

## Quality of Surface Waters in the Al Jabal Al Akhdar Region of Oman

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### Abstract

Al Jabal Al Akhdar (Green Mountain) is the largest structural domain in the western Hajar mountain range of northern Oman, with elevations ranging from 1000 to 3000 masl. It has long been recognized as an important terrestrial ecoregion. Rapid urban and agricultural development in the Jabal Akhdar region of northern Oman is exerting pressure on its water resources. A survey was conducted on the quality of surface waters in the region. Samples were collected from all types of surface waters including man-made reservoirs, *aflaj* systems, and *wedian*. Samples were analyzed for temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD<sub>5</sub>), fluoride, chloride, sulphate, nitrate, sodium, calcium, magnesium, potassium, and trace elements (Ni, Cu, Zn, Cd, Mn, Cr, Co, Fe, V, Ba), coliforms and *Escherichia coli*. Based on the completed survey of about 40 surface water samples, it can be said conclusively that surface water in the area is not fit for human consumption. All samples clearly failed to satisfy Oman drinking water standards.

This study establishes that the most crucial issue is the anthropogenic fecal contamination of surface waters. The eutrophication of all reservoirs is linked to the fecal input from goats and donkeys. Although other types of contamination are rare, there is one distinct case of a *falaj* contaminated with diesel. Heavy metal concentrations in some sites are not at acceptable levels.

The development of the Jabal Akhdar region if not sustainable will inevitably lead to a water crisis involving supply-demand scenarios, water costs and water quality degradation. Management strategies are sorely needed to address these issues.

### 1.0 Introduction

Al Jabal Al Akhdar lies at the heart of Al.Hajar, the mountains of northern Oman. It rises from about 1000 to 3000 m above sea level. The highest peak (3003 m) in the Western Hajar Mountains is at Jabal Shams. Jabal Al Akhdar has long been recognized as an important terrestrial ecoregion [1]. It also has valuable biodiversity unique to Oman. Jabal Akhdar is currently under intense pressure due to development that is rapidly changing land use and economies; its conservation is an utmost priority. Victor used case study approach produced a conceptual framework for biodiversity conservation and sustainable development in Jabal Akhdar [2]. Based on this, a strategic research project, Al Jabal al Akhdar Initiative,

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investigating these issues was launched at Sultan Qaboos University in 2004. This project, expected to conclude in 2007 considers water quality assessments as one of its significant components.

Jabal Akhdar has freshwater that could support small communities. It receives about 3 to 4 times more rainfall than desert plains. The mean annual rainfall is about 300-400 mm. Rain water is drained by *wedian* (i.e. seasonal rivers; *wadi* singular). In olden days, small traditional dams intercepted floodwaters and water was stored in small reservoirs for human use. The erstwhile Ministry of Water Resources (presently Ministry of Regional Municipalities, Environment and Water Resources) planned to construct 64 dams in the Jabal Akhdar area and by 1994 completed building 24 retention dams. These new reservoirs are considerably large and store more water [3]. All these reservoirs are presently eutrophic and the water is not fit for drinking. The water is however used as drinking water for livestock, to irrigate kitchen-gardens and for other domestic uses. Ministry of Housing, Electricity and Water supplies villages with free of cost drinking water extracted from groundwater in Saiq, and in the foothills through motor tankers. Drinking water needs in excess of government-provided water are met by private water suppliers.

Water is the lifeline of the Jabal Akhdar environment. Rapid development in the Jabal Akhdar region is exerting pressure on water resources. Water quality issues are closely related to water use efficiency in the region. Water in the reservoirs is under-utilized because of quality constraints and its efficient exploitation requires improvement in water quality. Poor water quality is caused by eutrophication, primarily due to the enrichment of water by animal feces. Overexploitation of groundwater exceeding the water recharge potential of the area will have serious environmental consequences. Water quality assessments are essential in environmental monitoring and as such form an integral part of overall sustainable management of water resources in the region. Strategies for the assessment process and a suitable monitoring program for the area are being planned and its implementation will be recommended as part of the ongoing research at SQU.

## **2.0 Materials and Methods:**

The work comprises of two parts. The first part of the work is a survey and this includes all types of accessible water resources ( $n \approx 50$ ) in the study area for water quality using physical, chemical and biological variables. As of December 2005, 40 samples have been collected and analyzed for various water quality parameters. More specifically, the samples were analyzed for temperature, pH, dissolved Oxygen (DO), biochemical oxygen demand ( $BOD_5$ ), coliform bacteria and *Escherichia coli*, fluoride, chloride, sulphate, nitrate, sodium, calcium, magnesium, potassium, and trace elements (Ni, Cu, Zn, Cd, Mn, Cr, Co, Fe, V, Ba). In sampling and analysis, standard methods were followed [4]. Samples were analyzed in a quality assured laboratory.

The second part involves the selection of two aquatic systems affected by environmental impacts relating to health, eutrophication and pollution. These systems are being investigated as case studies. The assessment process will use selected water quality variables including particulate material and biota. Based on the results, suitable protocols for assessment process and a master plan for water quality monitoring in the area will be produced. The survey will provide baseline data that will show the state of each aquatic

system surveyed and indicate the pressures on the system. In some systems, the pressure may be obvious and its state will be an indicator to diagnose the health of other systems. The pressure-state information will be used to promulgate appropriate response (e.g. mitigation as remediation and restoration).

### 3.0 Results and Discussion

Based on the completed survey of about 40 surface water samples (reservoirs, *aflaj*, *weidan*) and a previous study done in 1996 [3], it can be said conclusively that surface water in Jabal Akhdar is not fit for drinking by humans. All samples clearly failed to satisfy Omani drinking water standards. The microbiological standards which are the most critical and decisive with regards to drinking water quality were not met. Some of the important quality parameters are described below (Table 1).

Table 1 Maximum, minimum and median values of water quality variables (2004-2005).

Parameter	Maximum	Minimum	Median
Air Temperature °C	42	10	21
Water Temperature °C	39	9	20
pH	9.66	7.2	7.8
EC (µS/cm)	1302	123	590
DO (mg l <sup>-1</sup> )	16.2	1	8.4
BOD <sub>5</sub> (mg l <sup>-1</sup> )	12	0.2	4.6
MPN of Coliforms	>200	0	>200
MPN of <i>E. coli</i>	>200	0	2
Fluoride (mg l <sup>-1</sup> )	1.49	0	0.14
Chloride (mg l <sup>-1</sup> )	109.1	3.6	24.6
Sulphate (SO <sub>4</sub> ) (mg l <sup>-1</sup> )	275.2	0.36	23
Nitrate (NO <sub>3</sub> ) (mg l <sup>-1</sup> )	25.2	0.04	4.4
Na (mg l <sup>-1</sup> )	123.4	1.25	10.35
Ca (mg l <sup>-1</sup> )	107	20.1	57.6
Mg (mg l <sup>-1</sup> )	75.1	1.68	25.5
K (mg l <sup>-1</sup> )	8.87	0.17	1.80
Ni (mg l <sup>-1</sup> )	17.6	0.005	1.945
Cu (mg l <sup>-1</sup> )	14.7	0.003	0.07
Zn (mg l <sup>-1</sup> )	12.2	0.001	0.006
Cd (mg l <sup>-1</sup> )	1.93	0.001	0.0025
Mn (mg l <sup>-1</sup> )	599	0.006	0.0246
Cr (mg l <sup>-1</sup> )	Not detected	Not detected	-
Co (mg l <sup>-1</sup> )	Not detected	Not detected	-
Fe (mg l <sup>-1</sup> )	0.877	0.013	0.156
V (mg l <sup>-1</sup> )	Not detected	Not detected	-
Ba (mg l <sup>-1</sup> )	1.08	0.007	0.0575
Pb (mg l <sup>-1</sup> )	19.5	0.025	1.85
Be (mg l <sup>-1</sup> )	Not detected	Not detected	-

pH: The pH ranged from 7.2-9.66. According to the Omani standards the range of pH is 6.5 to 8.5. The pH is an important water quality parameter that influences many biological and chemical processes within a water body. Eutrophic water bodies show pronounced variations of pH within a 24 h period.

DO: The dissolved oxygen ranged from 1.0 to 16.2 mg l<sup>-1</sup>. Concentrations in unpolluted surface waters are usually close to but less than 10 mg l<sup>-1</sup>. Concentrations below 5 mg l<sup>-1</sup> may adversely affect the functioning and survival of biological communities [5]. Of the forty samples, ten had dissolved oxygen above 10 mg l<sup>-1</sup>. For eutrophic waters DO values change on hourly basis and are also closely related to pH values.

BOD<sub>5</sub>: The BOD<sub>5</sub> values ranged from 0.2 to 10.4 mg l<sup>-1</sup>. Unpolluted waters typically have BOD<sub>5</sub> values of 2 mg l<sup>-1</sup> or less, whereas those receiving wastewater may have values up to 10 mg l<sup>-1</sup> or more [5]. Most of the samples had BOD<sub>5</sub> values greater than 2.0 mg l<sup>-1</sup> indicating presence of organic pollutants.

Electrical Conductivity: The conductivity ranged from 123 to 1302 uS/cm. Such values are within the limits for use in agriculture and domestic purposes.

Fluoride: Values ranged from non-detectable quantities to 1.49 mg l<sup>-1</sup>. Measurement of fluoride content is especially important when a water body supplies drinking water. The WHO guideline value is 1.5 mg l<sup>-1</sup>. At high concentrations fluoride is toxic to humans and animals and can cause tooth-decay and bone diseases.

Sulphate: The sulphate content ranged from 1.9 to 275.2 mg l<sup>-1</sup>. The Oman and WHO standards for sulphate permit 250 mg l<sup>-1</sup> in drinking waters. Sulphate concentrations in natural waters are usually between 2 and 80 mg l<sup>-1</sup>. The principal sources of sulphate are fertilizers, leachates from agricultural fields and precipitation.

Nitrates: The nitrate (NO<sub>3</sub>) values ranged from non-detectable levels to 25.2 mg l<sup>-1</sup>. The highest permissible limit for nitrate (NO<sub>3</sub>) in all drinking water standards is 45 mg l<sup>-1</sup>. In lakes, levels of nitrate in excess of 0.9 mg l<sup>-1</sup> (as NO<sub>3</sub>) tend to stimulate algal growth and indicate possible eutrophic conditions [5]. Visual inspections suggest that all the reservoirs in the study area are eutrophic.

Heavy metals: In majority of the samples heavy metals were below the detection level of the ICP (Inductively Coupled Plasma) instrument. But of the 12 metals investigated, eight (8) were found in some samples over the detection limit. These are: Ni, Cu, Zn, Cd, Mn, Fe, Ba and Pb. Four (4) metals (Cr, Co, V and Be) were not detected. High concentrations of heavy metals in natural, drinking, and wastewater can adversely affect humans and the general environment [6]. The primary health concern posed by metals is either by indirect poisoning, particularly through the formation of organic metal complexes in food stuff, or as long-term chronic effects.

Microbiological quality: Two parameters used were: total coliforms and *E. coli*. All samples except one showed presence of coliforms and 28 out of 39 samples showed presence of *E. coli* which is generally accepted as an indicator for the potential presence of pathogenic organisms. Under these circumstances it would not be possible to use such waters as potable

water. Sources of coliforms are from fecal matter and the presence of *E. coli* at all times is indicative of recurrent contamination, almost on daily basis.

#### 4.0 Conclusions

The study will provide baseline data that will show the state of each aquatic system surveyed and indicate the pressures on the system. The survey will form the basis for monitoring strategies using water quality assessments. These assessments are based on multidisciplinary synthesis of data that will be unique to the region. The master plan resulting from this study will be gift to the country from Sultan Qaboos University. The need for ecological restoration of reservoirs and *aflaj* and their benefits to mountain communities will be demonstrated. This study will serve as a model for the water quality management of other arid mountain ecosystems in the region.

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