJHs) wellfields. These samples were analyzed for various field measurements and Physical and chemical parameters including statistical measures, such as minimum, maximum, average, median, mode and standard deviation. The Chemical contents in the groundwater of studied area are primarily funded by the surrounding rocks. Most of the groundwater samples fell in the US Salinity Laboratory Classification of C3-S1 (medium salinity-low SAR). The order of abundance of cations was Ca>Na>K>Mg, whereas those of anions was No3>Cl>SO4. The Electric Conductivity in all samples were Exceeded (WHO) Permissible Limits, the Ca concentration exceeded the maximum permissible limit of 75 mg/ L in most of wells, the overall quality of groundwater of this area is safe for drinking, domestic purposes, and suitable for irrigation use.

***Keywords*—** groundwater, Jabal al Hasawnah, Water quality, wellfields.

I. Introduction

GROUNDWATER resources in arid and semi-arid regions play a vital role in the socioeconomic development [1]. In the last few decades there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization [2]. The chemical composition of groundwater is controlled by many factors that include composition of precipitation, geological structure and mineralogy of the watersheds and aquifers, and geochemical processes within the aquifer. The interaction of all factors leads to various water faces [3]. The periodic monitoring of groundwater quality is necessary to safeguard its long term sustainability [4]. In addition, several studies focused on groundwater quality monitoring and assessment for domestic, irrigational and industrial purposes. [5], [6], [7].Understanding the quality of groundwater is as important as that of its quantity [8]. Binsariti [9] has studied the Salinity Variations for some exploration wells and piezometers in the Jabal al Hasawnah, he reported that the exhibits wide variation for TDS from 940 mg/L to 2293 mg/L, and the EC values ranged between = 3850 μS/cm, and 1540 μS/cm [24].

In this Study, 16 parameters of water quality were monitored during 12 months at 150 sites (71 NEJHn and 79 NEJHs) in north east jabal al Hasawnah, northern and eastern wellfields. The study was thus carried out to assess groundwater quality and its suitability for drinking, domestic, and agricultural uses. The quality of groundwater examined relative to (WHO) standard and recognized the controlling factors quality of groundwater using multivariate statistical tool such as factor analysis. The Physical and chemical parameters such as pH, Total dissolved solids (TDS), Total Hardness (TH), Electrical Conductivity (EC), Total alkalinity, Sulphate (SO4), Nitrate (NO3), Sodium (Na), Calcium (Ca), Potassium (K), Magnesium (Mg), Chloride (Cl), Iron (Fe), Flour (F), and Phosphorus (P), also percentage of sodium (Na %) , Residual Sodium Carbonate RSC, Permeability index (PI), Kelly's Index (KI) and hazard of magnesium (MH) have been used for evaluating the suitability of groundwater for irrigation purposes(Table.1).

II. Study Area

Libya is a country located in North Africa with population is 6.4 million; more than 80% of the population lives in a narrow strip along the Mediterranean Sea. The total area of Libya is about 1.76 million km^2. Around 95 percent of the country is desert. The cultivable area is estimated at about 2.2 million ha which is 1.2 % of the total area of the country. Libya is in one of the driest regions of the world with Annual rainfall is extremely low from just10mm to 500mm. Average annual rainfall is 26 mm. Evaporation rates from 1,700 mm in the north to 6,000 mm in the south[10].

There are four major underground basins In Libya, these

Fathi m. Sanok is Ph.D. Candidate at University Kebangsaan Malaysia Campus. Email: fathisanok@hotmail.com

M. Ekhwan b. Toriman (PhD) is with University Kebangsaan Malaysia Campus. Email: ikhwan@ukm.my

Mazlin B. Mokhtar is with University Kebangsaan Malaysia Campus. Email: mazlin@ukm.my

being the Kufra basin, the Sirt basin, the Murzuq basin and the Hamada basin, the first three of which contain combined reserves of 35,000 Km^3 of water. These vast reserves offer almost enormous amounts of water. These vast water basins were discovered during the exploration for oil. Experts predict that the Libyan people will be supplied with daily water consumption of 6 million cubic meters per day for over 50 years. The total water withdrawal of 4.26 Km^3, about 83 percent is used for agricultural purposes, 14 percent for municipal use and 3 percent for industrial use. The water comes from vast underground lakes that have formed as a result of glacier defrosting after the last ice age.

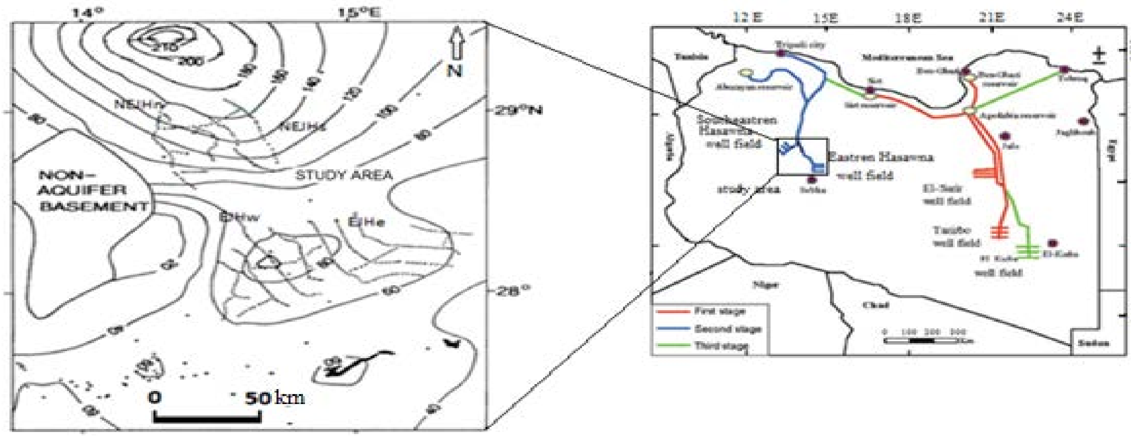

Fig.1 Layout of the study area at Great Man-Made River Project

The wellfields are situated to the east (EJH east and west) and northeast of Jabal al Hasawnah (NEJH north and south) as seen in Fig. 1.The northeastern field is bounded by longitudes 14° 13' 00" and 14°48' 00" E and by latitudes 28°42'00" and 29°16' 00" N, extending over more than 20,000 km^2 .The (NEJH) wellfields are almost just situated in the northern confined zone and is preset to supply a production rate of about 0.5 MCM/day. The (EJH) wellfields are situated to the east of Jabal al Hasawnah and is predetermined to provide the supplementing rate of 2.0 MCM/day.

III. Geology

Ordovician and Silurian-Devonian age overlain by the post-Tassilian and Nubian series of Triassic, Jurassic and Lower Cretaceous formations. The basin is covering an area of 450,000 km2 and estimated to hold 4,800km³ of waters [11]. The two geology groups designate the two major groundwater aquifer groups in the Murzuq [12]. The upper group, which includes the most extended and fresh water productive aquifers in the Lower Cretaceous beds, occurs virtually all over except in the north of the basin where older rocks are exposed. This group contains of sandstones and sands with irregular clay. The entire saturated thickness of the aquifers override 1000m in the center of the basin where the separating clay layers certify them acting as confined aquifers. Meanwhile, the lower group contains the Siluro-Devonian and Cambro-Ordovician formations, which is the main hydraulic unit of the lower groundwater aquifer group. At the north, however, the Silurian sandstones are often absent and the Devonian, although present, are reduced in thickness when matched to the southern part. Furthermore, various in the southern part, there is a good hydraulic association between the Devonian and the Cambro-Ordovician formations.

IV. Materials And Methods

The groundwater samples were collected from 170 observation wells, spread over the study area, using standard sampling procedures during sampling campaigns in 2009. The sample bottles were washed with different types of chemicals and rinsed with distilled water. The samples were carried in one litter bottle and kept in a low temperature until the samples were transported to main laboratory for determining the concentration of various chemical parameters. Field parameters such as pH and Electrical Conductivity were measured by using Hanna digital pH meter with Smart Electrode [model HI 98140] with an accuracy of ± 0.01 and Hanna digital Conductivity and TDS meter [model HI 99301] with an accuracy of ± 2% respectively. The parameters were analyzed for main chemical descriptors using standard methods, Electrical conductivity (EC) (ISO, 1985) and pH (ISO, 1994) .the total dissolved solids (TDS) were measured immediately at sampling site using portable meters. Whereas the rest of the parameters Ca, Na, Mg and Fe were determined using inductively coupled plasma atomic emission spectroscopy (ICP-AES).The parameters Cl, F, SO4, NO3, and Sio2) Ion Chromatograph Method and total dissolved solids (TDS) were measured by Gravimetric by evaporation using standard procedures prescribed in [13]. All parameters were determined at the water quality Department laboratory at great man mad river authority.

V. Results And Discussion

The correlation matrices for 14 variables indicated that the results of the statistical analysis which are presented in (Table 2) provided an indication that EC has a positive and signification correlation with TDS, Na, Ca and Cl. However, there were Weak correlation with pairs TH, Fe, No3 and mg. And negative correlation with T.ALK. TDS has positive and significant correlation with Na, Ca, Cl, and SO4, weak correlation with TH, Fe, No3 and F, and negative correlation with T.ALK. The Na shows good correlation with Cl, Ca, and So4. Total alkalinity exhibit negative correlation with most of the variables but weak correlation with K. Calcium (Ca) ion also shows more significant correlation pairing with Cl and So4.

The average temperature in this study was 32.8 C^0. The pH value is an important index of acidity or alkalinity and the concentration of hydrogen Ion in groundwater [14]. The pH values from 6.3 to 7.51 were found in this study, with an average of 7.1. The electrical conductivity (EC) values ranges from 1049 to 3050 µS/cm. All EC values in the study area show higher EC values than the permissible limit as seen in Fig. 2. The undesirable effects caused to humans when the parameters exceed the allowable limits [15] are presented in (Table III)

TABLE I
STATISTICS DESCRIPTIVE FOR (NEJH) WELLFIELDS

	Mean	Median	Variance	Std. Dev.	Min.	Max.	Range	Skew.	Kurt.
Total alkalinity	132.5	128	686.3	24.9	92	201	109	0.67	0.08
calcium	109.4	102.8	450.45	21.2	80	177.5	97.5	0.98	0.79
magnesium	32.2	30.9	82.56	8.9	16.5	63.55	47	0.98	1.6
iron	0.07	0.05	0.01	0.12	0.01	0.9	0.90	6.08	41.9
chloride	245.7	217.5	6680.3	81.5	147.5	480.5	333	1.10	0.54
Sulfur	230.7	200	5812.1	75.8	137.5	487.5	350	1.45	1.97
Nitrate	50.5	47.8	435.3	19.1	16	107	91	1	1.08
phosphorus	0.11	0.06	0.03	0.18	0.01	0.92	0.91	3.7	14.99
Fluoride	1.14	0.93	0.67	0.81	0	3.7	3.7	1.07	1.03
Silicon	15.8	14.5	17.19	4.145	5.65	27.25	21.6	0.84	2.04
pH	7.07	7.08	0.05	0.22	6.39	7.51	1.13	-0.63	0.95
Electrical conductivity	1600.3	1471	162996.3	402.2	1113	2825	1712	1.16	0.79
Total dissolved solids	1043.8	957.5	68646.2	260.98	723.5	1836.5	1113	1.14	0.75
Total hardness	278.3	266	3865.5	51.5	205.5	459	253.5	1.01	1.31
sodium	161.8	148	2700.3	51.65	95	341	246	1.55	2.39
potassium	6.30	6.35	3.25	1.77	2.5	12.65	10.15	0.46	4.4

TABLE II
CORRELATION COEFFICIENTS BETWEEN DIFFERENT WATER QUALITY PARAMETERS

	pH	EC	TDS	TH	Na	k	Ca	mg	T.ALK	Fe	Cl	SO4	NO3	F
pH	1													
EC	0.234	1												
TDS	0.181	0.814	1											
TH	0.091	0.323	0.385	1										
Na	0.156	0.710	0.803	0.402	1									
k	-0.061	0.333	0.374	0.051	0.292	1								
Ca	0.217	0.795	0.869	0.474	0.800	0.363	1							
mg	-0.088	0.387	0.502	0.317	0.555	0.307	0.455	1						
T.ALK	-0.530	-0.199	-0.215	-0.107	-0.194	0.156	-0.305	-0.023	1					
Fe	0.056	0.034	0.021	-0.061	0.016	0.025	0.005	-0.067	-0.071	1				
Cl	0.236	0.770	0.884	0.325	0.900	0.294	0.872	0.568	-0.285	0.033	1			
SO4	0.151	0.665	0.736	0.596	0.802	0.398	0.785	0.619	-0.250	0.018	0.724	1		
NO3	0.278	0.293	0.321	0.324	0.572	-0.070	0.450	0.400	0-.487	-0.081	0.494	0.474	1	
F	0.024	0.177	0.221	0.238	0.170	0.018	0.229	0.065	-0.059	-0.046	0.217	0.162	0.085	1

TABLE III
WELLS EXCEEDING PERMISSIBLE WHO INTERNATIONAL STANDARDS LIMITS

Parameter n=150	WHO	Present study	No. of Wells Exceeding WHO Permissible Limits	Undesirable Effect on Humans
PH	6.5-9.2	6.3-7.5	NIL	taste
EC, µ mho/cm	300	1049-3050	150	Gastrointestinal imitation
TDS	500	682-1983	75	Scale formation
T. Hardness	-	103-740	12	-
Calcium	75	74-191	147	-
Magnesium	50	14-69	7	Scale formation
Sodium	200	88-383	24	Scale formation
Potassium	8.0	1.9-15.9	8	Stains and Taste
Chloride	200	134-534	96	heart and kidney diseases
T. Alkalinity	-	81-224	-	dehydration and diarrhea
fluoride	1.5	0.0-5.1	27	blue baby disease
Nitrate	50	6-133	54	dental fluorosis
Iron	0.3	0.01-0.9	NIL	taste
Sulphate	200	115-600	5	Gastrointestinal imitation

TABLE IV
CLASSIFICATION OF WATER BASED ON HARDNESS

Hardness as CaCO3 (mg/l)	Water Class	Representing wells
<75	Soft	Nil
75–150	Moderate hard	73, 74, 75, 76, 77, 81-105,107,111-113,116-150
150–300	Hard	72,78,79,80,83,84,105,106,108,109,110,114,115
>300	Very hard	1-71

Total dissolved solids (TDS) range from 682 mg/L to 1983 mg/L with an average value of 1041.3 mg/L. About 50% of the samples are exceeding the allowable limits for drinking proposes. According to U.S. Salinity Laboratory, electrical conductivity value of less than 750 µS/cm, which is satisfactory for irrigation insofar as salt content is concerned. Total hardness (TH) also exhibits wide variation from 103mgIL to 740 mg/L with an average value of 270.6 mg/L. Hardness of water depends upon the amount of calcium and magnesium salts. Acceptable limit of TH for drinking is 500 mg/L [15] About 13 samples have the TH values greater than 150 mg/L (Table 4). It is detected that 7 of the 150 sampling wells under investigation, which is about 4.7 %, contain Magnesium (mg) above the permissible level.

High Concentration detected of Calcium ion (Ca) in groundwater, it ranges from 74 mg/l to 191 mg/l with an average value of 109 mg/l. 147 samples from 150 samples exceeded the maximum allowable limit of 200 mg/l. Sodium (Na) values in the studied area are between 88-383 mg/L with an average value of 161.3 mg/l. The higher concentration of sodium can be related to woman toxemia associated with pregnancy and cardiovascular diseases.

There are 24 sampling sites showed higher in sodium concentration than the prescribed by (WHO). Potassium (K) values ranged between 1.9- 15.9 mg/Land the average was 6.32 mg/l. The potassium concentrations are relatively lower than those of sodium. The iron (Fe) values in the studied area varied between 0.01-0.9mg/l with an average value of 0.07 mg/l. The chloride (Cl) concentration varies from 134 mg/L to 534 mg/L. The average value is 399 mg/L. about 96 samples exceeded the most desirable limit of 200 mg/L but under maximum allowable limit200 mg/L. The nitrate concentration in groundwater samples range from 6 mg/l to 133 mg/L with an average value of 50.4 mg/L. fifty four samples exceed the desirable limit of 45 mg/l for drinking as per the WHO standard.

Sodium adsorption ratio (SAR) is an index for the amount of sodium ions in the soil water; it measures of the suitability of water for use in agricultural irrigation, the SAR determined by the concentrations of solids dissolved in the water as in (1).

$$SAR = \frac{Na}{\frac{\sqrt{Ca + mg}}{2}} \quad (1)$$

The SAR value range in the studied area from 2.1 meq/l to 6.51 meq/l with average 3.5 meq/l, about 42.7% samples are classify as Excellent for irrigation, and 44% of samples recorded values below 6 meq/l. some samples remarked as unsuitable quality for irrigation, as seen in Fig. 2,based on USDA classification C4 S2 and C4S1, but Most of the groundwater samples (92.7%) fell in the US Salinity Laboratory Classification of C3-S1 (medium salinity-low SAR) (Table V).

TABLE V
SUITABILITY FOR IRRIGATION BASED ON USDA CLASSIFICATION

EC µS/cm	Salinity Class	Number of samples	Percentage of sample	Remark on quality
<250	C1	Nil	Nil	Excellent or Low
250-750	C2	Nil	Nil	Good or medium
750-2250	C3	1-33,39-51,53-59,64-129,122-138,140-150	92.7	Permissible or high
2250-5000	C4	34-38,52,60-63,120,121,139	7.3	Unsuitable or very high

Sodium in soil is considered vital to determine the suitability of groundwater for irrigation because Na reacts with soil to reduce its permeability and support little or no plant growth. The sodium content is usually expressed as a percentage of sodium (Na %) calculated by the following formula as in (2).

$$\mathbf{Na\%} = \frac{(\text{Na} + \text{K})}{\text{Ca} + \text{Mg} + \text{Na} + \text{K}} \times 100 \qquad (2)$$

Based on Na% < 35 in ground water is suitable for irrigation purposes. The Na% ranging between 33.49 meq/l to 58.70 meq/l, and the average 46.41 meq/l. Only six samples are classified as a good for irrigation purposes depending on Na%, and 144 samples are fill in permissible limit (Table VI).

TABLE VI
CLASSIFICATION OF NEJH GROUNDWATER BASED ON NA%

Range	Categories	representing wells
<20	Excellent	Nil
20-40	Good	42,50,73,78,82,131
40—60	Permissible	1-41,43-49,51-72,74-77,79-81-83-130,132-150
60-80	Doubtful	Nil
>80	Unsuitable	Nil

Generally,>2.5 meq/l of RSC is unsuitable for irrigation purposes. RSC rangingfrom-2.67 to -12.46 was observed, and all samples were within the permissible limit. RSC is calculated by using the formula (3)

Residual Sodium Carbonate (RSC) = [(HCO3 +CO3) – (Ca + Mg)] (3)

Doneen [16] gives a criterion for evaluating the suitability of groundwater for irrigation based on IP, where concentrations are in meq/l. In the study area the PI values range from 42.4 to 69.5% with an average value of 57.1%. According to PI values all ground water samples can be labeled as class II (25–75%) implying that the water is of good quality for irrigation purposes. PI is calculated by using the formula (4)

Permeability index $$\mathbf{PI} = \frac{\left(\text{Na} + \sqrt{Hco3}\right)}{\text{Ca} + \text{Mg} + \text{Na}} \times 100 \qquad (4)$$

Kelly's index was applied to classify the water for irrigation purposes. Sodium measured against calcium and magnesium is considered for calculate this parameter. The values of KI < 1 indicate good quality water for irrigation, and KI > 1 indicate bad water. The values of KI in the present study varied between 2.0 to 7.4. Therefore, according to KI most of water samples considered as unfit for irrigation, and calculated by following the formula (5)

Kelly's Index $$KI = \frac{\text{Na}}{\text{Ca} + \text{Mg}} \qquad (5)$$

The values of the Magnesium Hardness range of 15.4 and 45.8 with a mean value of 32.6, and all samples fill under MH permeation limit, and calculated by using the formula (6)

$$MH = \frac{\text{Mg}}{\text{Ca} + \text{Mg}} \times 100 \qquad (6)$$

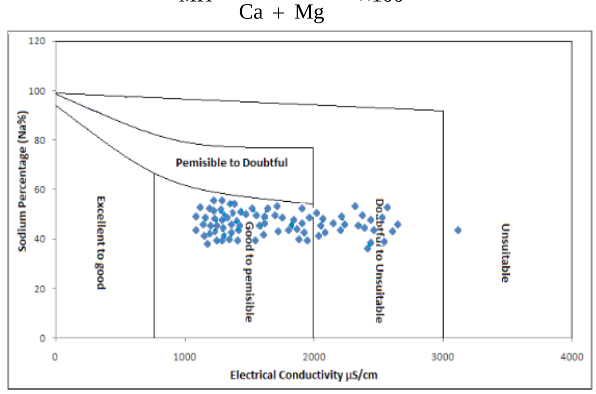

Fig. 2 Position of water samples on the Wilcox plots

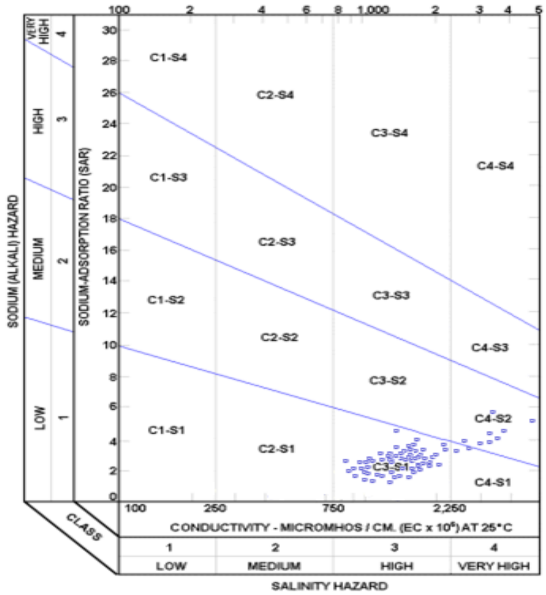

Fig.3.Salinity diagram of groundwater samples from the study area

VI. Conclusion

The present study was conducted to provide the data needed to facilitate the development of a more sustainable management program for the aquifer. The aquifer at Murzuq basin requires sustainable management to ensure it continue to meet the quantitative demands being placed upon it, and to maintain water quality. A sodium adsorption ratio (SAR) and PI values obtained for water samples from groundwater in the study area classify the water as good quality and suitable for potable use and crops irrigation. This research could serve as a preliminary study to provide basic information that can guide future studies to assess the water quality in the study area.

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Fathi m. Sanok is from Libya, born in December 1969. He Graduated From Soil and water Department Faculty of agriculture at Al-fateh University in Tripoli Libya. 1998. He has a Master's degree in land resource management from University putra Malaysia, 2002. He has worked as a Lecturer at alzawia University, Libya. Presently, he is with University Kebangsaan Malaysia Campus as a candidate of Ph.D. His current research interest is in water quality management.
Mr. Fathi can be reached at: fathisanok@hotmail.com

M. Ekhwan b. Toriman is from Malaysia, born in 11 September 1969.graduated from The University Kebangsaan Malaysia Bachelor in Geography with Honors (Second Class Upper) 1993 and then obtained his M.Sc. (Hydro-geomorphology), Faculty of Science and Engineering, University of Manchester, UK.1996. He has a Ph.D. in Hydrology fluvial and GIS Application, Faculty of Science, Agriculture and Engineering, Newcastle University, UK. 2002. Presently, His current research interests are River simulation using 2-D hydrodynamic model XPSWMM (River modeling), 1-D hydrodynamic model Info Work RS (Hydrological modeling and water quality) and GIS ArcView and Registered with Department of Environment (DOE)as "Subject Specialist" in hydrological studies.
Mr. Ekhwan can be reached at: ikhwan@ukm.my

Mazlin B. Mokhtar is from Malaysia, He received his BSc in Chemistry from the University of Tasmania, Australia, in 1984 and his PhD (Analytical and Environmental Chemistry) from The University of Queensland, Australia, in 1988.He is a Professor of Environmental Chemistry at University Kebangsaan Malaysia (UKM) where he has been with the Faculty of Science and Technology since 1997. He is currently a Principal Fellow (since 1999) as well as Director of the Institute for Environment and Development (LESTARI), UKM, since August 2005.He had published more than 180 articles in reputed journals; books; chapters of books, and other various forms on the subject matter of environmental analytical chemistry; science and governance of sustainability, IWRM, Chemicals Management, climate change, Capacity Building and Education for Sustainable Development. He was also Chairman, Working Group on Biodiversity & Environmental Management, involving NRE, BP, WWF-Malaysia, British Council, Ministry of Education, etc. (2000-2009) and Chairman of the Langat River Basin Research Group affiliated with UNESCO-HELP network, based in Paris involving more than 90 river basins from more than 65 countries. He was Founder &Cochairman of MyNICHE (Malaysian Network for Integrated Management of Chemicals and Hazardous Substances for Environment & Development) since 2005.
Mr. Mazlin can be reached at: Email: mazlin@ukm.my