TREND ASSESSMENT OF GROUNDWATER QUALITY IN ABU DHABI EMIRATE

AL AIN SUMMARY REPORT

JULY 2020

هـيـئـة الـبـيـئـة - أبـوظـبـي
Environment Agency - ABU DHABI

Content

Abbreviations:

^{226}Ra	Radium-226
^{228}Ra	Radium-228
^{222}Rn	Radon-222
µS/cm	micro Siemens per centimeter
Alk	Alkalinity
b.d.l.	below detection limit
BOD	Biological Oxygen Demand
Bq	Becquerel
CBE	Charge Balance Error
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
Dom.	Domestic
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
GLV	Guideline value
Hex.	Hexavalent
Irr.	Irrigation
QA	Quality Assurance
QC	Quality Control
SAR	Sodium Adsorption Ratio
S_y	Specific yield
TDS	Total Dissolved Solids
Tot.	Total
WHO	World Health Organization
WQI	Water Quality Index
WTF	Water Table Fluctuation (method)

1 INTRODUCTION

Following optimisation of the groundwater monitoring programme in 2016 and the subsequent Groundwater Quality Baseline Survey project in 2018, Environment Agency - Abu Dhabi (EAD) analysed the trend of all groundwater constituents (Natural & Anthropogenic) within the frame of our latest initiative Trend Assessment of Groundwater Quality in Abu Dhabi Emirate.

The goal is to sample, analyse and assess groundwater quality in the Abu Dhabi Emirate, focussing on Al Ain and the Al Dhafra region.

In the following, key findings and results for the Al Ain region are described.

As mentioned above, EAD is operating a Groundwater Quality Monitoring (GWQM) Programme since 2016 to assess the changes in groundwater quantities and qualities.

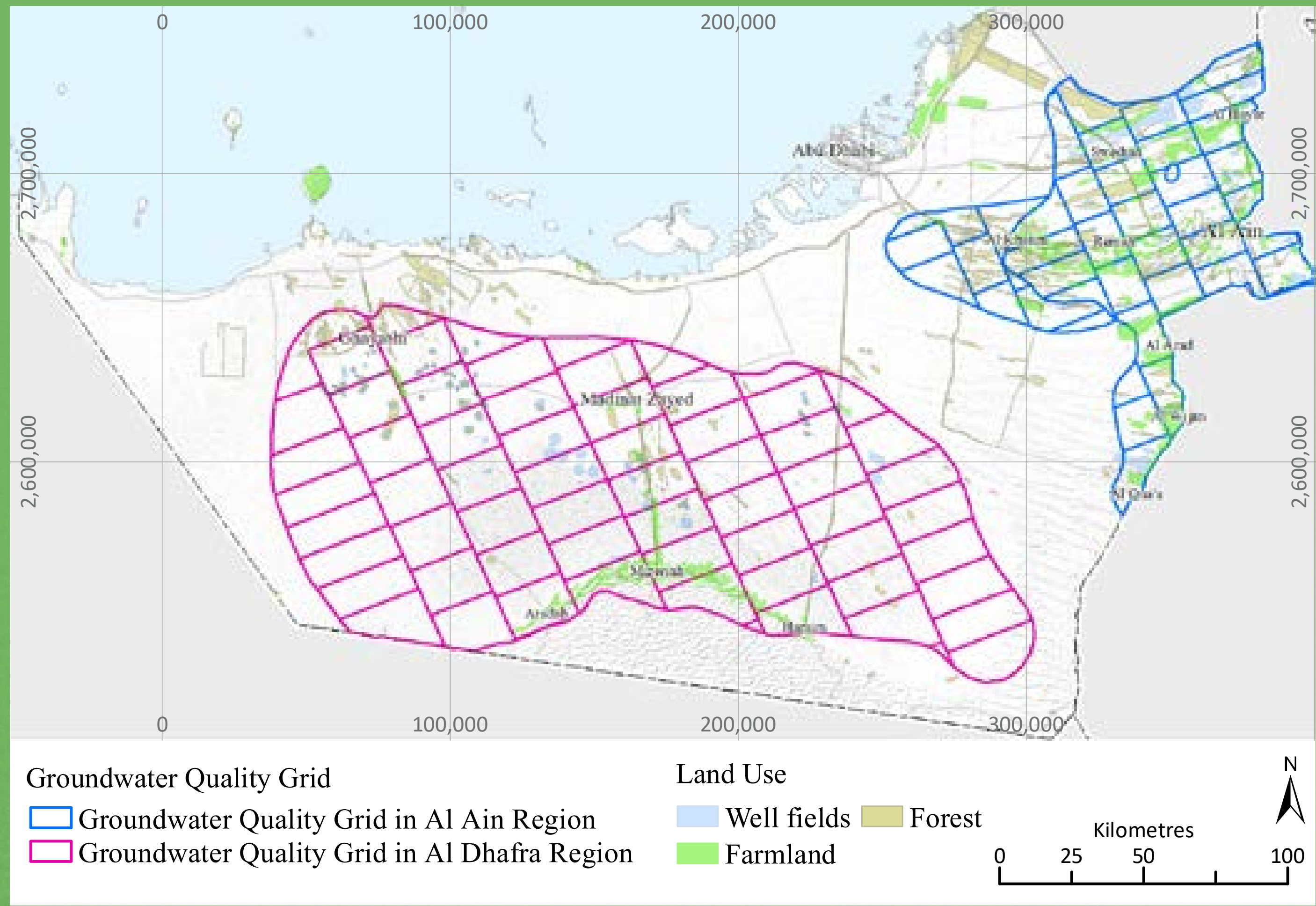
Due to increasing pressure on groundwater resources, the groundwater quality trend in the Emirate of Abu Dhabi shall be assessed, particularly, within areas with directly useable groundwater zones.

To conduct trend analysis of all groundwater constituents (Natural & Anthropogenic) and provide relevant interpretation, the groundwater quality monitoring programme comprises:

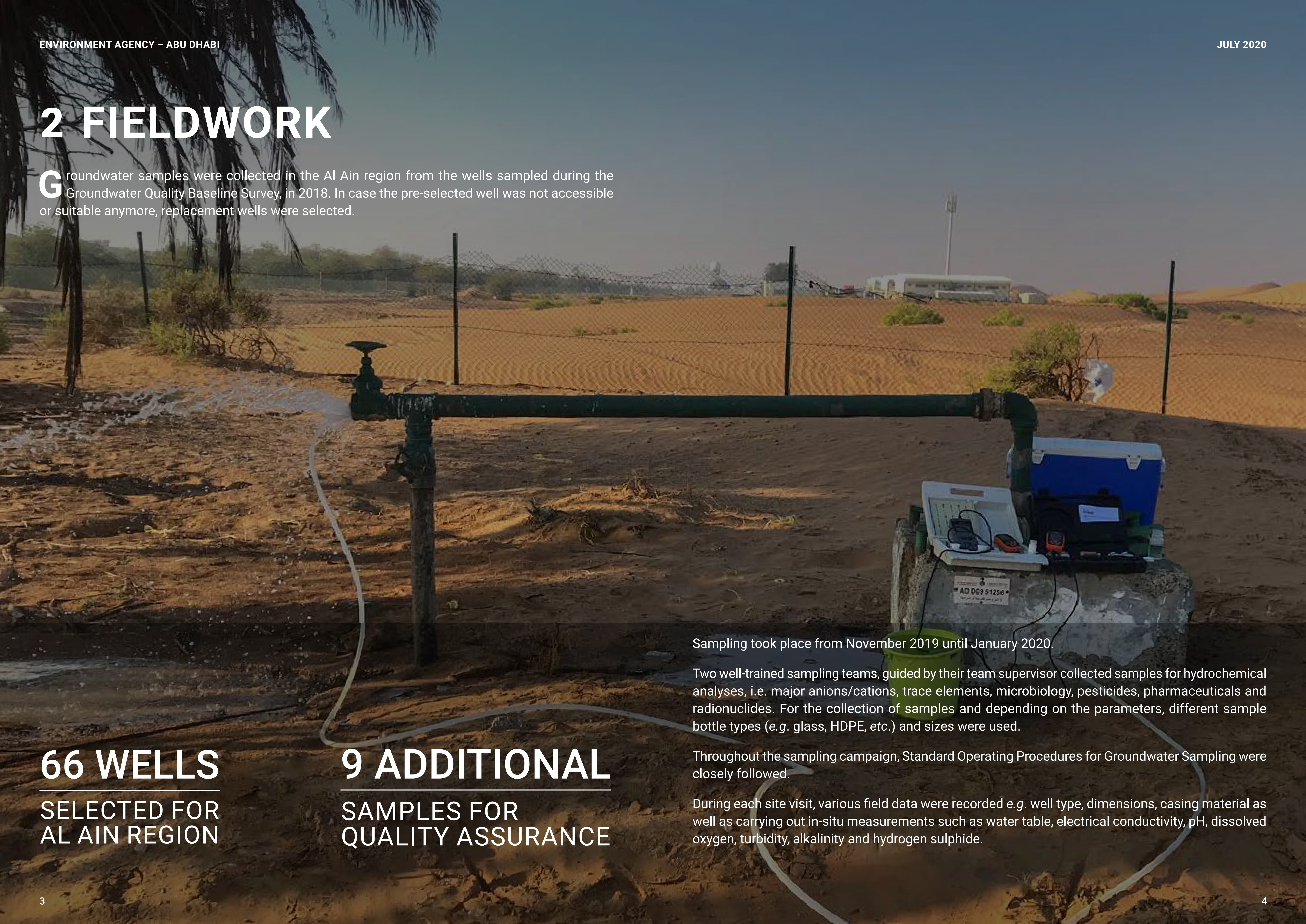
1 ASSESSMENT OF THE GROUNDWATER QUALITY

2 GROUNDWATER QUALITY MONITORING

3 ENHANCEMENT OF SALINITY MONITORING



The area of this campaign lies within the Groundwater Quality Grid of Abu Dhabi Emirate, which is designed to monitor groundwater quality of the surficial aquifer across the emirate and of the water bearing formations underlying the surficial aquifer.



2 FIELDWORK

Groundwater samples were collected in the Al Ain region from the wells sampled during the Groundwater Quality Baseline Survey, in 2018. In case the pre-selected well was not accessible or suitable anymore, replacement wells were selected.

66 WELLS

SELECTED FOR AL AIN REGION

9 ADDITIONAL

SAMPLES FOR QUALITY ASSURANCE

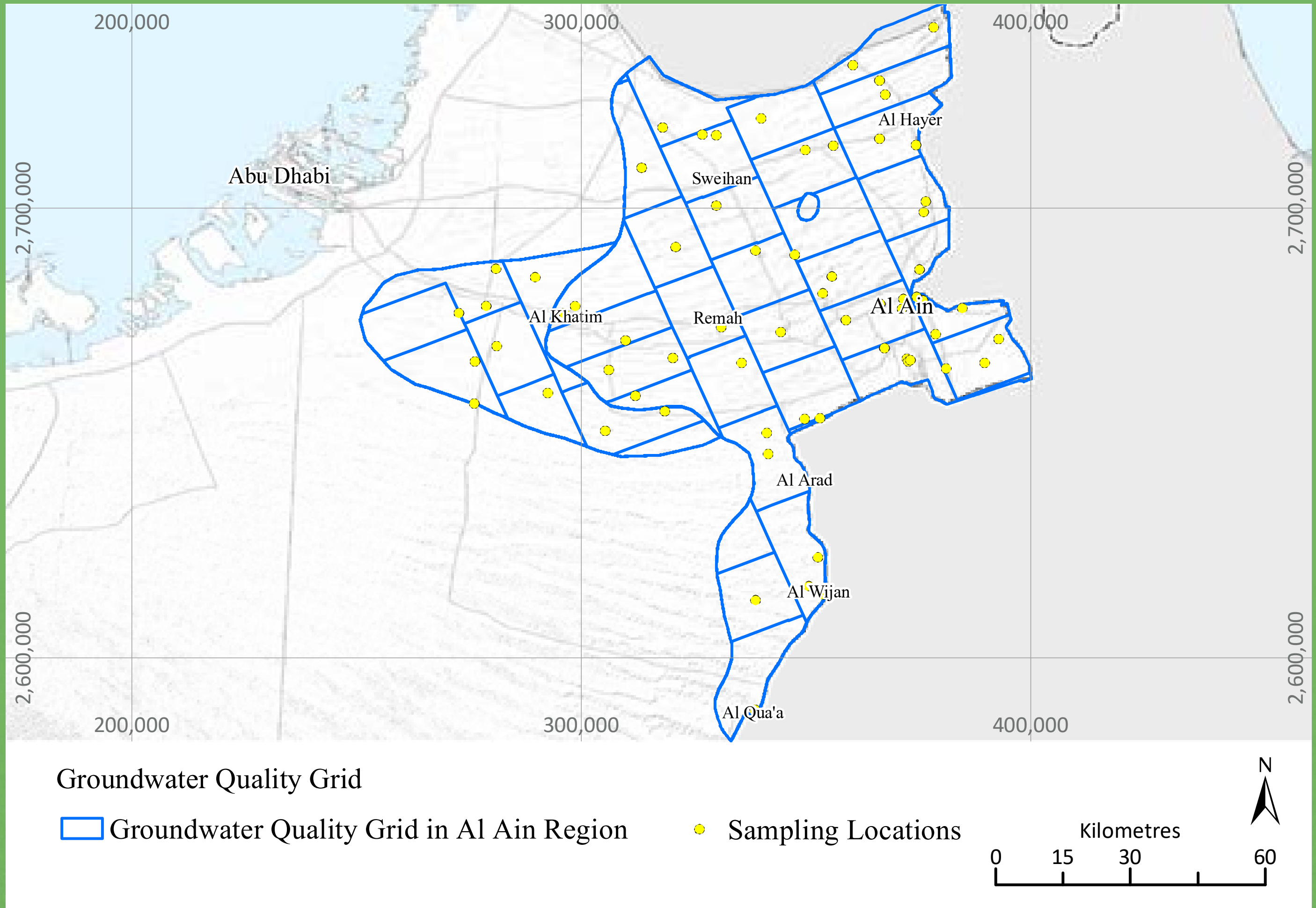
Sampling took place from November 2019 until January 2020.

Two well-trained sampling teams, guided by their team supervisor collected samples for hydrochemical analyses, i.e. major anions/cations, trace elements, microbiology, pesticides, pharmaceuticals and radionuclides. For the collection of samples and depending on the parameters, different sample bottle types (*e.g.* glass, HDPE, *etc.*) and sizes were used.

Throughout the sampling campaign, Standard Operating Procedures for Groundwater Sampling were closely followed.

During each site visit, various field data were recorded *e.g.* well type, dimensions, casing material as well as carrying out in-situ measurements such as water table, electrical conductivity, pH, dissolved oxygen, turbidity, alkalinity and hydrogen sulphide.

The required sampling approach for each well depended on the well status, *i.e.* whether the well was Operational (Type A) or Idle (Type B). Operational wells are preferred. Nevertheless, in case Idle wells were encountered, the field teams had to install a mobile pump.



After the *in-situ* measurements were taken, groundwater sampling took place.

Once the sampling was completed at one site, the sampling equipment was decontaminated to prevent cross contamination between sampling locations and events, and to protect the health and safety of the sampling staff that may be exposed to contaminated equipment.

A chain-of-custody form was implemented for each sampling bottle and clearly marked, showing sample ID, date and time, number of bottles per samples, parameter to be analysed, on-site results, if performed and the name of technician taking the sample.

IN-SITU MEASURMENTS

45 OPERATIONAL WELLS

21 IDLE WELLS

After the sampling was completed and the samples appropriately packed (*i.e.* placed in a cooler box filled with ice packs, *etc.*), the samples were handed over to Laboratory at an agreed meeting point.

A laboratory, accredited according to DIN EN ISO / IEC 17025, certified through the Emirates National Accreditation System (ENAS) and listed with the Abu Dhabi Quality and Conformity Council (ADQCC) was selected.

Laboratory analysis were conducted from November 2019 until March 2020.

Pharmaceutical products, NDMA and wastewater indicators were analysed from the same 30 wells, as for the Groundwater Quality Baseline Survey.

Duplicates (4 samples) and Field blanks (2 samples) for bacteria were taken for quality assurance.

For the radionuclides, all samples were included in analysis of ^{226}Ra and ^{228}Ra.

OVERVIEW OF SAMPLING PARAMETERS ANALYSED BY THE LABORATORY.

ITEM	GENERAL CONSTITUENT CATEGORY	SAMPLED CONSTITUENT(S)	QUANTITY
8		Ferrous iron	75
9	Basic Ions	Major cations	75
10		Major and minor anions	75
11		Nutrients (N and P compounds)	75
12	Trace Metals	Trace elements/metals including Chromium (total and VI)	75
13a	Bacteria	Total coliform, Escherichia (*E. colii*)	75
13b		Replicate sample Total coliform, Escherichia (*E. coli*)	4
13c		Field blank Total coliform, Escherichia (*E. coli*)	2
14	DOC/TOC	Dissolved/total organic carbon	75
15	Pesticides	Pesticides	75
17	Wastewater Reuse	Wastewater indicators	30
18		Pharmaceutical products	
19		N-nitrosodimethyl amine (NDMA)	
20	Radionuclides	Radium isotopes (^{226}Ra & ^{229}Ra)	75

FIELD BLANKS & REPLICATE SAMPLES FOR QUALITY ASSURANCE

MAJOR CATIONS

Ca^{2+} Mg^{2+} Na^{+} K^{+}

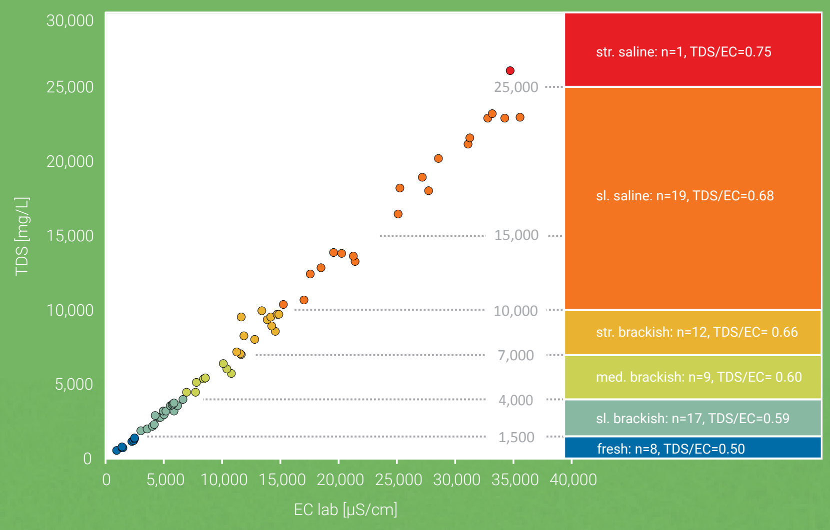
MAJOR ANIONS

Cl^{-} SO_4^{2-} HCO_3^{-}

3 INTERPRETATION OF GROUNDWATER ANALYSES

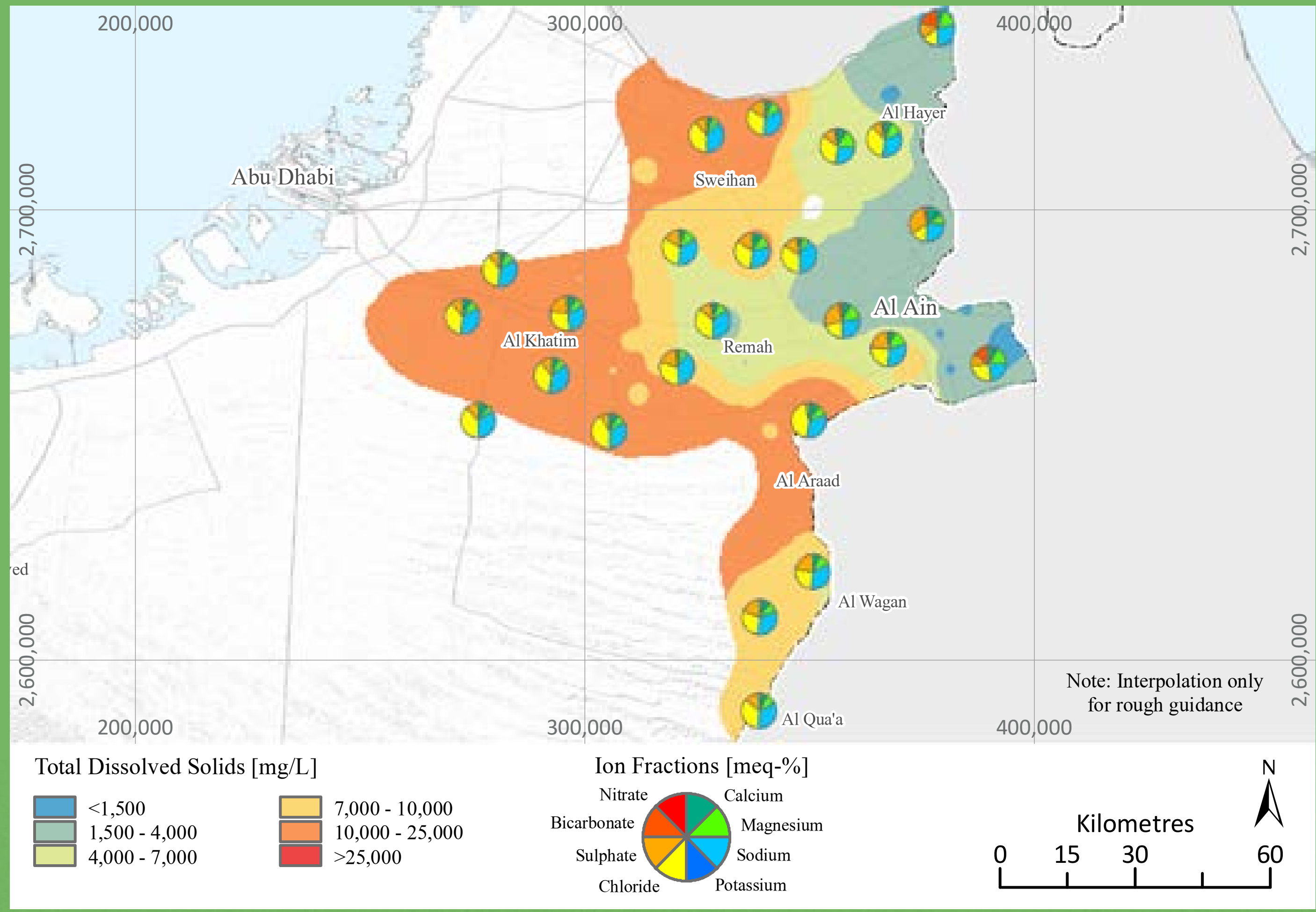
3.1 BASIC PARAMETERS

The internal QA/QC measures implemented by lab were complemented by own plausibility checks comprising blank and duplicate analyses (where validated), the calculation of charge balance errors (all errors within ± 5 %), and the correlation between parameters that were measured in the field and in the laboratory (where validated). Moreover, related parameters were compared. An example for the latter is given in the following figure.



Apart from the excellent correlation, the chart illustrates the wide range of encountered salinities, covering the following classes of the UAE salinity scheme: fresh (8 samples), slightly brackish (17 samples), medium brackish (9 samples), strongly brackish (12 samples), slightly saline (19 samples), and strongly saline (1 sample). However, overall salinities are rather high – 62 out of 66 values exceed the EAD (2017) guideline value of 1,000 mg/L for domestic purposes.

The fresh waters prevail in the very East of the study area, along the border with Oman. Towards the West, *i.e.* down-gradient, the groundwater becomes more saline. This pattern has also been observed in the Groundwater Quality Baseline Survey and is related to groundwater recharge by fresh waters in and around the mountains. The area is known to receive more rainfall and the high infiltration capacities of the commonly gravel-dominated plains bordering the mountains favour such replenishment.



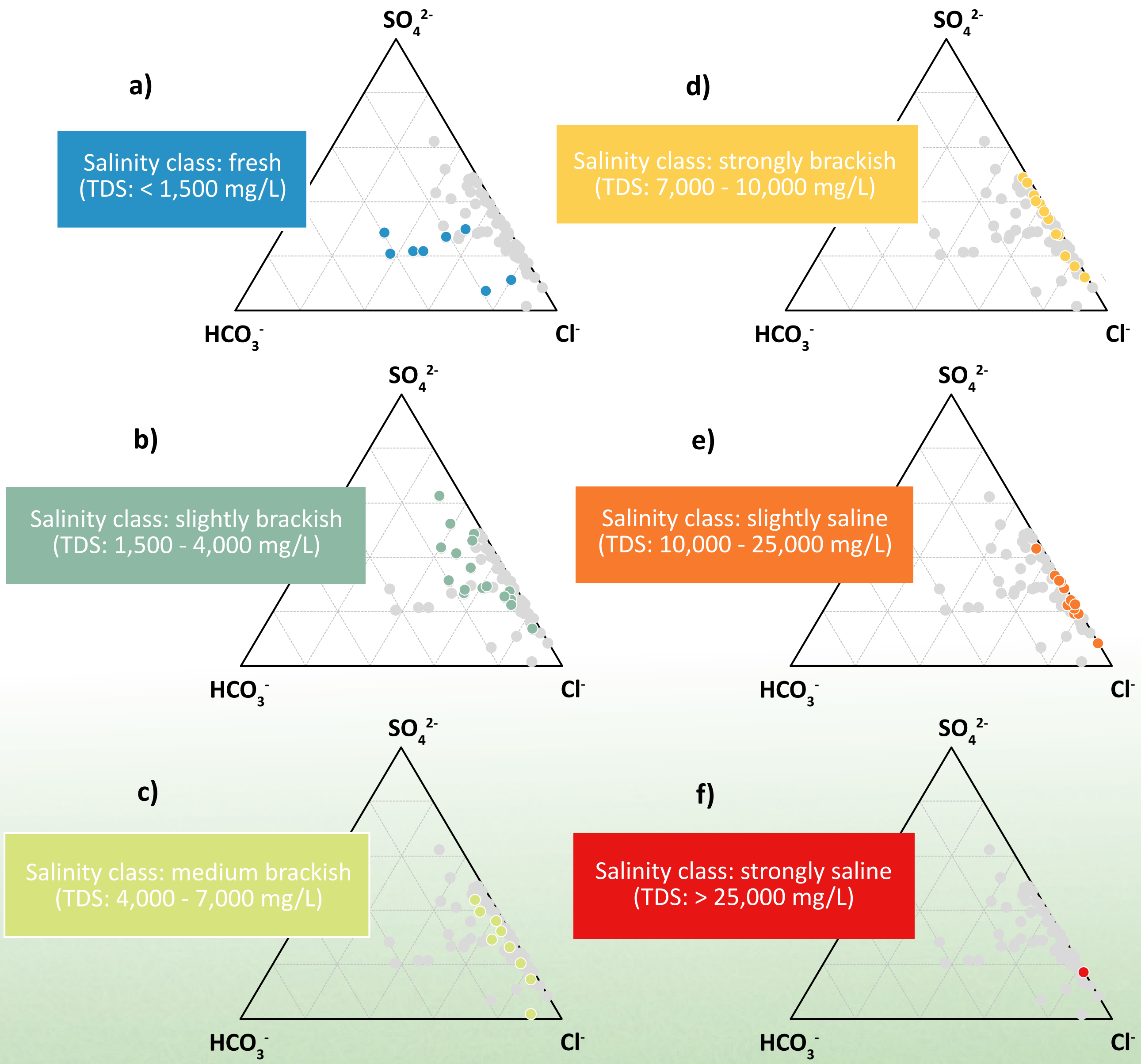
The calculation of relative changes since the last campaign yielded both increases and decreases. Since the latter cluster in the East and 2019 has been a particularly wet year (with sustained rainfalls and flooded streets), these TDS decreases seem to be linked to recent recharge.

Among the ions contributing to the total salinity, Sodium and Chloride are overall the most dominant, but also Magnesium and Sulphate often show significant contributions. Accordingly, Na-Cl-SO_4 is the most common water type (25 samples), followed by Na-Mg-Cl-SO_4 (15 samples), Na-Cl (7 samples), and Na-Ca-Cl (4 samples). The remaining water types play a subordinate role.

Which water type prevails in a given area also depends on the salinity of the water. This is illustrated in above figure in which several anion ternary plots are combined. Fresh waters show a somewhat balanced anion pattern, with significant bicarbonate shares. With increasing salinity, however, bicarbonate becomes less important and accordingly sulphate and especially chloride play a greater role.

ONLY 1 WELL

WITH TDS > **25,000** PPM



Correlation analyses revealed that several basic parameters are inter-related, in terms of their concentrations, but partly also in terms of concentration changes.

The correlation matrix reveals strong positive correlations among the major ions Calcium, Magnesium, Sodium, Potassium, Chloride, Sulphate, and the TDS – a common phenomenon. If the total salinity is high, most major ions will be enriched as well.

Although Bicarbonate is considered a major ion as well, it does not follow this trend. In fact, the data even indicates a negative correlation. This is largely due to the relatively low solubilities of carbonate minerals, which imply that Bicarbonate concentrations cannot rise proportionately during salinization.

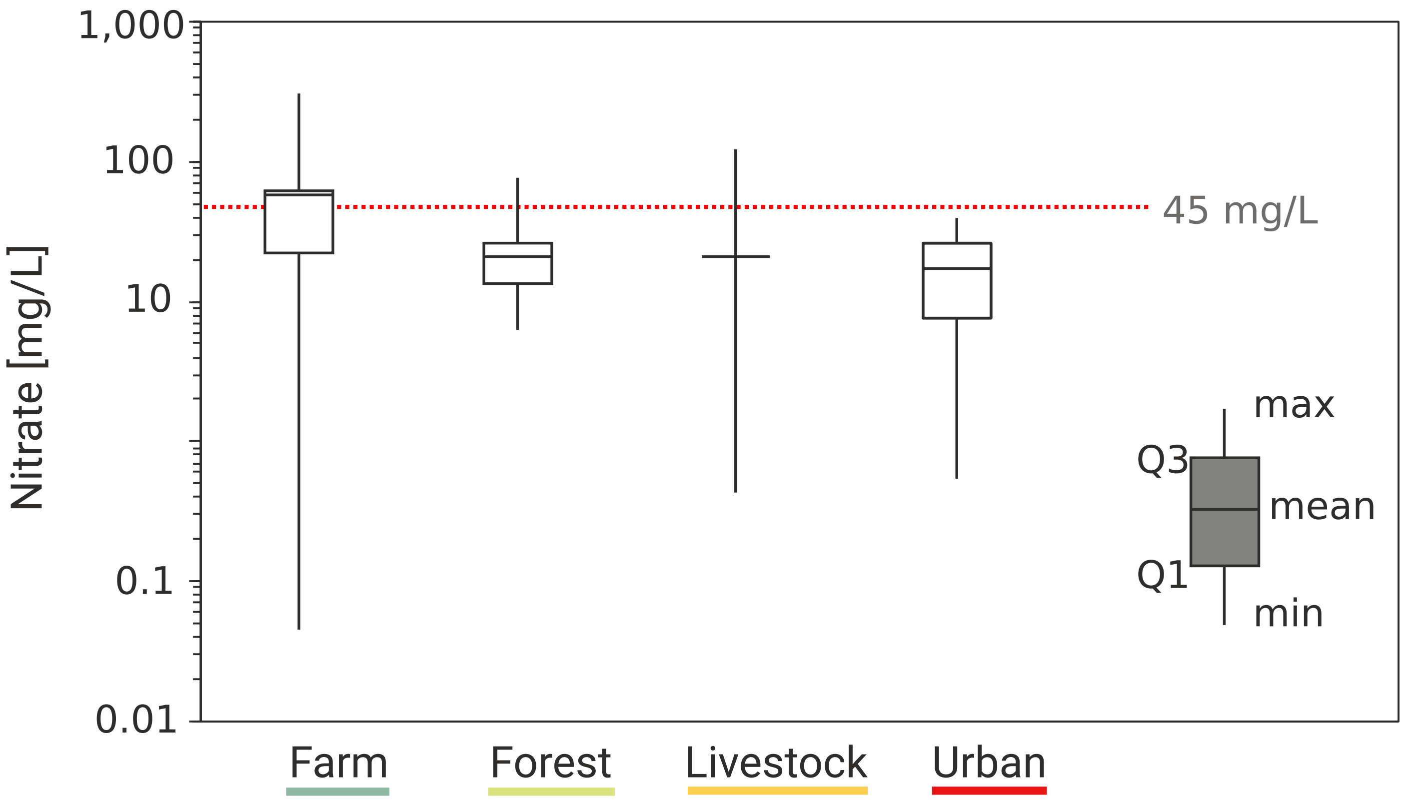
	TDS	Ca^{2+}	Mg^{2+}	Na^+	K	Cl^-	So_4^{2-}	HCO_3^-	Br^-	No_3^-
TDS										
Ca^{2+}	0.90									
Mg^{2+}	0.92	0.82								
^+Na	0.98	0.84	0.90							
K	0.94	0.84	0.85	0.94						
Cl^-	0.99	0.89	0.91	0.98	0.93					
So_4^{2-}	0.84	0.73	0.82	0.82	0.77	0.75				
HCO_3^-	-0.31	-0.30	-0.26	-0.28	-0.25	-0.29	-0.31			
Br^-	0.31	0.50	0.30	0.27	0.28	0.40	-0.07	-0.09		
No_3^-	-0.02	-0.05	0.12	-0.03	-0.04	-0.03	0.03	0.01	-0.03	

Color Legend

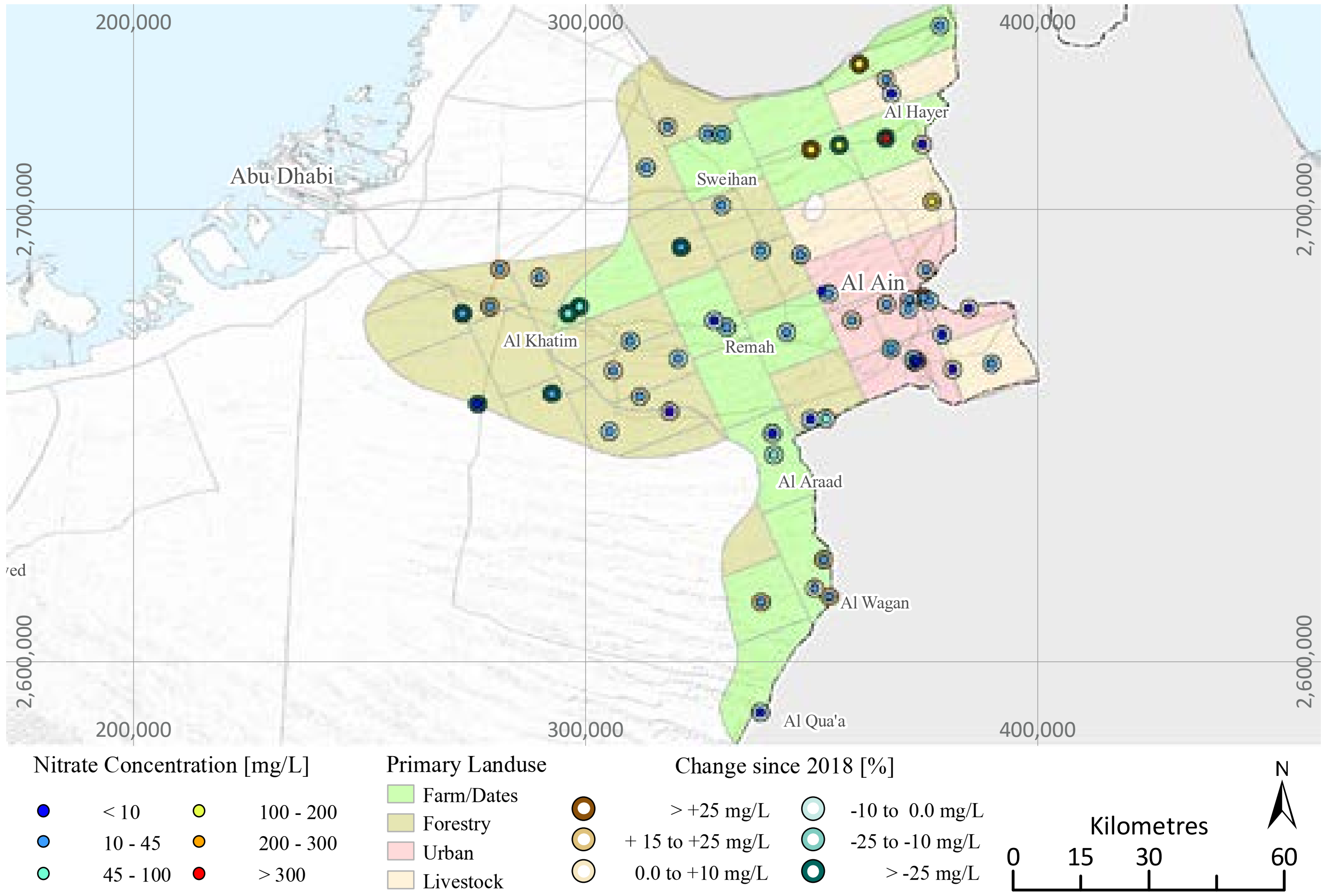
The light colours in the Nitrate line, reflecting low correlation coefficients, indicate that this anion is decoupled from the other constituents. Its abundance is not a function of salinity. Instead, it is contamination-controlled.

3.2 NITRATE

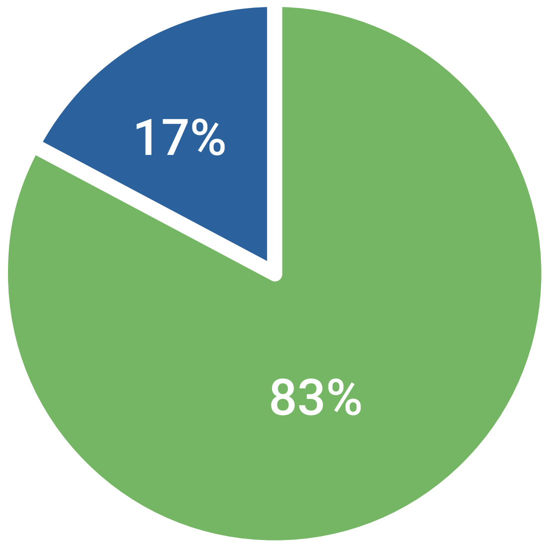
The variation of Nitrate concentrations ranges between levels below the detection limit and 310 mg/L. Its mean value amounts to 34 mg/L. Considering the EAD (2017) guideline value for domestic use of 45 mg/L, guideline violations are encountered in a total of 11 water samples.



Above figure reveals an appreciable scatter within each land use class, but the wells in farm-dominated cells exhibit higher values on average. Here, also the greatest number of EAD (2017) guideline value violations is encountered and even the mean value exceeds the threshold of 45 mg/L (for domestic, non-potable use). Hence, it seems that fertilizers used in agricultural settings play an important role in the Nitrate context.



NITRATE GUIDELINE VIOLATIONS



55 Below Guideline Value for Domestic Non-Potable Use

11 Exceeding Guideline Values for Dom. Non-Pot. Use > 45 mg/L

3.3 TRACE ELEMENTS

Most trace elements show a rather large scatter, which is in line with the distinct salinity variations and the presence of a range of water types. Only individual values show elevated concentrations.

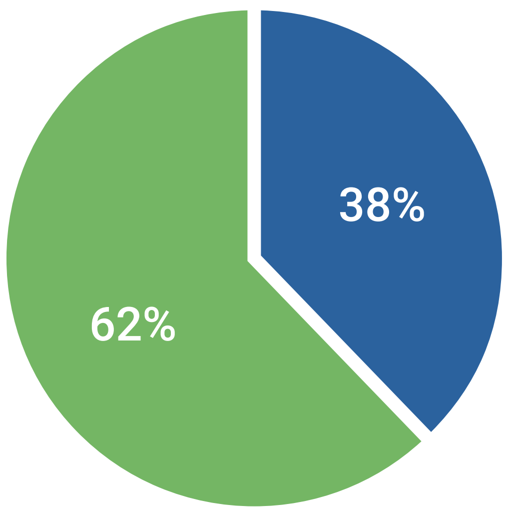
Concentrations of Arsenic for instance fall mostly below 10 µg/L, except for one, accounting for 48 µg/L, subsequently violating the guideline values for domestic and livestock use (18 µg/L and 25 µg/L, respectively). It has to be stressed that the concerned well showed similar concentration in the previous project and due to its relatively high TDS of 13,580 mg/L the use of this well is restricted anyway.

In case of Boron and Chromium however, the cases are more severe. Boron concentrations average around 2,620 µg/L, whereas the mean Chromium concentration amounts to 137 µg/L.

Elevated Boron concentrations are harnessed as wastewater indicators and are sometimes present in fertilisers. Additionally, Boron can be associated with desalination units. The number of Guideline violations is strongly dependent on which guideline value is considered. Thresholds for the different uses differ strongly. They range between 500 µg/L (irrigation) and 5,000 µg/L (livestock watering).

As for Chromium, the concentrations range from 1 to 2,011 µg/L. A total of 41 samples exceed the guidelines values of 50 µg/L for domestic, non-potable use. Lower values are in general clustered around the City of Al Ain with increasing concentrations towards the west.

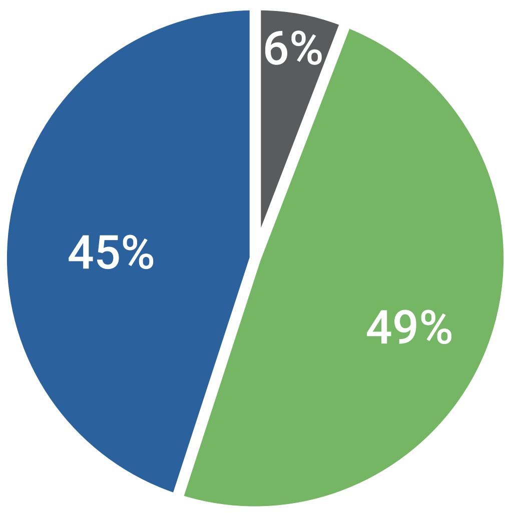
CHROMIUM



25 Below Guideline Value for Domestic Non-Potable Use

41 Exceeding Guideline Values for Dom. Non-Pot. Use > 50 µg/L

BORON



4 Below Guideline Value for Agricultural Irrigation [<0.5 mg/L]

32 Below Guideline Value for Domestic Non-Potable Use but exceeding the Guideline Value for Agricultural Irrigation (>0.5 mg/L to 2.4 mg/L)

30 Exceeding both Guideline Values (> 2.4 mg/L)

Since much of what has been mentioned has also been observed in the previous project, it can be summarized that the overall water character largely remained the same. Nevertheless, some parameters showed significant changes in some wells and the following potential processes may play a role in the study area.

- Recent (natural) groundwater recharge: Usually this will have a dilution effect, but also the opposite is, in principle, possible (flushing of accumulated salts from the unsaturated zone),
- Effects caused by irrigation practices (intentional salt flushing, unintentional irrigation return flow),
- Contamination through the (uncovered) well itself (*e.g.* drifting sand),
- Collapsed sections or blown-in sand possibly isolating previously contributing zones,
- Upconing of salty water,
- Well maintenance/rehabilitation,
- New pump/modified discharge,
- Changed pump position.

While the exact underlying process cannot be identified for each case, it is noteworthy that several of the most extreme concentration changes were found for shallow idle wells that were not or not sufficiently covered, highlighting a certain aquifer vulnerability. This conclusion is underscored by new microbiological contaminations – *E. coli*, an indicator for faecal contamination – was encountered in two wells.

Although human activities can lead to such phenomena, also natural contaminations were found. Examples comprise several trace elements (Boron, Chromium, Molybdenum, Nickel, Selenium; several areas), but also the radionuclide Radium-226 (Jabal Hafit area). While the corresponding concentrations showed some fluctuations, the phenomenon was known from the Groundwater Quality Baseline Survey.

By contrast, the pesticide and pharmaceuticals analyses were inconspicuous.

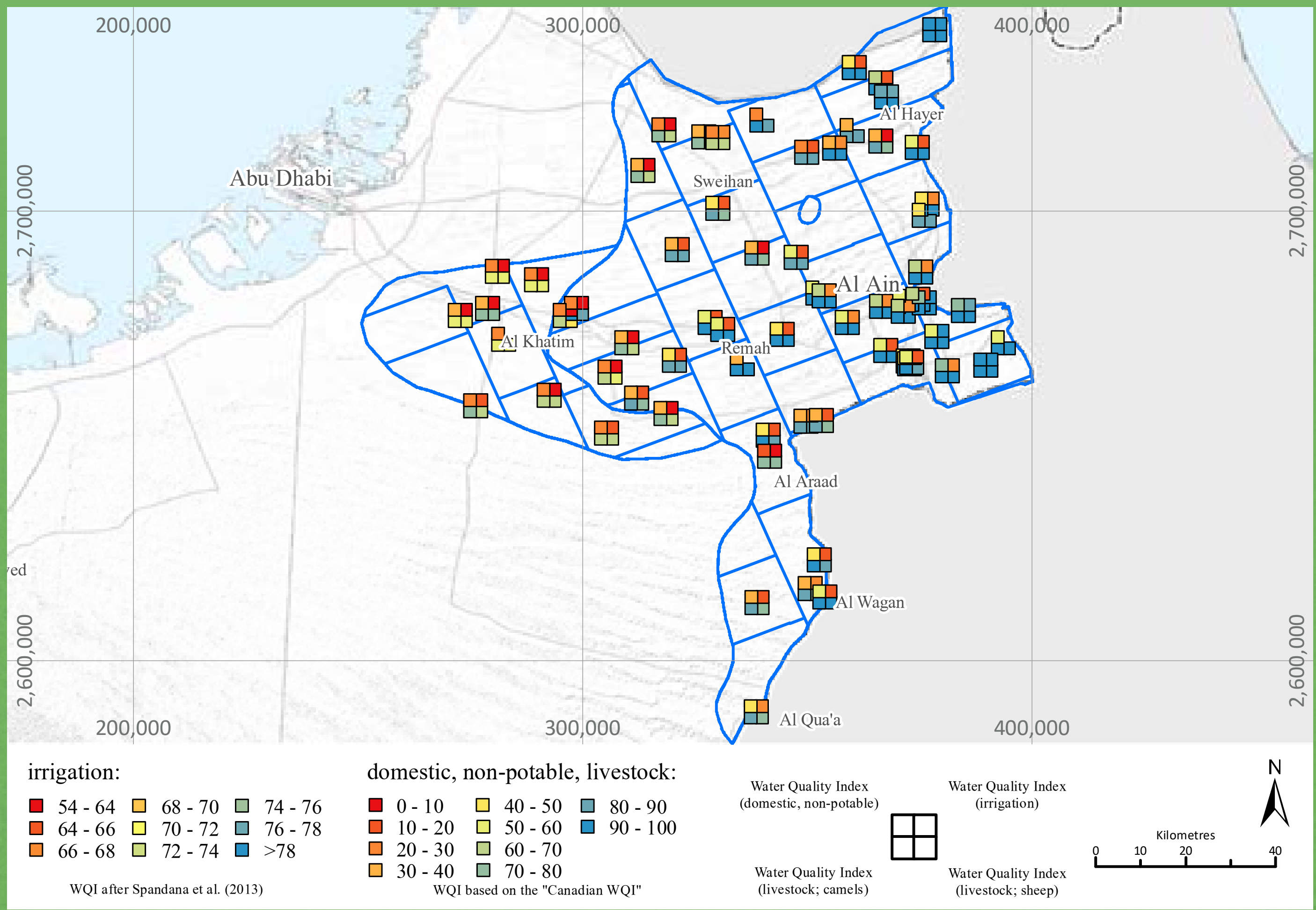
3.4 WATER QUALITY INDICES

In addition to the evaluation of single parameters and their EAD (2017) guideline value violations, water quality was also assessed in an integral way. To this end, several key parameters were combined to calculate so-called water quality indices (WQI). Like in the previous project, WQI values are calculated with respect to the following potential uses:

DOMESTIC (non-potable) use

IRRIGATION PURPOSES

LIVESTOCK WATERING



The WQI values for domestic use showed a large range (12 to 100; mean: 45) and reflect the greatly varying water qualities encountered in this study. Not surprisingly, the highest scores were found for the freshest waters, prevailing in the very East. Towards the West, the scores decrease. Hence, the overall spatial pattern did not change, but on average the WQI increased slightly (from 42 to 45). The greatest increases were observed for the Eastern wells for which recent recharge has been suspected.

With respect to irrigation, the groundwater use is rather restricted due to elevated salinities and the associated Sodium dominance. The elevated Boron values (see above) represent a further restriction. The WQI values, combining several relevant parameters, range between 62 % and 86 % (mean: 67 %). Better waters occur in the East. Individual wells did show some change and differences are also observed in the minimum value (increase from 57 % to 62 %) and the maximum value (increase from 83 %to 88 %). The mean WQI, by contrast, remained the same (67 %), *i.e.* individual hydrochemical shifts balanced each other out.

In terms of livestock, two cases were considered – camels and sheep. The WQI values for camel watering range from 56 to 100 and average at 88. As in the above-mentioned cases, better waters prevail in the East. A comparison with previous values reveals that the water in the study area improved slightly on average (increase of the mean from 84 to 88).

The overall pattern is largely the same for sheep watering. Here, the WQI values scatter between 49 and 100 and the mean accounts for 84. In comparison with the Groundwater Quality Baseline Survey, the average water quality became slightly better (increase of the mean from 81 to 84).

GREATLY VARYING WATER QUALITY INDICES

4 CASE STUDY:

REDUCTIVE CONDITIONS AND BACTERIAL ACTIVITY IN GROUNDWATER IN THE AL HAYER AREA

In the course of the sampling campaign in Al Ain region, one farm in Al Hayer Area was included. The owner of the farm had reported an H_2S smell (“rotten egg” odor), triggering an initial study in January, 2019. Hence, additional samples were taken during this campaign. The analytical programme included major ion, trace element, and microbiological analyses.

The results revealed that the encountered water was fairly salty. Furthermore, the low O_2 contents were noteworthy, indicating reducing conditions. As a result of this geochemical milieu, Sulphate is reduced microbiologically and H_2S is formed – both campaigns yielded a concentration of 1 mg/L.

While H_2S in a colourless, flammable, and hazardous gas, it usually only represents an immediate danger when occurring in high concentration in air. Nevertheless, a prolonged stay near the concerned well(s) is not recommended and if alternatives exist, such wells should not be used until further investigations are carried out. To create awareness of a potential danger, warning signs are recommended and further measures and studies are suggested.

5 CONCLUSION & WAY FORWARD

GENERAL DECREASE OF TDS

0 PESTICIDES DETECTED

CONTINUED MONITORING

Although some parameters and wells did show changes since the last sampling campaign, the overall picture remained the same. The groundwater in the study area is generally salty and several water constituents appear in concentrations that constitute violations of the EAD (2017) guideline values. Prominent examples comprise Boron and Chromium. A few wells in the Jabal Hafit area also stood out due to elevated Radium-226 activities. Pesticides and Pharmaceuticals, by contrast, were inconspicuous.

New *E. coli* contaminations and the greatest hydrochemical changes among the basic parameters were associated with shallow idle wells that were not or not sufficiently covered, highlighting a certain aquifer vulnerability.

Yet, contaminations do not only reach the groundwater through wells, but possibly also through the unsaturated zone, via groundwater recharge. That such replenishment does take place, even under the generally arid climate, is suggested by a number of wells that showed a decrease in TDS.

FUTURE

MONITORING

TRACE ELEMENT

PROJECT

GROUNDWATER

RECHARGE ESTIMATIONS

UPDATE OF GROUNDWATER

CONTOUR MAPS

RADON-IN-AIR

MONITORING

نحافظ على تراثنا الطبيعي . ضماناً لمستقبلنا

PRESRVING OUR HERITAGE · PROTECTING OUR FUTURE

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