Review Article

WATER POLLUTION, LIMNOLOGICAL INVESTIGATIONS IN KURDISTAN REGION AND OTHER PART OF IRAQ

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Abstract: The main principles of sustaining the quality of water supply varies socially, politically, and culturally according to the locations and the beneficiaries. Cultural issues of water supply relate to the customs and beliefs of, and naturally its impact on, the ethnic groups supplied, while the social perception may relate to the users, beliefs, desires, and their expectations of the type of water systems available for different stakeholders in the society. A great number of liminological studies have been conducted on various water systems within the Kurdistan region. Generally, the physico-chemical parameters were as follow; pH ranged 6.5-8, TDS ranged from, EC ranged from 0.37-2050, DO ranged from 0.0-12.8 mg l\(^{-1}\), Nitrate 16-230 N-NO\(_3\) l\(^{-1}\), Nitrite up to 1.4 N-NO\(_2\).l\(^{-1}\), chloride 0.02-0.06 meq l\(^{-1}\), hardness 3.64-286 mg CaCO\(_3\).l\(^{-1}\), reactive phosphate 0.28-12.7 P-PO\(_4\)l\(^{-1}\), respectively. Also, in the rest of Iraq, the physico-chemical variables were as follow; pH ranged from 6.8-8.2, TDS ranged from 122-540 mg l\(^{-1}\), Na, 35-95 mg l\(^{-1}\), K ranged from 1.4-2.2 mg l\(^{-1}\), chloride ranged from 35-165 mg l\(^{-1}\) nitrate value 46-300 as N-NO\(_3\) l\(^{-1}\) and nitrite from 1.4-3.6 N-NO\(_2\).l\(^{-1}\), alkalinity and reactive phosphours value ranged 5.4-29.6 meq.1\(^{-1}\) and 10-26 P-PO\(_4\)l\(^{-1}\), respectively. Also, heavy metals such as Cd, Fe, pb, and Zn were ranged 0.007-0.058, 0.01-0.130, 0.002-0.061, and 0.040-0.320 mg l\(^{-1}\), respectively.

All in all, according to Water Quality Index (WQI), most of the water sources requires primary treatment before use for drinking, whereas waters of Tanjaro river and Qiliasan stream cannot be used for drinking till they are treated (primary to tertiary treatments).

Keywords: Point and non-point sources, ground water, Kurdistan.

Introduction

Environmental impact of water

Environmental consideration is as significant as other commodities. The potential source of the water supply and its ability to supply the entire population are important factors to be taken into consideration. Furthermore, environmental consequences may occur especially where large amounts of bored wells are pumped which may have some implications (Ndege, 2001).
Hydrological cycle

Water movement between the earth (Geosphere) and the atmosphere through different reservoirs or Components, (atmosphere, hydrosphere, biosphere and androsphere), is illustrated in figure, 1.

When the sun heats seawater, it evaporates and becomes water vapor which then rises in the atmosphere, condenses and forms precipitation such as rain. Eventually it falls on the land and starts its journey via glaciers, creek and rivers whilst some evaporates from the surface of the vegetation and soil, or is soaked into the ground water where it gradually evaporates or is used by vegetation. This cycle is known as the hydrological cycle (DLWC, 1995). Depending on their locations these reservoirs are seen to have common interactions.

\[ \text{From: Eyre, 1993; DLWC, 1995; Ambient, 2001.} \]

\textbf{Figure (1): Transfer of water within major reservoirs}

Atmosphere

The atmosphere is largely transparent to long-wave solar radiation but absorbs most of the radiation emitted from the surface of the earth. Its behaviour is particularly influenced by the presence of clouds, which strongly affects both incoming and outgoing radiation (Australian Bureau of Meteorology, 1993).

Furthermore, atmospheric water vapor and carbon dioxide (even though in small amount) produce greenhouse effects which keep the temperature at the earth’s surface in the range within which complex life forms can exist. On planets such as Venus, with much greater levels of carbon dioxide (CO$_2$), the much stronger greenhouse effects produce temperatures too high to maintain life (Australian Bureau of Meteorology, 1991 and 1993).

Hydrosphere

It represents 1.41 billion cubic kilometers of water in the world, only 2% of this volume is fresh water and most of the fresh water is stored in glaciers, ice caps, and in deep ground
It has been estimated that about 40,000 km$^3$, only 2% of this volume is accessible in lakes, rivers and ground waters (Australian Bureau of Meteorology, 1991 and 1993).

**Biosphere**

The biosphere refers to the living and dead organisms in the environment, particularly terrestrial vegetation and the phytoplankton in the upper ocean (Australian Bureau of Meteorology, 1991 and 1993).

**Geosphere**

The geosphere consists of the solid land surface (Lithosphere), the oceans, rivers, and inland water (the hydrosphere) and the continental ice sheets, glaciers, sea ice, snow and permafrost (the cryosphere) (Australian Bureau of Meteorology, 1991 and 1993; Eyre, 1993; DLWC, 1995; Ambient., 2001).

**Availability of water**

It is perhaps, also important to note availability of water in the biosphere (Howell, 1993; Allenby et al., 1993). It is suggested that water varies across the earth both in terms of quality and quantity (defined by concentration of dissolved solids, suspended solids and organisms) (Howell, 1993). While the availability of water exists, the ecosystem (i.e. plants, animals and living organisms) utilizes it, but for human needs, modification of water is necessary. The destruction, especially of shallow riverine and coastal aquifers through over pumping and pollution is greatly adding to the water crisis now experienced by many areas in the Asia-Pacific region (UNEP, 1996).

**Water related issues**

In general, the availability of water depends on the location and climatic nature of the region (Allenby et al., 1993). Many factors that reflect on the nature of the water resources. The importance of water depends on the availability, quantity and the quality of sourced water in order to fulfill desired requirements. Detailed below is how some of the background and overviews of water related issues which are experienced throughout the world (United Nations, 1997).

**Water Pollution**

The pollution of water sources happens through point and non-point source pollution (figure, 2). Non-point source pollution is more ambiguous which cannot be related to a specific point for example, pesticides and fertilizers application to agriculture fields (Allenby et al., 1993; Viste et al., 1994; Hammer et al., 1996; Nathanson, 1997).
The characters of point source water pollution is that;

1) Pollution can be accurately determined.

2) Limited real extent (e.g.; contaminants introduced into water sources from the discharge of effluent from industries, septic tanks and leachate from landfill through waste discharges from public waste water treatment plants).

The problem of water pollution occurs when substances are added to the water that affect its chemical composition and threaten the human health and ecosystem (Allenby et al., 1993). Agricultural land, sewage effluent, debris, runoff from urban areas, and animal waste, are found to be responsible for the increased number of microorganisms found in water (Allenby et al., 1993; Berka et al.,1995; Boyd, 2000). In addition to chemical pollution the ground water quality can be further endangered through increasing levels of parameters affecting water quality such as, hydrogen ion concentration (pH), electrical conductivity (EC), turbidity, and microbiological content (WHO,1993).

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**Figure (2): The sources of water pollution**

- **Non-Point Source**
  - Mining and Logging
  - Suspended Solids
  - Acid mine drainage
  - Waste oil discharge

- **Point Source**
  - Feed lots
  - Organic Solids
  - Nutrients & Bacteria

- **WATER SOURCES**
  - Urban storm runoff
  - Industrial
  - Residential
  - Dust
  - Dirt and litter

- **Agriculture & land Drainage**
  - Silt from erosion
  - Fertilizer
  - Organic waste
  - Microorganism

- **Municipal Domestic Industrial waste**
  - Color, foam & Salt
Bore wells
Ground water sources differ from other natural water sources in that the hydrologic cycle and hydrosphere are two inextricably bound systems with each of them constantly exerting an influence over the other (Howell et al., 1993; Eyre et al., 1993). Ground water is described as water that is found underground in the saturated zone of rock i.e. at depth where the entire void of space of the rocks is filled with water (Allenby et al., 1993; DLWC, 1995). Ground water quality is of higher standard compared to surface waters because of its natural purification. Less treatment is required where minimal treatment is a high priority (Reinhold, 1992).

Bore wells are also popular in many of the rural communities in both developed and developing countries especially where the supply of treated tap water may not be feasible (SIA, 2000). It is primarily used for domestic consumption, agriculture, and industrial activities. The application and usage depends on the nature and quality of the source. (NDOH, 2000).

Ground water contamination
Ground water contamination by microorganism, point source and non-point source is a serious pollution problem in many countries in the world (Hammer et al., 1996; Tomar, 1999; Boyd, 2000).

There are a number of routes by which ground water is contaminated:

- Inter-aquifer leakage and irrigation returns (Reinhold, 1992; Hammer et al., 1996).
- Leached from soluble solids at the surface and leaking from broken sewer pipes or lines (WHO, 1993).
- Percolation of liquid sprayed over land (Beckett, 1993).
- Land fill leachate (Blight, 1995).
- Septic and sewerage effluent discharge (Boyd, 2000).

Ground water contamination by chemicals such as cobalt was reported in Bangladesh (Hueb, 2001). The (20%) had high levels of cobalt above 0.05mg.l⁻¹, after of the 25 000 tests on wells carried out in Bangladesh, which is contrary to the WHO (1993) drinking water quality guidelines (Merit et al., 1997) evaluated water quality, they reported that the high levels of calcium and magnesium occurred in aquifers found in limestone bedrock.
The nature aquifer that provides the deep well is free from contamination a pollution case is indicated cracked, faulty well casings, open well caps and spills from neighboring source are found to be responsible for such incidences (Merit et al., 1997).

**Nitrate contamination of ground water**

The inorganic contamination of greatest concern in ground water is the nitrate ion, which commonly occurs in aquifers near rural and suburban population. Although uncontaminated ground water generally has nitrate nitrogen levels of less than 2 ppm, nitrate in ground water originates mainly from four source:

- Application of nitrogen fertilizers, both inorganic and animal manure to cropland.
- Atmospheric deposition.
- Human sewage deposited in septic systems.
- Cultivation of the soil.

For example, almost 12 million tons of nitrogen are applied annually as fertilizer for agriculture in the United States, and manure production contributed almost 7 million tons or more. In most cases, the reduced forms of nitrogen was oxidized in the soil to nitrate, which then migrates down to the ground water, where it dissolves in water and is diluted because nitrate removal from well water is very expensive, water contaminated with high levels of nitrate normally is not used for human consumption, at least in public-health (Barid and Cann, 2005).

Jennings et al., (1998) undertook a study on toxicity of nitrate in ground water, they showed that among infants less than one -year old, pregnant women, and persons of all ages with reduced gastric acidity or hereditary lack of met hemoglobin reductase, those most at risk for exposure are those who according to shallow wells foe drinking water.

Reddy and Lin, (1999) conducted an investigation about nitrate removal from ground water using catalytic reduction process to selectively removing nitrate ion from ground water, associated with agricultural community. Three catalysts used were, palladium, platinum, and rhodium.

The transport of nitrate in a ground water aquifer in relation to age, landuse practies, and redox processes in west-central, Minnesota was investigated by (Puckett and Timothy, 2001). They found that nitrate concentrations were heigh, behaved like oxygen, decreasing with both increasing age and depth, suggesting that once O\textsubscript{2} was depleted, nitrate was utilized as the terminal election acceptor in the oxidation of organic carbon. Rosen et al., (2004)
investigated a prediction of ground water nitrate contamination after closure of an unlined sheep feedlot in Carson city, United States.

**Bacteria spread in ground water**

Ground water is held in the pore space of sediments such as gravels or sands or in the fissures of fractured rock such as limestone. The sediments or rock contain the water defined as an aquifer and the upper water level in the saturated body, which is defined as the water table (Moss, 2003).

Recently, several theories concerning the movement of bacteria in ground water showed that the bacteria tend not to travel along distance in fine soil but can travel very long distances in coarse soils particle or fractured formations (Bourwer H, 1978 and Reinhold, 1992). Surface water, which may carry pathogenic organisms in aquifer systems from sewage discharge, landfill leachate and polluted water, landfill leachate, and sewage discharge (Berka, 1995; Boyad, 2000).

In ground water growth of bacteria occurs within the optimal potential hydrogen range between 6.5-7.5, which is close to the intracellular hydrogen (Clark et al., 1989). Apparently only few species can grow at a value of potential hydrogen less than two or more than ten (Brock, 1979). Many studies have prepared reports indicating that a toxic environment is unavailable and do not contribute to the growth of microorganisms (Brock, 1979). The toxicity of the environment refers to many factors such as, sound and radiation, hydrostatic pressure, high and low temperatures (Reinhold, 1992). The activity of most enzyme, protein synthesis and membrane transport relatively contribute to enhance the microbial growth is some times affected by hydrostatic pressure at 200-600 atmospheres, but they grow well at atmospheric pressure in soil or shallow water (Reinhold, 1992).

**Ground water and health**

Historically, ground water has been a source of high quality and relatively clean, drinking water, needing little if any or no treatment (Reinhold, 1992), however surface water has usually requires some treatments as a result of ever increasing human interactions, through agriculture, sewage, disposal, industries, aquaculture and other activities.

**Water quality and public health**

Water quality and public health are linked in many ways (Brudtland, 2001). Safe and potable water is essential for human life (Michiels et al., 2000). Many theories have suggested that water was responsible for transmission of many waterborne diseases through the microbial
contamination of drinking water, which is the most critical risk factor in potential widespread of disease. It continues to be a major cause of morbidity and mortality (UNEP/WHO, 1996). Despite worldwide efforts and the availability of modern technologies utilized for the production of safe drinking water, it has been reported that the transmission of waterborne disease is a matter of major concern (Stevens et al., 1995). The contamination of drinking water during storage, a lack of regulations and limited understanding and awareness among the population is documented (Mackenzie, 1994; Roefer et al., 1996). The adverse implications of mechanical failure, human error or deterioration in the quality of the source water, even with the best treatment system and disinfection process, can sometimes degrade the water quality (Mackenzie, 1994; Roefer, 1996; Geldreich, 1996).

Diseases derived from chemical contamination of drinking water are negligible compared to the number due to microbial contamination (Herwaldt et al., 1992). High chemical concentration in drinking water can pose a health risk; however, in the case of bacteria contamination a presence of only small numbers many cause a health risk to the consumer (WHO, 1997). Epidemiological studies have shown that poor water drinking quality (referred to feces and environmental contamination or un-chlorinated water) as the major transmission route, was responsible for many of the waterborne diseases (Lee et al., 1993). Examples of these transmission routes for waterborne disease to humans are;

1. Consumption of untreated, inadequately treated, or contaminated water directly or indirectly through food preparation.
2. Body contact with contaminated waters for example, fresh water, marine water, swimming pool.

Global examples of waterborne disease

Epidemics of cholera have been reported in England (Weinstien, 1980) and Peru (Gray, 1994; Putnam and Wiener, 1995). Diarrhoea, typhoid and dysentery are common in many part of Papua New Guinea (NDOH, 2000). The most affected are children and the elderly people. A major outbreak of E.coli (0157) was reported in a small town of Walkerton, Ontario about 180 Km north of Toronto causing 7 fatalities, mainly the elderly people, and leaving several people in a serious condition (Health Stream, 2000). The incidence of diarrhoea disease caused by drinking contaminated water in Fujian province, south east of China has been reported (Chen et al., 1991). It was noted that the number of instances per year of people suffering from diarrhoea due to drinking contaminated water was 575.00 per 1000 persons in people drinking reticulated water, 846 per 1000 people drinking well water and an astounding
4567 instances per 1000 people per year drinking river water. Poor sanitary conditions, overcrowding <10 square meters per person and low income are some of the significant indicators which contribute to factors causing diarrhoea (Chen et al., 1991). The relationship between microbial quality of drinking water from different sources, and the prevalence of diarrhoea disease among children under two years was studied in Cebu, Philippines (Moe et al., 1991). The percentage of different wells investigated yielding greater than 1000 coliforms per 100ml were; 21% of 123 spring water wells, 21% of open dug wells, 14% of 52 wells with pumps, 6% of 75 boreholes and 60% of 5 non-municipal reticulated tap water supplies. The microbial were studied in all the water sources (Moe et al., 1991).

The immense risk of gastroenteritis disease among the elderly, young, pregnant woman, and those whose immune systems are compromised by cancer, and AIDS (Acquired Immune Deficiency Syndrome) was investigated (United State Environmental Protection Agency, 1993; Payment et al., 1997).

**Limnological Investigations in Kurdistan region**

It is clear that, numerous limnological studies were carried out on various water systems within the of Kurdistan region. But in general, it can be said that the first ecological investigation in Iraq dates back to many papers prepared by German group led by (Kolbe and Krieger, 1942).

These investigations consist of ninety-seven collections from eleven locations carried out by Handel Mazzetti’s expedition to Iraq and Turkey around Euphrates and Tigirs, it recorded 248 taxa of diatoms from fresh and brackish water habitats.

One of the important investigation on different well waters in Sulaimani province was conducted by Anon (1957). He showed a detail information for different well waters, by examining the water samples for several physical, chemical and bacteriological testses. The mean value of water temperature was 19.5 °C, potential of hydrogen ion value ranged between 6.7 to 7.71, electrical conductivity value ranged from 0.37 to 1.150 mhos.cm⁻¹. While the mean value of alkalinity as CaCO₃ between 2 to 6.4 meq.l⁻¹, concentration of dissolved oxygen ranged from 2.37 to 8.8 mg.l⁻¹. The mean value of biological oxygen demand for five days of incubation under 20°C did not exceed 0.81 mg.l⁻¹. Nitrate concentrations revealed that all the wells water were found to be suitable for irrigation purpose.

Ecological studies in Iraq developed with developing universities and scientific centers, therefore from beginning of 1970s on word many papers have been published in Kurdistan...
region (Antoine, 1977 and Hameed, 1978). They were almost restricted to aquatic and marine ecology. Limnologically, phycologically, and oceanographically considerable areas of these water bodies. Made a comprehensive ecological survey for Iraqi inland waters, have been studied by (Islam and Hameed, 1985).

The initial limnological studies on the water quality in Iraqi Kurdistan region started at Sulaimani province by Maulood and Hinton (1978). Some dissertations have been produced in Sulaimani University which have a great role in limnological study in Iraq. In Kurdistan only a few post graduated students dealt with limnological studies in various aquatic ecosystems. It is clear that water systems cover a wide range of Kurdistan area, they include surface water, ground water, wells, Kahreeze, spring, lake and impoundment in one hand, channel, tributaries, river on the other hand. Results of various investigation shows the presence of mineral water, sulfer spring, stenothermal and eurythermal water system. The variation in their chemical and physical properties in various area have been dealt by many authors and investigators.

EL-Yossif and Al-Najim, (1977), studied the hydrology and quality of Serchinar spring water. They provided that mean value of potential hydrogen ranged from 6.95-7.39, electrical conductivity values ranged from 500-680 µS.cm⁻¹, chloride from 0.02-0.06 meq.l⁻¹, whereas the mean value of calcium concentration ranged from 0.40-0.39 meq.l⁻¹, and magnesium values ranged from 0.40-4.72 meq.l⁻¹. Maulood and Hinton, (1979) estimated that trace elements content of Sarchinar spring was higher than of water of Killiassan river but, never reached the toxic level.

Kamees (1979) studied the ecology of water pollution in Tanjaro valley which is fed by Chaqchaq river and Sarchinar spring. He studied the assessment of water quality. However, Al-Shahwani, (1980) studied the primary productivity of Sarchinar spring.

The study on the chemical status of drinking water in Sulaimani city in investigated by Al-Shahwani (1980). The water of Sulaimani from it is principal sources was analyzed monthly throughout years. The value of total hardness ranged from 110-286 mg.CaCO₃.l⁻¹, calcium hardness ranged from 28-70 ppm, while the magnesium hardness ranged from 0.0-35 ppm.

Ibrahim, (1981) conducted a study on some physico-chemical properties and phycological studies of thirty-seven springs at different regions within Sulaimani province. Only three springs from the total were thermostatic with a temperature fluctuation ±1°C around annual mean temperature, while the lowest and the highest temperature were recorded in Balkian and Khurmal springs which were 12.8°C and 29.5°C respectively. The potential of hydrogen
values were generally >7.0 within an overall mean of 7.28 for all sources, the electrical conductivity values were ranged from 226-2050 µS.cm⁻¹, reactive phosphorus ranged from 0.28-12.7 µg at P-PO₄⁻³, and alkalinity 148-352 mg CaCO₃.l⁻¹. On the other hand nitrate ranged from (16.1-275 µg at N-NO₃⁻¹, nitrite ranged from 0.0-0.81 µg at N-NO₂⁻¹. Calcium and magnesium concentrations were ranged between 50-361.2 mg.l⁻¹, and 4.1-34.1 mg.l⁻¹ respectively, the value of dissolved oxygen ranged from 0.0-12.8 mg.l⁻¹, biological oxygen demanded for five days ranged from 1.5 mg.l⁻¹.

A study on water and soil pollution in Sulaimani city investigated by Khorshid (1981). He selected seven various wells. It is found that the temperature of the studied well waters did not vary greatly, the changes in temperature did not exceed 2°C, the mean potential hydrogen ranged from 6.7-7.7, whereas the mean alkalinity ranged from 2.0-6.4 meq CaCO₃.l⁻¹, while the mean of electrical conductivity values ranged from (0.37-1.15 mmhos.cm⁻¹. The mean values of biological oxygen demanded for five days under incubation at 20°C was 2.0 mg.l⁻¹, it is clear that all the well waters were very clean in relation to BOD₅ values. Moreover the mean values of nitrate ranged from 49-230.5 µg at N-NO₃⁻¹, while the mean value of nitrite concentration was 1.4 µg at N-NO₂⁻¹, total hardness ranged from 3.64-10.74 meq CaCO₃.l⁻¹. All the well waters were similar in their content of total bacteria count, coliform and fecal coliform, but their numbers varied among themselves. The organic matter percent and total nitrogen increased in the soils after irrigation. However the available phosphorus and potential hydrogen values decreased in the soils after irrigation.

A study on diurnal variation of some physical and chemical characteristic of Sulaimani well water was conducted by Khorshid (1988). Seven wells were selected at various locations. It was observed that diurnal variation would be influenced by specific well location, well depth, and the water’s specific properties.

Muhammad (2004) studied the aquatic life in Sarchinar spring, Chaq-chaq and Kliassan streams within Sulaimani city. Water samples were collected at fortnight interval periods from ten various water resource sites. He indicated that the hydrogen ion concentration of the all studied areas were on the alkaline side of neutrality. Alkaline waters ranged from 102-340 mg. CaCO₃.l⁻¹, water hardness ranged between moderately hard to very hard waters 110-355 mg CaCO₃.l⁻¹ within low or saturated by oxygen 1.00-9.00 mg.l⁻¹ and healthy situation with regard to biological oxygen demand for five days under incubation at 20°C 0.20-9.50 mg.l⁻¹. In all investigated sectors, cations were dominated by calcium followed by magnesium, sodium and potassium with decreasing their concentrations in order.
Ganjo and Toma (2004) conducted a limnological investigation on vertical profile of Dokan lake, water samples were analyzed for five days in May 2000. The ecological variables determined: potential hydrogen in epilimnion were on the alkaline side of neutrality, electrical conductivity values were moderately high.

Mustafa (2006) made a study impact of sewage waste water on the environment of Tanjaro river and its basin with in Sulaimani city, and he revealed that as a whole, Tanjero river, Qiliasan stream and ground water of the area were polluted with sulfate, nitrate, nitrite, ammonia, ammonium and heavy metals (Cadmium, Copper, Nickel, Lead and Zinc). Moreover according to Water Quality Index (WQI), ground water requires primary treatment before use for drinking, whereas waters of Tanjaro river and Qiliasan stream cannot be used for drinking till they are treated (primary to tertiary treatments).

On the other hand, quite many dissertation and papers on regional limnological and bacteriological studies on ground water have been published in Salahaddin University during the two decades.

General survey of Hawler ground water area has been conducted by Hadad et al., (1974), they concluded that the area of Hawler is relatively well endowed with good aquifers containing water of quality generally suitable for drinking and irrigation purpose.

A bacteriological study on twenty well waters of Hawler, Kirkuk, and Sulaimani was carried out by Abdul-Rida (1981). The water samples were analyzed for the following parameters: total bacterial count that revealed a minumum of 100 cell/cm$^3$ to maximum of 260 000 cell/cm$^3$, while potential hydrogen of the investigated wells were in the alkaline side of neutrality, chloride concentrations ranged from 4.0-237 mg.l$^{-1}$, and biological oxygen demanded for five days ranged from 0.1-4.5 mg.l$^{-1}$.

A limitation of some ground water suitability in Hawler plain for different uses was conducted by Esmail (1986). Eleven wellls were using during the growing seasons(1984-1985) in the experiment; the electrical conductivity values ranged from 0.9-8.9 mmohs.cm$^{-1}$.

In (1994) Rasheed conducted a limnological study on some various water systems containing Karezes, springs, impoundments, and streams, within Hawler province. He indicated that the value of potential hydrogen of the water system ranged from neutral to alkaline, electrical conductivity ranged from 173-1570 μS.cm$^{-1}$, total hardness ranged from 144-958 mg.CaCO$_3$.l$^{-1}$, moreover dissolved oxygen levels exceeded saturation levels, and reactive phosphours ranged from 0.02-16.21µg at P-PO$_4$. 
Furtheromre, Al-bayathi et al., (1994) made an assessment quality of ground water wells belonging to Wdi-Lilan basin, in southeast Kirkuk. He analyzed nine sample well waters for their physical and chemical characteristics, and showed that most of the studied water wells except three wells were available for drinking purposes because of undesirable concentrations of hydrogen ion concentration values which were higher than 7.0 in all studied wells, electrical conductivity values ranged from 7.0-1880 µs.cm⁻¹, total hardness values ranged from 225-914 ppm, and total dissolved salts ranged from 415-1273 mg.l⁻¹.

Ganjo (1997) conducted a study on Ruwandiz river basin. He stated that the basin carries moderate amount of sewage and considerable levels of soil originated substances through out erosion loads when rainfall enters the refuse within the catchment area.

Dohuki (1997), carried out a limnological study monthly for a year on some water systems such as, wells and spring, to estimate water quality for drinking and irrigation purpose within Dohuk city. He observed that the electrical conductivity of water in these studied areas ranged from 0.47-2.57 dS.m⁻¹, 268-1513 meq.l⁻¹ for total hardness, 2.56-24.92 meq.l⁻¹ for calcium concentration, 1.6-45.44 m.eq.l⁻¹ for magnesium concentration, 0.3-3.8 meq.l⁻¹ for chlorocity, 0.01-25.3 meq.l⁻¹ for sulfate.

The WHO and Ministry of Health (1998) conducted a survey on physico-chemical and bacteriological drinking water source in Hawler governorate. The potential hydrogen values always were above 7.0, while concentrations of calcium, sodium, potassium and total dissolved solid ions ranged between 18-55 mg.l⁻¹, 3.0-33.5 mg.l⁻¹, 0.6-3.0 mg.l⁻¹ and 100-424 mg.l⁻¹ respectively.

Hassan (1998) investigated the urban hydrology of Hawler basin ground water aquifer. After taking samples from thirty-five wells, he analyzed for physical and chemical characteristics. Water temperatures ranged from 19-22.5°C, electrical conductivity ranged between 330-1685 µS.cm⁻¹, total hardness between 117.5-669.9 ppm, the concentration of calcium ion ranged from 24-127 ppm, while the concentration of magnesium ion ranged from 1-40 ppm. Moreover total dissolved solid ranged from 230-1179 ppm, chloride ion from 10-106.4 ppm, nitrate from 0-30 ppm, sodium from 6.5-58 ppm and potassium from 1-14 ppm.

The WHO had a huge role via investigating a survey on assessment quality of drinking water sources in Erbil, Sulaimani and Duhok cities in Kurdistan. They investigated that most of water sources were within WHO guidelines for chemical and bacteriological contamination. According to WHO guidelines the state percentage of contaminated samples must be under five percentage to define water as safe. They revealed that 11% of the sample (mostly water
wells) taken from urban area in Hawler was contaminated bacteriologically, 20% and 40% of water samples respectively taken from semi-urban and rural locations of Hawler governorate were also bacteriologically contaminated.

Shekha, (2001) carried out a study of assessment quality of ground water within Hawler province by selecting forty-four wells and studied only one trial. All well water samples were analyzed physically, chemically and bacterologically, the parameters of the studied sites were as follows: value of hydrogen ion potential ranged from 7.08-7.97, electrical conductivity values ranged from 214-540 µS.cm⁻¹, with a high level of total hardness, furthermore, the value of nitrate, reactive phosphous, dissolved oxygen and biological oxygen demanded for five days under incubation were 0.21-42.9 mg.l⁻¹, 0.16-0.97 mg.l⁻¹, 5.2-12.1 mg.l⁻¹, and 0.4-7.2 mg.l⁻¹ respectively.

In 2002 Al-Naqishbandi published limnological and phycological studies on some various water systems at Duhok province such as spring and impoundment and it is catchment area by selecting fourteen sampling sites. He studied some physico-chemical variables of water samples, concluding that air temperatures ranged from 4.5-46 C°, electrical conductivity of them ranged from 767-2560 µs.cm⁻¹, reactive phosphorous, dissolved oxygen, nitrite and nitrate were 0.172-5.363 µg at P-PO₄.l⁻¹, 0.112-1.442 µg at N-NO₂.l⁻¹, 0.29-147.64 µg at N-NO₃.l⁻¹, respectively.

Chnaray (2003), made a hydrological and hydro-chemical study on Kapran basin of Erbil city, involved nineteen well water samples, the results of physico-chemical water parameters as follow: the temperatures ranged from 18.8-23.5 C°, hydrogen ion potential from 6.85-7.86, however total hardness, calcium hardness, magnesium hardness, total dissolved solid, and chloride ranged from, 135.48-306.93 mg.l⁻¹, 34.7-80.4 mg.l⁻¹, 10.5-26.5 mg.l⁻¹, 271-481 ppm and 2.5-30.8 mg.l⁻¹ respectively. Reactive phosphorous ranged from 0.00-0.31 mg.l⁻¹, dissolved oxygen, biological oxygen demanded for five days, nitrate and sulfate ranged from 0.8-3.26 mg.l⁻¹, 0.00-1.21 mg.l⁻¹, 5.2-57.2 mg.l⁻¹ and 12.2-121.73 mg.l⁻¹ respectively.

However, Aziz and Ganjo (2003), conducted a study on water quality of spring and small ponds at Halgurd mountain area in Kurdistan at an altitude (2800-3728 masl). The results showed that water temperature never exceeded 4.7 C° and air temperature was around15 C°, dissolved oxygen ranged between4.1-5.4 mg.l⁻¹, total hardness, alkalinity, electrical conductivity ranged between 93-122 mgCaCO₃.l⁻¹, 117-136 mgCaCO₃.l⁻¹, and 156-198 µS.cm⁻¹, respectively. The potential hydrogen was slightly alkaline, nitrate, reactive
phosphors, and reactive silica were ranged from 12.7-21.2 µg at N-NO$_3$.l$^{-1}$, (0.12-0.65 µg at P-PO$_4$.l$^{-1}$, and 45.6-67.6 µg at Si-Sio$_2$.l$^{-1}$ respectively.

Moreover, Bilbas (2004) carried out limnological and phycological investigation of twenty springs within Erbil province. He showed that the range of ecological parameters were as follow: 6.4-8.6 for hydrogen ion potential, 10-22.5 Cº for water temperature, (100-2180 mg CaCO3.l$^{-1}$ for alkalinity, 0.27-330 mgCaCO$_3$.l$^{-1}$ for acidity, 70-1560 mg.l$^{-1}$ for total dissolved solids, 22.6-275.7 µg atN-NO$_3$.l$^{-1}$ for nitrate, 37-440 mg.l$^{-1}$ for sulfate, 3.99-126.7 mg.l$^{-1}$ for chloride, 0.00-12.0 mg.l$^{-1}$ for dissolved oxygen, 0.00-13.00 mg.l$^{-1}$ for biological oxygen demanded under incubation situation at 20 ºC for five days.

Bapper (2004), conducted a phycological and limnological study on various water resources within different sites of Erbil province. Water resources which were under the study belonged to fifty-seven locations which included streams, wells, karezes, springs, ponds and water impoundment. The physico-chemical variables were determined as follow: hydrogen ion potential values above 7.0, higher value of electrical conductivity were recorded, which reached to 1809 µS.cm$^{-1}$ in pond near Suse. Alkalinity of the all studied water samples are 164-777 mg.CaCO$_3$.l$^{-1}$, acidity value ranged from 7.273-7.542 mg.CaCO$_3$.l$^{-1}$, dissolved oxygen ranged from 1.30-10.95mg.l$^{-1}$, biological oxygen demand for five days ranged from 0.01-10.0 mg.l$^{-1}$, chloride from 0.76-90.39 mg.l$^{-1}$, reactive phosphorous, nitrate, nitrite ranged from, 0.05-6.59 µg at. P-PO$_4$.l$^{-1}$, 3.57-43.0 mg.l$^{-1}$ and 0.011- 45.5 µg at N-NO$_2$.l$^{-1}$, with highest degree of water temperature reached to 31 Cº.

Nabi (2005) conducted a limnological and bacteriological study on some well water within Erbil city. He analyzed fifteen well water samples for their physical, chemical and bacteriological properties, and the ranged of parameter as follow: hydrogen ion potential ranged from 6.8-7.6, electrical conductivity values were between 380-1130 µS.cm$^{-1}$. Whereas, dissolved oxygen concentrations were 1.0-6.0 mg.l$^{-1}$, biological oxygen demand ranged from 0.2-2.6 mg.l$^{-1}$. Total alkalinity ranged from 96-410 mg.CaCO$_3$.l$^{-1}$ and total dissolved salts were ranged from 225-665 mg.l$^{-1}$, and all water samples ranged from hard to very hard waters according to the total hardness values from 138-446 mg.CaCO$_3$.l$^{-1}$, while in all studied sites, cation were dominated by calcium followed by magnesium, then sodium and potassium in a descending order of concentrations. However anion concentrations were ranging from 24-544 mg.l$^{-1}$ recorded for sulfate, 50-660 mg.l$^{-1}$ for chloride, and from non detectable values of reactive phosphorus up to 1.14 µg at P-PO$_4$.l$^{-1}$. Furthermore, relatively high nitrate concentrations were found among all studied wells with concentrations ranging
from 14-147 mg.l\(^{-1}\) that were unacceptable at sites 1, 5 and 8. Bacteriologically, about nintey-seven point 15 of the studied well water samples were suitable for drinking purposes, according to USEPA and WHO (2004) guideline.

Al-Naqishbandi et al., (2006) investigated the quality of water in Makhmur area. Duplicate samples of some natural water were taken, from twenty-one sites in Makhmur area along Debaga, Bakerta Makhmur center, and surrounding area during July and September 2006 to investigate the water quality, with regard to pollution as far as biological oxygen demand for five days incubation concerned the water found to be resonable in quality as BOD\(_5\) never exceeded 1.4 mg.l\(^{-1}\) whereas, in relation to nitrite the indignation of pollution where quite evident, however the value exceeded 28.46 in studied sites, as a whole the water very hard and often the hardness exceeded 3400 mg.CaCO\(_3\), alkalinity was generally low whereas, hydrogen ion concentration ranged from 7.0-8.8, in conclusion the area need continuous monitoring and more detailed investigations.

**Limnological investigations in other parts of Iraq**

A great number of investigations on the ground water quality were performed by many investigators in various places in other parts of Iraq. Maulood et al., (1981), carried out a limnological and phycological studied on lowland Iraqi marshes. The physico-chemical variables were as follows; hydrogen ion potential ranged from 6.8-8.2, nitrate value ranged from 46-300 µg as N-NO\(_3\).l\(^{-1}\) and nitrite from 1.4-3.6 µg as. N-NO\(_2\).l\(^{-1}\). While alkalinity and reactive phosphorous values ranged from 5.4-29.6 meq.l\(^{-1}\) and 10-26 µg at P-PO\(_4\).l\(^{-1}\) respectively.

Depending on the salinity and total yield discharge and depth Iraqi’s ground water classified into six districts. The first of which, include Duhok, Hawler, Sulaimaniyah, Mosul and part of Diyala, total yield of each well in these locations has a diameter of 6-10 inch, ranging between 150-1000 gallon per minute, with depth of about 10-50m and the total dissolved salt content is near 2000 ppm, while in certain places of the Kirkuk desert exceeds than 2000 ppm. Because of their importance for water supply and irrigation purposes the latter has been examined periodically during the last 40 years, but never on a seasonal basin. The analysis have been confined to the major ions in solution Sodium, Calcium, Potassium, Magnesium, Chloride and Bicarbonate, whereas the concentration of micronutrients had been neglected (Al-Sahaf et al., 1983).

Khorshid (1988) determined the levels of some important elements in drinking water of Baghdad city. Twelve districts on both sides of the Tigris river were chosen. The physico-
chemical parameters were as follow: total hardness values ranged from 122-540 mg CaCO₃.l⁻¹, sodium values ranged from 35-95 mg.l⁻¹, potassium value ranged from 1.4 -2.2mg.l⁻¹, chloride values ranged from 35-165 mg.l⁻¹, while heavy metals (Cd, Fe, Pb, Zn) ranged from 0.002 -0.061mg.l⁻¹, 0.040 -0.320mg.l⁻¹, 0.007 -0.058mg.l⁻¹, and 0.01-0.130mg.l⁻¹, respectively. Al-Jalil (2000) studied the impact of industrial water percolation on the pollution groundwater and surface water in Qaim, Iraq. Eight water wells were analyzed for a period of one year on monthly intervals and he found that the values of TDS, Chloride, Sulfate, Calcium, Sodium were high, whereas EC. and Phosphates were out of permissible limit. He concluded that there was a relative pollution with nitrate, sulfate, and calcium.

**Conclusion**

A great number of liminological studies have been conducted on various water systems within the Kurdistan region. Generally, the physico-chemical parameters were as follow; pH ranged 6.5-8, TDS ranged from , EC ranged from 0.37-2050 , DO ranged from 0.0-12.8 mg.l⁻¹, Nitrate 16-230 N.NO₃ l⁻¹, Nitrite up to 1.4 N-NO₂.l⁻¹, chloride 0.02-0.06 meql⁻¹, hardness 3.64-286 mgCaCO₃.l⁻¹, reactive phosphate 0.28-12.7 P-PO₄.1⁻¹, respectively. Also, in the rest of Iraq, the physico-chemical variables were as follow; pH ranged from 6.8-8.2, TDS ranged from 122-540 mg.l⁻¹, Na, 35-95 mgl⁻¹, K ranged from 1.4-2.2 mgl⁻¹, chloride ranged from 35-165 mgl⁻¹, nitrate value 46-300 as N.NO₃ l⁻¹ and nitrite from 1.4-3.6 N-NO₂.l⁻¹, alkalinity and reactive phosphours value ranged 5.4-29.6 meq.l⁻¹ and 10-26 P-PO₄.1⁻¹, respectively. Also heavy metals such as Cd, Fe, pb, and Zn were ranged 0.007-0.058, 0.01-0.130, 0.002-0.061, and 0.040-0.320 mg.l⁻¹, respectively.

All in all, according to Water Quality Index (WQI), most of the water sources requires primary treatment before use for drinking, whereas waters of Tanjaro river and Qiliasan stream cannot be used for drinking till they are treated (primary to tertiary treatments).

**References**


and Workshop, Kwantlen College, Surrey, BC, Canada.


