RAPID ASSESSMENT OF DRINKING-WATER QUALITY IN THE HASHEMITE KINGDOM OF JORDAN

COUNTRY REPORT

World Health Organization

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RAPID ASSESSMENT OF DRINKING-WATER QUALITY IN THE HASHEMITE KINGDOM OF JORDAN

COUNTRY REPORT OF THE PILOT PROJECT IMPLEMENTATION IN 2004-2005

Prepared by

Federico Properzi

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Foreword

Among the infectious diseases, diarrhoeal diseases are the second major cause of death, killing an estimated 2.2 million people yearly, the vast majority children in developing countries. In 2000, heads of state adopted the Millennium Development Declaration at a special session of the United Nations General Assembly, and this led to the universal adoption of eight Millennium Development Goals (MDGs). One of the targets under MDG 7, environmental sustainability, is to halve, by 2015, the proportion of people without sustainable access to safe drinking-water and basic sanitation; this target links to targets under MDGs 4, 5 and 6 (the so-called "health MDGs" –reduction of child mortality, improvement of maternal and child health and reduction of the burden of HIV/AIDS, malaria and tuberculosis-) in that it creates the basis for sustained progress in the overall reduction of the burden childhood illness.

Since 2000, the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) is the formal instrument to measure progress towards achieving MDG 7 target C. The JMP builds on monitoring experience gained during the International Drinking Water Supply and Sanitation Decade of the 1980s. In 2000 it took a major methodological departure from its past practice, and started to base its estimates on household surveys and censuses. The definitions of drinking-water and sanitation facilities are categorized as "improved" and "not improved". This refers to the probability that "improved" water sources give access to safe drinking-water and that improved sanitation facilities effectively separate human waste from drinking-water sources.

The JMP statistics on water and sanitation do not, however, provide specific evidence about the quality of water being provided to communities, households and institutions through direct measurements; so far, in these statistics, the safety of the drinking-water can only be inferred. There is, therefore, an urgent need to obtain independently verifiable water-quality data, using reliable, low-cost methods that ideally can be correlated with the datasets on access obtained through the household surveys and censuses. On the basis of such data, governments will be able to make informed decisions to further improve the situation with respect to drinking-water supply in their countries, actions to accelerate progress towards achieving MDG 7 target C can be better targeted and the evidence base on the correlation between lack of access to safe drinking-water and the burden of water-borne disease could be further strengthened. The data would also reveal the extent of major water-quality problems at national, regional and global levels and inform future investment priorities.

A possible method to obtain the data on drinking-water quality could be a rapid, low-cost, field-based technique for assessing water quality. As a result, at a consultative meeting in Bangkok in 2002 organized by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) six countries were selected to implement pilot projects on the Rapid Assessment of Drinking-Water Quality (RADWQ). The countries were China, Ethiopia, Jordan, Nicaragua, Nigeria and Tajikistan.

The project was implemented in The Hashemite Kingdom of Jordan during 2004–2005 with the local support of the WHO and UNICEF country offices and of the WHO/EMRO Centre for Environmental Health Activities (CEHA). Over a period of five months field teams visited more than 1600 drinking-water supply sites in 67 clusters to collect water samples and statistical data required for the RADWQ study. To plan and oversee the project, a steering committee was formed that included representatives of WHO, UNICEF, the Water Authority of Jordan, the Ministry of Health, the Department of Statistics, the Royal Scientific Society, the University of Jordan and the Jordan University for Science and Technology. Dr Nawal Sunnà of the Water Authority of Jordan was appointed as the national project coordinator.

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The author wishes to acknowledge the financial support received from the Department for International Development/UKAID of the United Kingdom. The technical and logistical support received from WHO and UNICEF headquarters, from the WHO/EMRO Regional Centre for Environmental Health Activities, and the WHO and UNICEF offices in Amman was essential for the successful completion of the RADWQ project in Jordan.

The author also wishes to express his appreciation and gratitude to the professional contributions of all members of the Steering Committee (Annex 1), particularly those of the Water Authority of Jordan and the Jordanian Ministry of Health, as well as the level of commitment of all field staff (Annex 2). Their efforts were the driving force behind the planning, implementation and completion of the RADWQ project.

Special thanks go to the staff, consultants and associates of the Water, Engineering and Development Centre, Loughborough University, UK, for their expert advice and technical support throughout the entire project.

Acronyms and abbreviations

CEHA	Centre for Environmental Health Activities (WHO/EMRO)
DFID	Department for International Development of the Government of the United Kingdom
EMRO	WHO Eastern Mediterranean Regional Office
JMP	WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation
RADWQ	Rapid Assessment of Drinking-Water Quality
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WHO	World Health Organization
WSS No.	Water Supply Scheme Number

Executive summary

In 2004 and 2005 the Hashemite Kingdom of Jordan participated with five other countries in a World Health Organization/United Nations Children's Fund (WHO/UNICEF) pilot project to test a method for the rapid assessment of the quality of drinking-water. The purpose of the Rapid Assessment of Drinking-Water Quality (RADWQ) project was to develop a tool that would support the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) in strengthening its monitoring efforts of the global access to safe drinking-water.

The RADWQ methodology is based on the UNICEF Multiple Indicators Cluster Surveys and uses a cluster sampling approach to select individual drinking-water sources across an entire country. The selected sources are then tested for relevant parameters, the number and types of which depend on the scope of the survey and on the health hazards found locally. The output of RADWQ surveys is the quality of the drinking-water at each improved source tested.

Using the RADWQ methodology, field teams visited more than 1600 sample sites in 67 clusters over a period of five months. Water was analysed with portable field kits and in local laboratories for the following parameters: thermotolerant coliforms, pH, turbidity, faecal streptococci, appearance, conductivity, free/total chlorine, arsenic, nitrate, fluoride, and iron. Additional samples were taken from households at 10% of the sites visited, to analyse the deterioration of water quality from network to consumer's tap.

The results of the RADWQ pilot project in Jordan confirm the validity of routine national monitoring data, which show that drinking-water quality is generally high in the distribution network. Compliance with WHO guideline values and national standards for bacteria is 99.9%, and overall compliance is 97.8% (this figure includes data for chemical contaminants). The overall compliance rate increases to 99.9% if the Jordanian maximum permitted limits are used as the references, instead of the allowed limits[1]. In some areas, the results for nitrates, conductivity and iron indicate there is cause for concern. Although household samples show that some contamination occurs between the network pipes and household taps, the chlorination level usually ensures the safety of water at the time of consumption.

The overall results of the RADWQ pilot project show that rapid assessments provide a useful tool to successfully carry out both routine and global monitoring of the quality of drinking-water sources, but in the form in which it was implemented it is expensive. There may be scope to increase its efficiency by enhancing the underlying statistical approaches. The RADWQ methodology is well-suited to specific studies, such as assessments of emerging risks or selected chemicals, or as an auditing tool to validate existing surveillance data.

[1] The Jordanian national standards for drinking-water quality allow the maximum permitted limit to be used as the standard when the allowed limit is exceeded and an alternative water supply is not available.

1. Introduction

1.1 The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation

In 1990, at the end of the International Drinking Water Supply and Sanitation Decade, WHO and UNICEF decided to combine their experience and resources in a Joint Monitoring Programme for Water Supply and Sanitation (JMP). At its inception, the overall aim of the JMP was to improve planning and management of the water supply and sanitation within countries by assisting countries in the monitoring of their drinking-water supply and sanitation sector. This concept, and the associated objectives, evolved over time. The Millennium Declaration in 2000 and the subsequent formulation of targets under the Millennium Development Goals (MDGs) marked a fundamental change. As the official monitoring instrument for progress towards achieving MDG 7 target C, the JMP prepares biennial global updates of this progress. Prior to 2000, JMP assessments had been undertaken in 1991, 1993, 1996 and 2000. The results for the year 2000 survey are presented in *Global water supply and sanitation assessment 2000 report* (WHO/UNICEF, 2000), which contains data for six global regions: Africa, Asia, Europe, Latin America and the Caribbean, Northern America, and Oceania. This report introduced a monitoring approach based on household surveys and censuses which has subsequently been refined. The methods and procedures lead to an estimate of numbers of people with access to improved water sources and improved sanitation. Since the 2000 report, five more JMP reports have been published. The latest, published in March 2010, shows that by the end of 2008 an estimated 884 million people in the world lacked access to improved sources of drinking-water and 2.6 billion people lack access to improved sanitation facilities. If the current trend continues, the MDG drinking-water target will be exceeded by 2015, but the sanitation target will be missed by about 1 billion people (over and above the 1.7 billion who would not have access even if the target were achieved).

In the past, the JMP drew guidance from a technical advisory group of leading experts in water supply, sanitation and hygiene, and from institutions involved in data collection and sector monitoring. With the formulation and adoption of the JMP Strategy for 2010-2015, this technical support structure will be further strengthened. The JMP strategy further states the vision and mission of the JMP as, respectively: *To accelerate progress towards universal, sustainable, access to safe water and basic sanitation by 2025*[1]*, including the achievement of the MDG targets by 2015 as a key milestone* and *to be the trusted source of global, regional and national data on sustainable access to safe drinking-water and basic sanitation, for use by governments, donors, international organizations and civil society.*

To fulfil its mission, the JMP has three strategic objectives:

- to compile, analyse and disseminate high quality, up-to-date, consistent and statistically sound global, regional and country estimates of progress towards internationally established drinking-water and sanitation targets in support of informed policy and decision making by national governments, development partners and civil society;
- to serve as a platform for the development of indicators, procedures and methods aimed at strengthening monitoring mechanisms to measure sustainable access to safe drinking-water and basic sanitation at global, regional and national levels;
- to promote, in collaboration with other agencies, the building of capacity within government and international organizations to monitor access to safe drinking-water and basic sanitation.

These priorities translate into four strategic priorities for the JMP over the next five years:

- maintaining the integrity of the JMP data base and ensuring accurate global estimates:
- dissemination of data to sector stakeholders;
- fulfilling JMP's normative role in developing and validating target indicators;
- interaction between countries and the JMP

The JMP defines access to drinking-water and sanitation in terms of the types of technology and levels of service afforded. The JMP definitions used at the time of this study are shown in Table 1.1, while current definitions can be found on www.wssinfo.org .

Table 1.1 **JMP definitions of water supply and sanitation (2004)**

Category	**Water supply**	**Sanitation**
Improved	• Household connection • Public standpipe • Borehole • Protected dug well • Protected spring • Rainwater collection	• Connection to a public sewer • Connection to septic system • Pour-flush latrine • Simple pit latrine • Ventilated improved pit latrine
Unimproved	• Unprotected well • Unprotected spring • Vendor-provided water • Bottled water[a] • Tanker truck-provided water[b]	• Service or bucket latrines (where excreta are manually removed) • Public latrines • Latrines with an open pit

[a] Normally considered to be "unimproved" because of concerns about the quantity of supplied water.
[b] Considered to be "unimproved" because of concerns about access to adequate volumes, and concerns regarding inadequate treatment or transportation in inappropriate containers.

The JMP database is the source for WHO and UNICEF estimates on access to and use of drinking-water and sanitation facilities. At the time of the RADWQ pilot studies the database drew upon some 350 nationally representative household surveys, but the database has rapidly expanded and by the beginning of 2010 contained over 1200 such datasets. The data come from household surveys and censuses, including the Demographic Health Survey, the UNICEF Multiple Indicators Cluster Surveys, the World Bank Living Standard Measurement Survey and the World Health Survey (by WHO). These are national cluster sample surveys, covering several thousand households in each country. The samples are stratified to ensure that they are representative of urban and rural areas of each country.

Prior to 2000, coverage data were based on information from service providers, such as utilities, ministries and water authorities, rather than on household surveys. The quality of the information thus obtained varied considerably. Provider-based data, for example, often did not include facilities built by householders themselves, such as private wells or pit latrines, or even systems installed by local communities. For this reason, in 2000, JMP adopted the use of household surveys, which provide a more accurate picture by monitoring the types of services and facilities that people actually use.

Information collected by the JMP is analysed and presented for dissemination in the form of maps and graphs, which can be found, together with other information, on the JMP web site www.wssinfo.org.

Although the use of household surveys and the presentation of data by drinking-water and sanitation ladders and wealth quintiles have significantly increased the quality and comparability of information on improved drinking-water sources and sanitation, there continues to be room for further improvements in the JMP database so it will be even more useful to policy-makers by:

- *Harmonizing indicators and survey questions*. Surveys use different indicators and methodologies, making it difficult to compare information. A guide that harmonizes questions and response categories for drinking-water supply and sanitation, *Core questions on drinking-water, sanitation and hygiene for household surveys* (WHO/UNICEF, 2007), has been prepared and is regularly updated. On-going discussions aim to incorporate updated and new questions into major household survey programmes and population censuses. Currently, the Demographic

Health Survey, the Multiple Indicators Cluster Surveys, and the World Health Survey have all adopted the harmonized set of questions for their surveys.

- *Measuring gender disparities*. Data on water and sanitation are collected at the household level and therefore gender-specific data cannot be calculated. However, questions can be designed to determine who bears the main responsibility for collecting water and how much time is spent collecting it. Questions along these lines are being incorporated into the design of new surveys.
- *Measuring water quality*. Existing surveys do not provide reliable information on the quality of water, either at the source or at the household level.

In response to the last challenge, WHO and UNICEF, with the support of the Department for International Development of the Government of the United Kingdom, developed a method for the rapid assessment of drinking-water quality. Pilot studies using the method, referred to as RADWQ (rapid assessment of drinking-water quality), have been carried out in China, Ethiopia, Jordan, Nicaragua, Nigeria and Tajikistan. The six pilot countries represent different regions of the world with a range of environmental and socio-economic conditions, presenting different water quality issues and at various stages of development.

At the conception of the RADWQ pilot studies it was foreseen that the methodology, if proved feasible and successful, could be of value to many countries as a vehicle for building capacity in water quality monitoring at policy, institutional and technical levels. The direct involvement of water authorities and national experts in the studies was also expected to enhance a sense of ownership. Countries could benefit from RADWQ surveys by using the data to create a baseline for future monitoring programmes (e.g. post-2015); for external evaluations; to assess the drinking-water quality in specific geographical areas; or to assess a specific drinking-water supply technology. The RADWQ approach would also provide the international community with the tools to measure improvements in access to safe drinking-water worldwide.

1.2 State of drinking-water sources in Jordan (2005 data)

The Hashemite Kingdom of Jordan is a relatively small country, with fewer than 5.5 million people living in 90 000 km^2 (see Annex 3 for a map of Jordan and the Middle East). Yet the dry climate and the fact that the population is concentrated into roughly 10% of its surface area make it a water-scarce country. Drinking-water comes mainly from groundwater sources (80%), with the remainder coming from surface water. The average demand in the distribution network is estimated to be 85 litres per capita per day (2005 data). In reality, the demand is higher and most people buy water from tanker trucks. The main problems with the drinking-water supply are:

- there is a shortage of water, and the water supply is intermittent, especially during the summer;
- the quality of source waters is deteriorating;
- the demand on the water supply system is increasing;
- water leakage throughout the distribution network is estimated to account for the loss of 35% of the total water distributed.

1.3 The structure of the Jordanian water-quality surveillance and monitoring system, and national standards

The structure of the Jordanian surveillance and monitoring system for drinking-water quality is summarized in Table 1.2. The two major actors are the Water Authority of Jordan and the Ministry of Health. The former is responsible for managing water, from extraction to distribution, while the latter is the monitoring agency responsible for public health. Both agencies carry out routine tests of drinking-water quality at their laboratories.

The main laws regulating the Jordanian system for monitoring drinking-water quality are:

- Water Authority Law number 18, promulgated in 1988 and amended in 2001, which defines the role of the Water Authority of Jordan.
- Public Health Law number 54, promulgated in 1988 and amended until 2002, which defines the role of the Ministry of Health.
- Law number 12, passed in 1995, which created the Ministry of Environment.

The current Jordanian standard for drinking-water quality is number 286/2001, issued by the Jordan Institute of Standardization and Metrology. National standards on drinking-water quality were initially issued in 1982 and have been revised four times between 1982 and 2005. The Jordanian national standards for drinking-water quality allow the maximum permitted limit to be used as the standard when the allowed limit is exceeded and an alternative water supply is not available. Allowed and maximum permitted limits of the most common parameters for drinking-water quality, as well as further information on microbiological guidelines, are given in Annexes 4 and 5. The main references for the Jordanian standards are (2005 data):

- *Standard methods for the examination of water and wastewater*, 20th edition. Washington, DC, American Public Health Association, 1998.
- *Guidance manual for compliance with filtration and disinfection. Requirements for public water systems using surface water sources.* Washington, DC, US Environmental Protection Agency Office of Drinking Water, Criteria and Standards Division, 1990.
- *Guidelines for drinking-water quality*, Vol. 2. *Health criteria and other supporting information*, 2nd ed. Geneva, World Health Organization, 1996.

1.4 Historical water-quality data for Jordan

In 1998, there was a generalized failure of drinking-water quality in Jordan, immediately after which action was undertaken within the water sector to avoid a similar emergency in the future. Minimum requirements for water treatment were set, and an extensive programme was started to protect water resources, to install new treatment plants and to rehabilitate the distribution network. As a result, the microbiological quality of drinking-water in the country has improved (Table 1.3).

Table 1.2 **Structure of the Jordanian surveillance and monitoring system for drinking-water quality (2005 data)**

Actor	Type	Role/responsibilities
Water Authority of Jordan	Government	Responsible for providing and maintaining the drinking-water supply and regulating water suppliers. The Authority has comprehensive water-quality monitoring programmes using its own laboratories.
Ministry of Health	Government	Drinking-water quality surveillance agency, responsible for public health. The Ministry monitors programmes by direct assessment and coordinates with the Water Authority of Jordan in critical cases, such as disease outbreaks or chemical spills.
Ministry of Environment	Government	Responsible for the quality of water sources, for protecting water sources from pollution and for monitoring programmes that involve other agencies, such as the Royal Scientific Society. The Ministry was created in 1995.
Jordan Institution of Standardization and Metrology	Government	Responsible for all national standards.
Ministry of Industry and Commerce	Government	Participates in the development of national standards.
Municipality of Greater Amman	Government	Responsible for monitoring drinking-water quality in the Amman area.
Royal Scientific Society	Government/ Academic	Runs source water monitoring programmes on behalf of the Ministry of Environment.
Various universities	Academic	Carry out tests of drinking-water quality for researchers and private customers.
LEMA in Amman and ASEZA in Aqaba	Private	LEMA and ASEZA are water-supply companies that monitor water quality under the terms of a contract or licence.
International donors (e.g. USAID, European Union, Japan International Cooperation Agency)	International	Technical support and capacity building.

Table 1.3 **Microbiological quality of drinking-water in Jordan, 1994-2003**[a]

Year	**Totals**			**Private tankers**			**Private resources**			**Public networks**			**Public resources**		
	%	**U/S**	***n***	**%**	**U/S**	***n***	**%**	**U/S**	***n***	**%**	**U/S**	***n***	**%**	**U/S**	***n***
1994	2.11	862	40 799	4.12	280	6 791	3.26	59	1 809	1.74	420	24 174	1.28	103	8 025
1995	1.60	619	38 788	3.21	210	6 550	1.54	25	1 628	1.49	339	22 729	0.57	45	7 881
1996	1.50	594	39 494	2.71	246	9 061	1.81	27	1 489	1.27	271	21 356	0.66	48	7 320
1997	1.81	712	39 375	3.17	335	10 565	1.78	27	1 514	1.42	274	19 337	0.95	70	7 382
1998	1.95	841	43 036	3.04	368	12 101	2.45	53	2 166	1.58	321	20 352	1.25	94	7 517
1999	2.10	1 054	50 242	3.08	421	13 662	1.88	67	3 568	1.84	398	21 634	1.50	130	8 687
2000	1.60	839	51 015	2.40	331	13 865	1.80	72	4 050	1.3	264	20 087	1.10	90	8 499
2001	1.30	585	43 296	1.90	257	13 255	2.20	86	3 774	1.00	204	18 610	0.40	38	7 657
2002	1.30	466	35 537	1.90	223	11 790	2.60	66	2 568	0.90	146	15 353	0.90	146	5 826
2003	1.00	350	33 246	1.70	179	10 742	1.80	40	2 230	0.70	105	14 915	0.50	26	5 359

[a] Source: Jordan Ministry of Health. U/S = number of unsafe samples. *n* = total number of samples tested. Percentages refer to the proportion of the corresponding total number of samples that tested unsafe for drinking.

2 Methods

2.1 General design of RADWQ surveys

Six countries participated in RADWQ pilot surveys - China, Ethiopia, Nicaragua, Nigeria, Jordan and Tajikistan - and the results will be presented in individual country reports and an overall synthesis report. The methodology for the RADWQ pilot surveys is detailed in the RADWQ handbook: *Rapid assessment of drinking-water quality: a handbook for implementation* (Howard et al., 2003; a revised version of this handbook is in preparation). The main steps are:

- select water sources as representative sampling points, using a statistically-based survey design (cluster sampling);
- implement a field analysis of the selected water sources for a suite of parameters (Table 2.1);
- analyse the data and compare the results with historical data;
- formulate conclusions and recommendations based on the data analysis.

RADWQ surveys used cluster sampling to identify the number, type and location of water supplies to be included in the assessment. Cluster sampling means that the water supplies included in the assessment will be geographically close to one another (in "clusters"), but are representative of all water-supply technology types. Therefore, costs can be reduced (e.g. by reducing transportation costs to/from the sampling points) without compromising the statistical validity of the sampling method[2]. The choice of this method for RADWQ surveys is also related to the fact that it is already used in major international surveys of water, sanitation and health that contribute to the WHO/UNICEF JMP database, such as the Multiple Indicators Cluster Surveys.

To try to ensure that the results of any RADWQ survey accurately reflect the situation in a country, only improved technologies supplying more than five percent of the population were included in the survey. The basic sampling unit is the water supply, rather than the households that use it, and thus RADWQ surveys primarily assess the quality and sanitary condition of the water supplies, and hence the risk to water safety. For a limited number of households, RADWQ surveys also compare the quality of water stored in households with that of the matched source.

The number of water samples to be taken was calculated using Equation 2.1:

$$n = \frac{4P(1-P)D}{e^2} = \frac{4 * 0.5(1-0.5) * 4}{0.05^2} = 1600 \qquad \text{(Equation 2.1)}$$

n = required number of samples;
P = assumed proportion of water supplies with a water quality exceeding the target established;
D = design effect;
e = acceptable precision expressed as a proportion.

For the RADWQ pilot survey in Jordan, it was assumed that P = 0.5, $e = \pm 0.05$ and D = 4, giving the number of water supplies to be included in the assessment, $n = 1600$. The steps of a generalized RADWQ survey are summarized in Figure 2.1 and the parameters tested and inspections undertaken are presented in Table 2.1.

2.2 RADWQ survey design for Jordan

The design of the RADWQ survey for Jordan is summarized in Figure 2.2, and the successive steps shown in the figure are described in more detail in the following sections. As far as possible, the RADWQ survey in Jordan was carried out according to the methods in the RADWQ handbook (Howard, Ince & Smith, 2003; a revised handbook is in preparation). Exceptions to the standard RADWQ approach are noted in Table 2.2. The parameters tested in the RADWQ survey of Jordan,

[2] It is to be noted that seasonality is not taken into account in the survey design.

and the frequency of testing are given in Table 2.3, while the methods used to measure water quality are listed in Table 2.4.

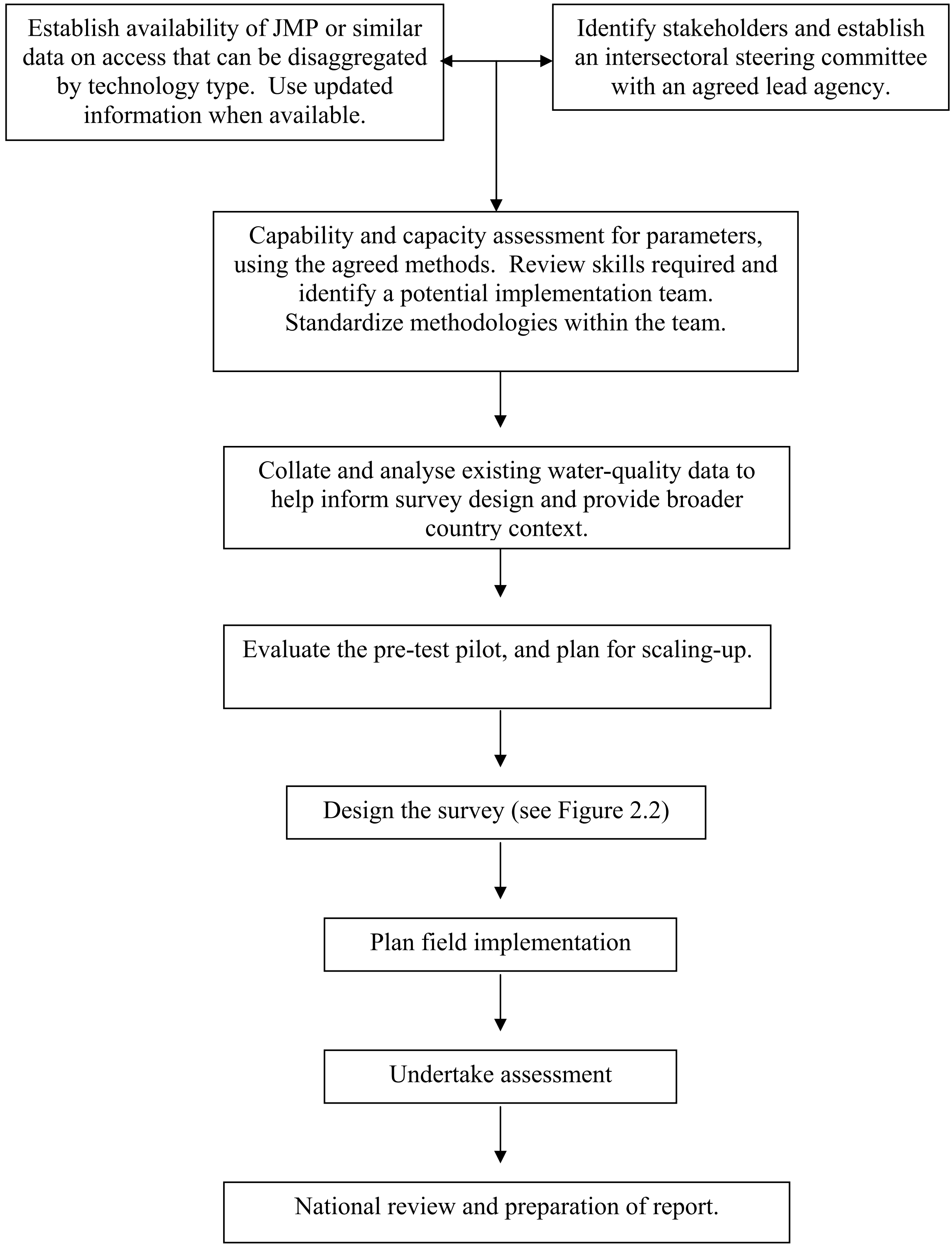
Table 2.1 **Water-quality parameters and inspections for RADWQ surveys**

Microbiological and related parameters	Physical and chemical parameters	Inspections
Chlorine residuals	Appearance	Sanitary inspection
Faecal streptococci	Arsenic	
pH	Conductivity	
Thermotolerant coliforms	Copper	
Turbidity	Fluoride	
	Iron	
	Nitrate	

According to information from the JMP and the 2002 national survey for Jordan (Population and Family Health Survey, 2002), most of the Jordanian population was served by piped water supplies in 2004 (Table 2.5). For this reason, to carry out a cluster survey of the piped water system in Jordan, the network first was divided into zones serving a given number of people (2500, in the case of Jordan). The zones then act as virtual water sampling points, which field teams visit and take samples from water treatment plants, reservoirs, pumping stations, etc. This zoning step was necessary because a distributed piped water system does not consist of discrete sampling points (such as a system of wells), and in essence the zones act as "virtual wells", which allows a cluster analysis of the piped system to be carried out. A zone is thus equivalent to one water supply point. This method does not distinguish between piped water treatment processes (e.g. treatment plants) and sampling points in the distribution network.

The RADWQ handbook suggests creating zones of 5000 people served by piped water (Howard, Ince & Smith, 2003). However, this was not practical for Jordan, which at the time had a total population of fewer than six million people, because zoning on this basis would have yielded fewer than 1600 zones. This number is smaller than the total number of water sampling points needed for the required statistical power (Equation 2.1). Therefore, the steering committee adopted a zone size of 2500 people. The zones were created by grouping communities served by piped water according to the geography and to the layout of the distribution network.

Figure 2.1 **Steps in RADWQ surveys**



Determine the sample size

The Steering Committee (composition presented in Annex 1) decided to use the standard sample size of 1600 for the number of water supply points to be assayed, rather than a smaller sample size, even though historical data showed that over 90% of Jordanian water supplies were microbiologically safe. The committee considered a sample size of 1600 to be conservative and noted that other countries involved in the RADWQ pilot studies had used the same value.

Figure 2.2 **Design of the RADWQ survey for Jordan**

Determine the sample size
This is the total number of water sampling points to be visited in the RADWQ survey.

↓

Primary stratification of sampling points
Proportionally weight the sampling points by technology type, for technologies that serve at least 5% of the population. In Jordan, only piped water supplies met this criterion (Table 2.5).

↓

Secondary stratification of sampling points
Proportionally assign the sampling points by broad area. In Jordan, the broad area corresponded to the governorates, and the sampling points were assigned according to the populations of the governorates (Table 2.6).

↓

Define cluster size
This is the number of water sampling points that can be visited in one week by one team. For the RADWQ survey in Jordan, cluster size was 24 sampling points.

↓

Designate large area sampling units
The governorates are divided into non-overlapping, large area sampling units, each containing at least one cluster. The sampling units are used to build weighting tables for randomly assigning the clusters of water sampling points to be visited by field teams.

↓

Designate clusters and individual water supplies
These are the clusters and associated water sampling points that will be visited by the RADWQ survey field teams (Annex 6).

Table 2.2 **RADWQ survey design for Jordan**

Step	Method in RADWQ handbook	Method used in Jordan	Justification for not using RADWQ handbook method
1	Calculate **sample size** required (= 1600).	According to survey design: • 1600 normal samples; • 268 quality-control samples; • 160 household samples.	After implementation: • 1639 normal samples; • 267 quality-control samples; • 155 household samples. The difference arose from adjustments made during the first weeks of project implementation.
2	**Primary stratification**: proportional weighting by technology type (based on percentage of population served). NB: only includes technologies serving at least 5% of population.	The survey was carried out across the whole country. The only eligible technology was piped water. Stratification was by population served and by governorate.	The method in the RADWQ handbook was strictly followed.
3	**Secondary stratification**: proportional weighting by broad areas (based on number of water supplies across country).	The stratification was by population served and by governorate. The piped water "zone" size was 2500 people instead of 5000.	The zone size had to be reduced because the population of Jordan (fewer than 6 million people) was less than that required for zone sizes of 5000 people (5000*1600 = 8 million people).
4	**Define clusters** (size and number): based on the number of water sampling points (zones) that can be visited in one week by one team (cluster size).	Cluster size = 24 Total number of utility piped water clusters = 67	
5	**Designate large area sampling units**: areas from which clusters are selected by proportional weighting.	The large area sampling units were created by grouping communities served by piped water according to the geography and to the layout of the distribution network. The large area sampling unit contained at least one cluster (i.e. 2500 people/zone * 24 zones = 60 000 people).	
6	**Designate clusters and individual water supplies**: identify supplies for water-quality assessment.	Clusters were selected by expert judgement. Individual water supplies were identified during the weekly planning day and then visited by the field teams.	The workplan was affected by the network pumping schedule. If a sampling tap was missing, a nearby household was chosen as the sampling point.

Table 2.3 **RADWQ parameters and frequency of testing in Jordan**

Parameter	Proportion of all water supplies tested	Proportion of all households tested
Thermotolerant coliforms, turbidity, pH	100%	100%
Faecal streptococci	10%	0%
Free chlorine residual	100%	100%
Total chlorine residual[a]	0%	100%
Appearance, conductivity	100%	100%
Arsenic, fluoride and iron	100%	100%
Nitrate[b]	100%	100%
Copper[c]	100%	100%

[a] Total chlorine residual was tested only for household samples because of the limited number of DPD3 tablets.
[b] Nitrate and arsenic were tested in 100% of samples because the availability of consumables allowed a countrywide survey for these two chemicals.
[c] Testing for copper was only necessary in piped water supplies when copper pipes were present.

Table 2.4 **Methods of testing**

Parameter	Method
Thermotolerant coliforms, faecal streptococci	Membrane filtration (Wagtech field kits)
Fluoride, iron, free/total chlorine, nitrate, copper, pH	Photometer (Wagtech field kits)
Arsenic	Visual and digital arsenator (Wagtech field kits)
Turbidity	Turbidity meter (Wagtech field kits)
Conductivity	Conductivity meter (Wagtech field kits)
Appearance	Five-point scale

Table 2.5 **Drinking-water supply technologies in Jordan**[a]

Source of drinking-water	Population served (%)
Piped water	85.8
Rainwater	4.5
Tanker truck	1.7
Bottled water	7.6
Other	0.4

[a] Source: Population and Family Health Survey (2002).

The total number of water samples analysed during the pilot project exceeded the planned sample size of 1600 because additional samples were included, such as quality-control samples (one sample/day for bacteria, one sample/week for chemicals) and household samples (which increased the total sample size by 10%). The total number of samples actually analysed was 2061 (1639 regular samples, 267 quality-control samples and 155 household samples). This was somewhat larger than the 2028 total number of samples we calculated to be necessary for statistical power, mainly owing to adjustments during the first weeks of implementation. The adjustments did not reduce the statistical validity of the results.

Primary stratification of the sampling points

In Jordan, the only water-supply technology acceptable for a RADWQ survey was piped water, because rainwater and tanker trucks served less than 5% of the population, and bottled water and other technologies are not considered to be improved water sources (see JMP definitions, Table 1.1). Consequently, the primary stratification of sampling points by technology type assigned all of the water sampling points to the piped water category.

Secondary stratification of the sampling points

Secondary stratification of water sampling points in RADWQ surveys is carried out by broad area. Depending on the country, the broad areas may correspond to geophysical features, such as mountains, highlands and plains or to administrative areas. In Jordan the governorates were designated as the broad areas. The secondary stratification of the RADWQ survey sampling points was then carried out by governorate, in proportion to the population of each governorate (Table 2.6).

Define the cluster size

The cluster size was defined as the number of water sampling points a field team could visit in one week (4 working days + 1 planning day). The Steering Committee estimated that a field team could visit an average of six such sites per day in every governorate. Therefore, cluster size in Jordan was 24 water sampling points.

Designate large area sampling units

The governorates were divided into non-overlapping, large area sampling units, created by grouping the communities served by piped water according to geography and the layout of the piped water system. The sampling units were used to build proportional weighting tables, which were needed to randomly select the location of the clusters in Jordan (see Howard, Ince & Smith, 2003). Each large area sampling unit contained at least one cluster. Since each cluster consisted of 24 zones that each served 2500 people, there was a minimum of 60 000 people in the large area sampling units.

Designate the clusters and individual water supplies

The number of clusters assigned to each governorate was calculated by proportionally distributing the sample size (i.e. 1600 water sampling points) according to the 2002 census population figures for the governorates, and then dividing these numbers by the cluster size (i.e. 24). There was a total of 67 clusters in the RADWQ survey for Jordan (Table 2.6). The locations of the clusters were designated by expert judgement, guided by the need to have the water sampling points in a cluster sufficiently close to one another for the field teams to be able to visit all of them in one day (Annex 6).

Individual water supplies that were to be visited within a cluster were chosen during the weekly planning day for field trips, with priority given to water treatment plants, reservoirs, pumping stations, sample taps and valves. If an official sampling tap was missing, a nearby household was chosen as the sampling point and the results recorded as if they came from the official sampling tap.

Table 2.6 **Number of clusters per governorate**[a]

Governorate	Population in 2002 census	% of total population	No. of sampling points	Cluster size	No. of clusters
Amman	2 085 140	38.1	610	24	25
Albalqa	359 485	6.6	106	24	6
Alzarqa	862 000	15.7	251	24	10
Madaba	139 740	2.6	41	24	1
Irbid	977 635	17.8	285	24	11
Almafraq	252 625	4.6	74	24	3
Jarash	161 115	2.9	46	24	3
Ajloun	121 660	2.2	35	24	2
Alkarak	220 295	4.0	64	24	3
Altafiela	83 295	1.5	24	24	1
Ma'an	106 860	2.0	32	24	1
Aqaba	110 150	2.0	32	24	1
Total	5 480 000	100.0	1 600		67

[a] Using expert judgement, the steering committee decided whether to round up or down to the nearest integer the number of clusters per governorate.

2.3 Field implementation and data recording

Field implementation

Field implementation was carried out from 10 October 2004 to 10 March 2005, with a one-month break during Ramadan. The survey design called for four field teams (two each from the Ministry of Health and the Water Authority of Jordan) to travel around Jordan and collect and analyse samples. This would have required both the Ministry of Health and the Water Authority of Jordan to hire cars for transportation, but owing to budgetary constraints (see Annex 7) field implementation was carried out by only two teams, with each team collecting double the number of samples every day.

The field implementation workplan was drafted by the field coordinators on a monthly basis and confirmed weekly in consultation with the field teams (see Annex 8). The workplan had to take into account the network pumping schedule, so that field teams could find water in the pipes. Interruptions in the water supply are common in Jordan and virtually every building or household has a reservoir. If a field team found no water in the pipes, even after checking the pumping schedule, it would move to a nearby cluster. The individual sample points were then determined by the field teams, according to the RADWQ handbook recommendations. The criteria for including households in the survey were ease of access and representation of social/economic differences.

Given the size of Jordan, field teams could travel from Amman to the sample sites and return to the laboratory on the same day. To use time more efficiently, some tests were done on-site (sanitary inspection, pH, turbidity, conductivity, free/total chlorine), while for the remaining tests for faecal streptococci, thermotolerant coliforms, arsenic, copper, fluoride, iron and nitrate samples were taken back to the laboratory.

Each team was responsible for its own field kit. For arsenic measurements, only the visual arsenators were used because the digital one did not work properly and by the time it was replaced the project had already begun. Otherwise, the equipment worked well and there were adequate supplies of chemical reagents.

Data recording
In the field, data were recorded on record sheets (see Annex 9). Copies of the record sheets were sent weekly to the data manager for entry into the storage software (SanMan). Electronic data were then checked by the UNICEF local consultant, who would send them and the weekly report to the international consultant.

In SanMan, each sample site was identified by a unique eight-digit code or Water Supply Scheme (WSS) number. In the case of Jordan, given the lack of primary stratification, the following coding system was used:

- "JO" for Jordan;
- Two digits for the governorate (standard governmental codes: Amman = 11, Albalqa = 12, Alzarqa = 13, Madaba = 14, Irbid = 21, Almafraq = 22, Jarash = 23, Ajloun = 24, Alkarak = 31, Altafiela = 32, Ma'an = 33, Aqaba = 34);
- Two digits for the cluster. Every cluster was identified by a unique number, 01–67);
- Two digits for each sample. Every water sample taken from a site in a cluster was identified by a unique number:
  - 01–24 for the single, mains samples taken from sites where household testing was *not* carried out;
  - 90–95 for water samples taken from sites where household testing *was* carried out. By convention, the number 90 indicated the sample taken from the mains water supply at the site, and the numbers 91–95 indicated the five corresponding household water supply samples taken at the site.

Examples of WSS numbers are: JO112204 (the single sample taken from the mains water supply at site 04 in cluster 22 of the governorate of Amman, Jordan, and household testing was not carried out); JO325690 (the mains water sample taken from the site in cluster 56 in the governorate of Altafiela from which household samples were collected); JO325694 (one of five household water samples corresponding to the mains sample, JO325690).

2.4 Data analysis

Data collected from the water sources were stored using SanMan and exported to Microsoft Excel for analysis. The proportion of water samples in compliance with WHO guideline values and Jordanian national standards for microbial, physical and chemical parameters was disaggregated by technology and by governorate. Household samples were also analysed to determine if the quality of the drinking-water decreased between the distribution pipes and the household taps.

In line with *WHO guidelines for drinking-water quality* (WHO, 2004), all samples (including household samples) were assessed for sanitary risk and assigned to risk categories, using a standard set of questions developed for the RADWQ pilot project (WHO/UNICEF, 2007). Microbiological and sanitary risk inspection results were also cross-checked in a "risk-to-health" matrix, which gave an indication of the potential risk to health by comparing the risk score with the bacterial count. Again, this was carried out according to WHO guidelines.

Finally, an analysis of proxy parameters (turbidity for bacteria, conductivity for chemicals) was carried out by graphing the results on scatter plots and performing linear regression analyses of the data. Pearson's *r* was calculated for pairs of parameters, using Microsoft's Excel spreadsheet. The disadvantages of Pearson's *r* are that the calculation assumes a normal distribution for the data, and the coefficient is disproportionately influenced by outlier data[3]. Spearman's *rho* is less influenced by outlier data and does not assume the data are distributed normally, but it cannot be readily calculated in Excel.

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[3] An outlier is a value far from most others in a set of data.

3 Results

The data in Tables 3.1–3.20 refer to utility-piped water supplies, which was the only technology in Jordan to qualify for inclusion in the RADWQ survey (i.e. at least 5% of the population was served by the technology). RADWQ Level 1 parameters for drinking-water quality are summarized in Annex 10.

3.1 Microbiological parameters

Thermotolerant coliforms were used as indicator bacteria to assay the bacteriological contamination of drinking-water supplies, and were detected in only one sample, from the Almafraq governorate in the north-east of Jordan (Tables 3.1, 3.2). All samples met both WHO and national standards for faecal streptococci. Thus, overall compliance of the Jordanian piped water system was high for bacteriological parameters (99.9–100%, Table 3.1).

Table 3.1 **Compliance of Jordanian utility piped water supplies with WHO guideline values and national standards for bacteriological parameters**[a]

Broad area	Thermotolerant coliforms			Faecal streptococci		
	n	**Compliance with WHO GV (%)**	**Compliance with national standard (%)**	***n***	**Compliance with WHO GV (%)**	**Compliance with national standard (%)**
Amman	611	100.0	100.0	50	100.0	100.0
Albalqa	146	100.0	100.0	9	100.0	100.0
Alzarqa	244	100.0	100.0	20	100.0	100.0
Madaba	25	100.0	100.0	5	100.0	100.0
Irbed	270	100.0	100.0	30	100.0	100.0
Almafraq	73	98.6	98.6	5	100.0	100.0
Jarash	73	100.0	100.0	4	100.0	100.0
Ajloun	49	100.0	100.0	5	100.0	100.0
Alkarak	73	100.0	100.0	5	100.0	100.0
Altafiela	25	100.0	100.0	5	100.0	100.0
Ma'an	25	100.0	100.0	5	100.0	100.0
Aqaba	25	100.0	100.0	5	100.0	100.0
National	1 639	99.9	99.9	148	100.0	100.0

[a] *n* = total number of samples assessed. WHO GV = WHO guideline value.

Table 3.2 Bacterial counts for Jordanian utility piped water supplies[a]

Count category (cfu/100 ml)	Thermotolerant coliforms		Faecal streptococci	
	(%)	Cumulative frequency (%)	(%)	Cumulative frequency (%)
<1	99.9	99.9	100.0	100.0
1-10	0.1	100.0	0	100.0
11-100	0	100.0	0	100.0
>100	0	100.0	0	100.0
Total number of samples assayed	1639		148	

[a] cfu = colony forming unit. The percentages in the table refer to the proportions of the total water supplies assayed that fall into the corresponding count category.

3.2 Chemical parameters

Jordanian piped water supplies were tested for three chemical parameters: arsenic, fluoride and nitrate. All of the samples analysed met WHO and national standards for arsenic and fluoride (Tables 3.3, 3.4). In contrast, water supplies in the Amman and Alzarqa governorates were contaminated with nitrate (Table 3.5). The Amman and Alzarqa governorates are both urban areas, and it is considered likely that the contamination originates from the sewer systems, which has old pipes, and from frequent interruptions to the water supplies.

Table 3.3 Compliance of Jordanian utility piped water supplies with WHO guideline values and national standards for arsenic[a]

Broad area	Arsenic		
	n	Compliance with WHO GV of 0.01 mg/l (%)	Compliance with national standard of 0.01 mg/l (%)
Amman	611	100.0	100.0
Albalqa	146	100.0	100.0
Alzarqa	244	100.0	100.0
Madaba	25	100.0	100.0
Irbed	270	100.0	100.0
Almafraq	73	100.0	100.0
Jarash	73	100.0	100.0
Ajloun	49	100.0	100.0
Alkarak	73	100.0	100.0
Altafiela	25	100.0	100.0
Ma'an	25	100.0	100.0
Aqaba	25	100.0	100.0
National	1 639	100.0	100.0

[a] *n* = total number of samples assessed. WHO GV = WHO guideline value.

Table 3.4 Compliance of Jordanian utility piped water supplies with WHO guideline values and national standards for fluoride[a]

Broad area	Fluoride		
	n	Compliance with WHO GV of 1.5 mg/l (%)	Compliance with national standard of 2.0 mg/l (%)
Amman	611	100.0	100.0
Albalqa	146	100.0	100.0
Alzarqa	244	100.0	100.0
Madaba	25	100.0	100.0
Irbed	270	100.0	100.0
Almafraq	73	100.0	100.0
Jarash	73	100.0	100.0
Ajloun	49	100.0	100.0
Alkarak	73	100.0	100.0
Altafiela	25	100.0	100.0
Ma'an	25	100.0	100.0
Aqaba	25	100.0	100.0
National	1 639	100.0	100.0

[a] *n* = total number of samples assessed. WHO GV = WHO guideline value.

Table 3.5 Compliance of Jordanian utility piped water supplies with WHO guideline values and national standards for nitrate[a]

Broad area	Nitrate			
	n	Compliance with WHO GV of 50 mg/l (%)	Compliance with allowed national standard of 50 mg/l (%)	Compliance with maximum national standard of 70 mg/l (%)
Amman	611	94.4	94.4	100.0
Albalqa	146	100.0	100.0	100.0
Alzarqa	244	99.6	99.6	100.0
Madaba	25	100.0	100.0	100.0
Irbed	270	100.0	100.0	100.0
Almafraq	73	100.0	100.0	100.0
Jarash	73	100.0	100.0	100.0
Ajloun	49	100.0	100.0	100.0
Alkarak	73	100.0	100.0	100.0
Altafiela	25	100.0	100.0	100.0
Ma'an	25	100.0	100.0	100.0
Aqaba	25	100.0	100.0	100.0
National	1 639	97.9	97.9	100.0

[a] *n* = total number of samples assessed. WHO GV = WHO guideline value.

3.3 Aesthetic parameters

The three aesthetic parameters tested were conductivity, iron content and turbidity. Conductivity was used as a surrogate for the level of dissolved solids in the water supplies and hence was a measure of the salinity of the water. For almost the entire country, conductivity was above the Jordanian permitted limit of 700 μS/cm, although none of the water supplies exceeded the Jordanian maximum limit of 2100 μS/cm (Table 3.6).

Table 3.6 **Compliance of Jordanian utility piped water supplies with WHO recommendations and national standards for conductivity**[a]

Broad area	**Conductivity**			
	n	**Satisfying WHO suggested value of 1400 μS/cm (%)**	**Compliance with allowed national standard of 700 μS/cm (%)**	**Compliance with maximum national standard of 2100 μS/cm (%)**
Amman	611	100.0	3.3	100.0
Albalqa	146	100.0	33.6	100.0
Alzarqa	244	94.7	0.4	100.0
Madaba	25	100.0	0	100.0
Irbed	270	100.0	15.9	100.0
Almafraq	73	100.0	38.4	100.0
Jarash	73	100.0	28.8	100.0
Ajloun	49	100.0	18.4	100.0
Alkarak	73	91.8	15.1	100.0
Altafiela	25	100.0	96.0	100.0
Ma'an	25	100.0	44.0	100.0
Aqaba	25	100.0	56.0	100.0
National	1 639	98.8	14.1	100.0

[a] *n* = total number of samples assessed.

Water supplies in the Albalqa, Alzarqa and Ajloun governorates were contaminated with iron, which likely was caused by rusting pipes and intermittent water supplies (Table 3.7). Generally, Jordanian water supplies were clear: All of the samples had a turbidity of less than 5 NTU, and 99.8% of the samples were in compliance with the more stringent allowed national standard of 1 NTU (Table 3.8).

Table 3.7 Compliance of Jordanian utility piped water supplies with WHO recommendations and national standards for iron[a]

Broad area	Iron			
	n	Satisfying WHO suggested value of 0.3 mg/l (%)	Compliance with allowed national standard of 0.3 mg/l (%)	Compliance with maximum national standard of 1.0 mg/l (%)
Amman	611	100.0	100.0	100.0
Albalqa	146	91.8	91.8	100.0
Alzarqa	244	95.1	95.1	100.0
Madaba	25	100.0	100.0	100.0
Irbed	270	100.0	100.0	100.0
Almafraq	73	100.0	100.0	100.0
Jarash	73	100.0	100.0	100.0
Ajloun	49	93.9	93.9	100.0
Alkarak	73	100.0	100.0	100.0
Altafiela	25	100.0	100.0	100.0
Ma'an	25	100.0	100.0	100.0
Aqaba	25	100.0	100.0	100.0
National	1 639	98.4	98.4	100.0

[a] *n* = total number of samples assessed.

Table 3.8 Compliance of Jordanian utility piped water supplies with WHO recommendations and national standards for turbidity[a]

Broad area	Turbidity			
	n	Satisfying WHO suggested value of 5 NTU (%)	Compliance with allowed national standard of 1 NTU (%)	Compliance with maximum national standard of 5 NTU (%)
Amman	11	100.0	100.0	100.0
Albalqa	46	100.0	100.0	100.0
Alzarqa	44	100.0	100.0	100.0
Madaba	5	100.0	100.0	100.0
Irbed	70	100.0	100.0	100.0
Almafraq	3	100.0	98.6	100.0
Jarash	3	100.0	100.0	100.0
Ajloun	9	100.0	95.9	100.0
Alkarak	3	100.0	98.6	100.0
Altafiela	5	100.0	100.0	100.0
Ma'an	5	100.0	100.0	100.0
Aqaba	5	100.0	100.0	100.0
National	639	100.0	99.8	100.0

[a] *n* = total number of samples assessed.

3.4 Overall compliance

The RADWQ survey results were consistent with those of the Jordanian national surveillance system, and confirmed that drinking-water quality was generally high in the distribution network. Overall compliance with WHO guideline values and national standards was 97.8% (including chemicals relevant to health), but this increased to 99.9% if the Jordanian maximum permitted limits were used as references (Table 3.9).

Table 3.9 **Overall compliance of Jordanian utility piped water supplies with WHO guideline values and national standards**[a]

Broad area	Overall compliance			
	n	Compliance with WHO GVs (%)	Compliance with allowed national standards (%)	Compliance with maximum national standards (%)
Amman	611	94.4	94.4	100.0
Albalqa	146	100.0	100.0	100.0
Alzarqa	244	99.6	99.6	100.0
Madaba	25	100.0	100.0	100.0
Irbed	270	100.0	100.0	100.0
Almafraq	73	98.6	98.6	98.6
Jarash	73	100.0	100.0	100.0
Ajloun	49	93.9	93.9	100.0
Alkarak	73	100.0	100.0	100.0
Altafiela	25	100.0	100.0	100.0
Ma'an	25	100.0	100.0	100.0
Aqaba	25	100.0	100.0	100.0
National	1 639	97.8	97.8	99.9

[a] Compliance was calculated for thermotolerant coliforms, arsenic, fluoride and nitrate. *n* = total number of samples assessed. WHO GVs = WHO guideline values.

3.5 Sanitary risk factors

The sanitary risk inspections (Tables 3.10–3.12) showed that the most common risk factors for the water supplies included:

- Sewer lines close to the water distribution network. This is frequently unavoidable, especially in urban settings.
- A failure to maintain household storage tanks. Water storage tanks are common in all water-scarce countries, including Jordan, where intermittent water supplies have increased the need for storage. Poor maintenance of the tanks increases the risk that water will become contaminated, which in turn would jeopardize the health of individuals using the household water supply.
- Old pipes in the water distribution network. Many pipes in the network are rusted and leak, and need to be replaced to reduce losses and breakdowns in the supply system, as well as to prevent iron contamination of the piped water (Table 3.7).

Table 3.10 **Responses to sanitary risk questions for the piped water treatment process in Jordan**

Sanitary risk inspection question	**Frequency of affirmative response (%)**
1. Are cracks evident in the pre-filters?	0
2. Are there leaks in the mixing bag?	0
3. Is the mixing tank insanitary?	0
4. Are hydraulic surges evident at the intake?	0
5. Is any sedimentation tank insanitary?	0
6. Is the distribution of the air and water supply uneven in any sand bed?	0
7. Are there mud balls or cracks in any of the filters, or is the filter performance not good?	0
8. Are cross-connections evident between the backwashed and treated water?	0
9. Is there evidence that insufficient doses of coagulant (e.g. alum) have been used?	0
10. Is the minimum free residual chlorine concentration (0.2 mg/l) not being achieved, or is the retention tank missing?	0
Total number of samples = 6	

Table 3.11 **Responses to sanitary risk questions for the piped water distribution system in Jordan**

Sanitary risk inspection question	**Frequency of affirmative response (%)**
1. Do any taps or pipes leak at the sample site?	12.4
2. Does water collect around the sample site?	12.3
3. Is the area around the tap insanitary?	4.0
4. Is there a sewer or latrine within 30 m of any tap?	95.2
5. Has there been a service disruption in the last 10 days?	43.4
6. Is the water-supply main exposed in the sampling area?	0.6
7. Have users reported any breaks in the pipes within the last week?	17.6
8. Is the supply tank cracked or leaking?	0.4
9. Are the vents and covers on the water tank damaged or open?	0.4
10. Is the inspection cover, or the concrete around the cover, damaged or corroded?	0.0
Total number of samples = 1 632	

Table 3.12 **Responses to sanitary risk questions for household piped water in Jordan**

Sanitary risk inspection question	Frequency of affirmative response (%)
1. Is the main source tap located outside the house?	27.3
2. Is the water stored in a container (including rooftop tanks or underground tanks) inside the house/building?	51.3
3. Are any taps leaking or damaged?	14.9
4. Are any taps shared with other households?	0.0
5. Is the area around the main source tap insanitary?	1.3
6. Are there any leaks in the household pipes?	6.5
7. Do animals have access to the area surrounding the pipe?	1.3
8. Have users reported pipe breaks in the last week?	22.1
9. Has the water supply been interrupted in the last week?	50.0
10. Is the water obtained from more than one source?	0.0
Total number of samples = 155	

3.6 Risk-to-health analysis for Jordanian utility piped water supplies

The risk-to-health analysis indicates the potential risk to health by comparing the sanitary risk score with the bacterial count (Table 3.13). For a given sample site, a very low risk score and a very low bacterial count indicate a very low risk to health. As the risk score, the bacterial count, or both increase, the risk to health also increases. The RADWQ results for Jordan show a very low risk to health in 75.3% of the piped water supplies analysed, and a low risk to health in the remaining 24.7%.

Table 3.13 **Risk-to-health analysis for thermotolerant coliforms, Jordanian utility piped water supplies**[a]

Sanitary inspection score	Thermotolerant coliform count (cfu/100 ml)			
	<1	1–10	11–100	>100
0–2	1233	1	0	0
3–5	404	0	0	0
6–8	0	0	0	0
9–10	0	0	0	0

Risk category	Number of supplies	Proportion of total (%)
Very low	1233	75.3
Low	405	24.7
Medium	0	0
High	0	0

[a] Risk-to-health categories: very low ( ); low ( ); medium ( ); high ( ).

3.7 Analysis of proxy parameters

A proxy analysis for bacteria was not possible because bacterial counts were <1 cfu/100ml for all samples except one. Similarly, a proxy analysis for arsenic was not possible because all the water samples tested had arsenic concentrations <0.01 mg/l. Proxy analyses were possible for conductivity versus nitrate (Figure 3.1) and conductivity versus fluoride (Figure 3.2), and the Pearson's *r* analysis is shown in Table 3.14. Given the small values of Pearson's *r* (0.13, 0.09), no useful correlations can be assumed for either chemical.

Figure 3.1 **Conductivity as a proxy for nitrate levels in Jordanian piped water supplies**

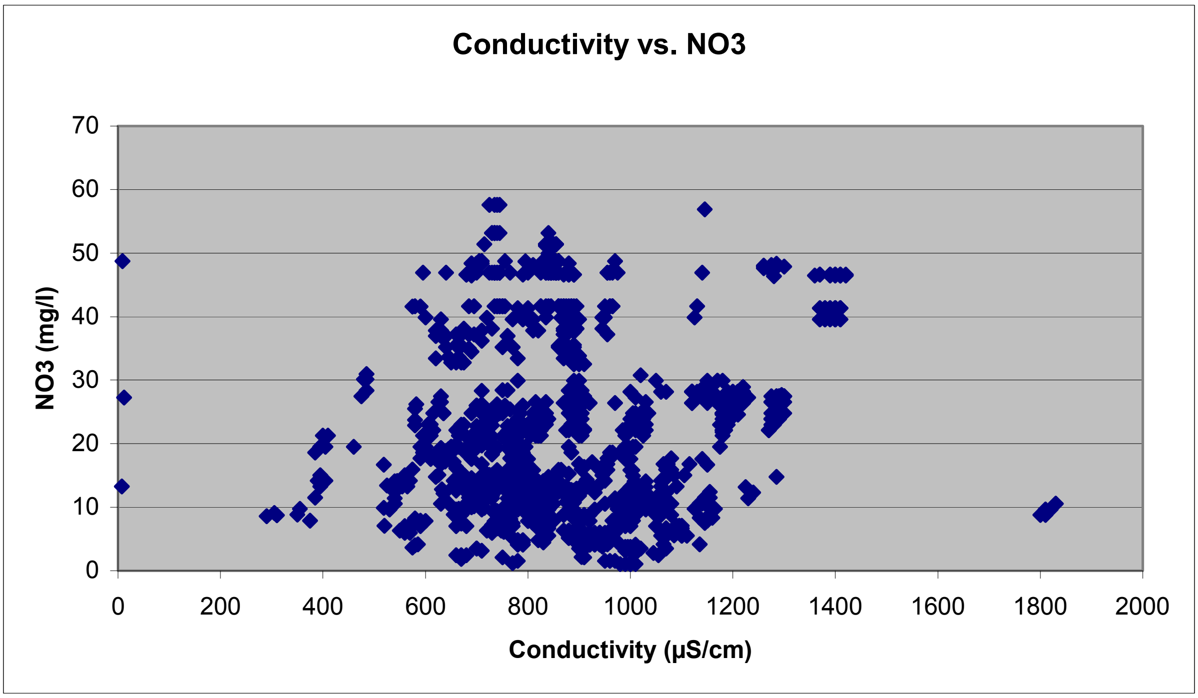

Figure 3.2 **Conductivity as a proxy for fluoride levels in Jordanian piped water supplies**

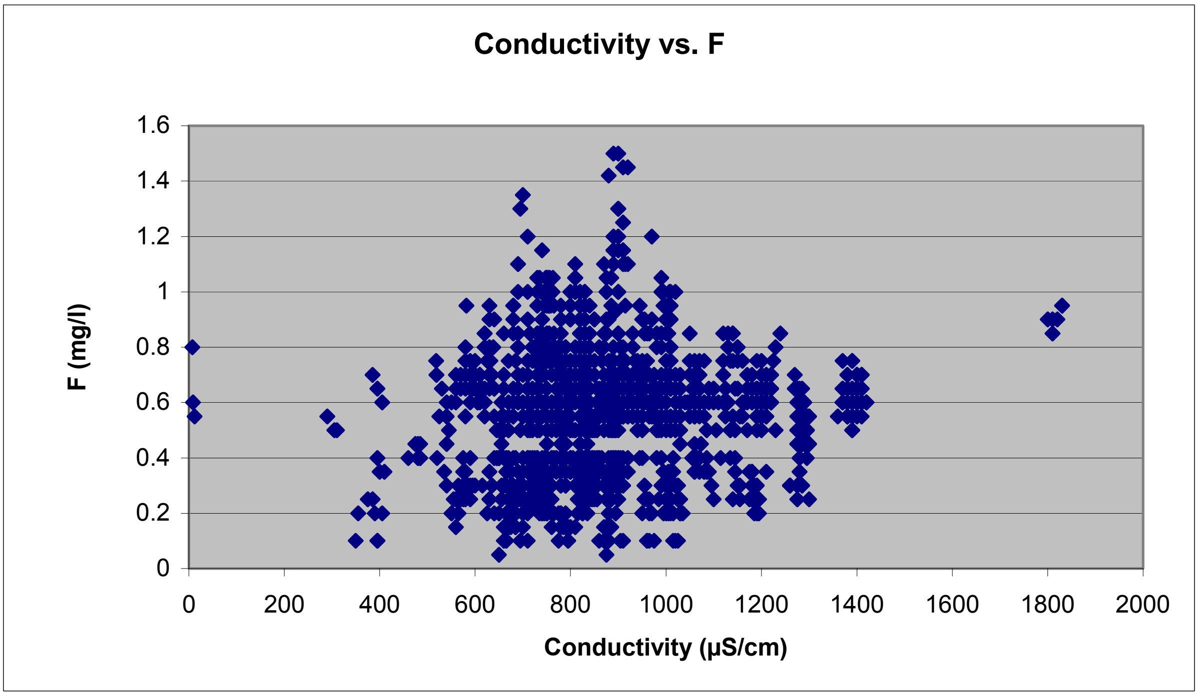

Table 3.14 **Pearson's *r* analysis of proxy parameters**

Technology	Conductivity versus	
	Nitrate	Fluoride
Utility piped water supply	0.13	0.09

3.8 Household water quality compared with mains water quality

The household water supplies met WHO guideline value and national standard for thermotolerant coliforms (Tables 3.15), even though a comparison of household water samples with water from the piped utility system showed that all household samples had lower concentrations of free chlorine than found in the utility piped water system (Table 3.16). This indicated that chlorine levels in household water supplies were nevertheless adequate to ensure safe water, which was consistent with the fact that the thermotolerant coliform count was the same for both source and corresponding household water supplies (Table 3.17). As a result, 77.4% of the household water supplies fell into the very low risk category for thermotolerant coliform contamination, with the remaining supplies in the low risk category (Table 3.18).

Table 3.15 **Compliance of Jordanian household-piped water supplies with WHO guideline value and national standard for thermotolerant coliforms**[a]

Technology	*n*	Proportion of total samples in compliance with WHO guideline value (%)	Proportion of total samples in compliance with national standard (%)
Household piped water	155	100.0	100.0

[a] *n* = total number of samples assessed.

Table 3.16 **Free chlorine concentrations in corresponding source and household water supplies**

Free chlorine concentration in household water compared with the source	Range	Number of samples	Proportion of total (%)
Increased by	≤10%	0	0.0
	>10%	0	0.0
Decreased by	≤10%	155	100.0
	>10%	0	0.0

Table 3.17 **Comparison of thermotolerant coliform counts in corresponding source and household water supplies**

Thermotolerant coliform count in household water compared with the source	Number of samples	Proportion of total (%)
Lower	0	0
Equal	155	100
Higher	0	0

Table 3.18 **Risk-to-health analysis for thermotolerant coliforms, Jordanian household piped water supplies**[a]

Sanitary inspection score	Thermotolerant coliform count (cfu/100 ml)			
	<1	1–10	11–100	>100
0–2	120	0	0	0
3–5	35	0	0	0
6–8	0	0	0	0
9–10	0	0	0	0

Risk category	Number of supplies	Proportion of total (%)
Very low	120	77.4
Low	35	22.6
Medium	0	0
High	0	0

[a] Risk-to-health categories: very low ( ); low ( ); medium ( ); high ( ).

More than half of the household water samples had higher nitrate levels than water in the utility system (Table 3.19), indicating that contamination occurred between the network pipes and the household taps. There are many possible reasons for this, such as poor maintenance of rooftop water reservoirs.

Table 3.19 **Nitrate concentrations in corresponding source and household water supplies**

Nitrate concentration in household water compared with the source	Range	Number of samples	Proportion of total (%)
Increased by	≤10%	18	11.6
	>10%	70	45.2
Decreased by	≤10%	54	34.8
	>10%	0	0.0

3.9 Quality control procedures

Field teams followed the methods suggested in the RADWQ project handbook. Officers from the Water Authority of Jordan and Ministry of Health who were in charge of quality control checked the record sheets before passing them to the data manager. The field results were also double-checked in the laboratory every week. No sample failed the quality control screen and therefore no suspect samples were recorded.

Table 3.20 **Summary of quality control procedures**

	Parameter	
	Bacteriological	**Chemical**
Frequency	Once per day	Once per week
Test	Is sample within 95% confidence interval?	Is sample within 10% precision?
Action if test is failed	Sample is marked suspect	Sample is marked suspect

4 Conclusions and recommendations

4.1 Water quality in Jordanian piped utility supplies

The RADWQ survey results were consistent with those of the Jordanian national surveillance system, and confirmed that drinking-water quality was generally high in the distribution network. Overall compliance with WHO guideline values and national standards was 97.8% (including chemicals relevant to health), but this increased to 99.9% if the Jordanian maximum limits were used for those cases in which an alternative water supply was not available (Table 3.9).

- *Thermotolerant coliforms*: Compliance of the piped water system was high for bacteria, at 99.9%, and thermotolerant coliforms were detected in only one sample, from the Almafraq governorate in the north-east of Jordan (Table 3.1).
- *Nitrate*: Water supplies in the Amman and Alzarqa governorates were contaminated with nitrate (Table 3.5). The Amman and Alzarqa governorates are both urban areas, and it is likely the contamination originated from the sewer systems, which had old pipes, and from frequent interruptions to the water supplies.
- *Conductivity*: The conductivity of the water supplies was above the Jordanian permitted limit of 700 µS/cm for almost the entire country, although 100% of the water supplies were in compliance with the Jordanian maximum limit of 2100 µS/cm (Table 3.6).
- *Iron*: Water supplies in the Albalqa, Alzarqa and Ajloun governorates were contaminated with iron. The likely causes were rusting old pipes and intermittent water supplies (Table 3.7).

A comparison of household water samples with water from the piped utility system showed that all household samples had lower concentrations of free chlorine than in the utility water system (Table 3.16). The household water was bacteriologically safe, however, indicating that chlorine levels in household water supplies were nevertheless adequate to ensure safe water (Table 3.17). Nitrate levels were higher in more than half of the household water samples, compared with water in the utility system (Table 3.19), indicating that some contamination occurred between the network pipes and the household taps. There could have been many reasons for this, such as poor maintenance of rooftop water reservoirs.

4.2 Sanitary risk factors for Jordanian water supplies

The results of the sanitary risk inspections showed that the most common risk factors for the water supplies included:

- The presence of sewer lines close to the water distribution network, which was unavoidable, especially in urban settings.
- A failure to properly maintain household storage tanks, which are common in all water-scarce countries, including Jordan, where intermittent water supplies have increased the need for storage. The lack of sound management to prevent contamination of the water increases the risk to the household water supplies.
- Old pipes in the water distribution network, which needed to be replaced to reduce losses and breakdowns in the supply system.

4.3 The RADWQ project in Jordan

Methodology

- The RADWQ methodology was clear and the chosen parameters produced a good snapshot of water quality in Jordan.
- The standard sanitary risk questionnaires used in the pilot project were not completely appropriate for Jordan. Sanitary risk questionnaires should be adapted to the local situation.
- The RADWQ field tests are not appropriate for regular surveillance programmes because of expense and because laboratory tests are more aseptic and efficient.
- The RADWQ methodology could be used for specific studies, such as rapid assessments of emerging risks and specific chemicals, or to audit existing surveillance data.
- The RADWQ pilot projects assessed water quality across different developing countries. For a wider analysis, the pilot studies could have included more industrialized and developed countries.

Project management and implementation

- The main problems with in-country management of the project were confusion over WHO and UNICEF roles, and on the budget available. This altered the workplan and delayed implementation of the field tests.
- Neither the Ministry of Health nor the Water Authority of Jordan had funds readily available for project implementation. The field coordinator for the Water Authority of Jordan had to advance money from his own pocket, and then be reimbursed from UNICEF and WHO.
- Because of budget constraints cars could be hired for only two field teams, instead of four. The two teams had to visit two clusters per week, and faced serious difficulties and worked long hours. The fact that the project was not delayed suggests that the cluster size chosen during the survey design was probably too small.
- Field implementation of the RADWQ survey was generally well-planned and the survey helped to strengthen collaboration among national agencies.
- WHO and UNICEF provided good in-country and remote technical support, and the training materials were clear.

Field kits

- The field kits used in the RADWQ survey were less sophisticated than those commonly used in Jordan, but they will be useful for future field tests.
- The digital arsenator originally sent to Jordan was not working and it took Wagtech two months to replace it, by which time field teams were accustomed to not using it. There were also safety concerns about the arsenic fumes.
- The consumables for assaying total chlorine levels in the water samples did not work properly, and it took Wagtech 10 weeks to replace them.
- Wagtech training on field equipment was good.

Data storage software

The SanMan data storage software was not user-friendly. For example, it did not allow data to be cut from one spreadsheet and pasted to another, and data entry was therefore very slow (1–2 hours/cluster). There were also problems with the password and with the import/export function. Overall, the SanMan software package was not user-friendly, it was deficient in some basic utility functions and had some bugs.

4.4 Suggestions for improving the RADWQ methodology

- The sample size was fine because it allowed a large, wide-area survey and a comparison with other pilot countries. But adapting future surveys to local conditions, using historical data on drinking-water quality as a guide, would be an improvement.
- For countries with small populations, the size of the zone chosen for the RADWQ survey should contain fewer than the 5000 people recommended in the RADWQ handbook, otherwise the number of water supplies available for assessment would be smaller than the recommended sample size.
- The number of household samples assayed should be increased for countries like Jordan, where piped water coverage is extensive, but water supplies are intermittent.
- The sanitary risk inspection questionnaires should be tailor-made to reflect local hazards and risk factors.
- The SanMan data storage software should be improved. An alternative would be to use readily available software, such as Microsoft Excel or Access.
- To reflect the worst situation for drinking-water quality in Jordan, the RADWQ survey should be conducted during the summer months.

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Annex 1 RADWQ Steering Committee for Jordan

Name	Job title	Organization	E-mail	Tel./fax
Hamed Bakir	Regional Adviser, Centre for Environmental Health	World Health Organization	bakirh@who-ceha.org.jo	+962 6 5524655
Zakaria Tarawneh	Assistant Secretary General, Laboratories and Quality Affairs	Water Authority of Jordan	zakft@hotmail.com	+962 (0) 77 519307
Nawal Sunna'	Director, Laboratories and Quality Department	Water Authority of Jordan	nawalborgan@yahoo.com	+962 (0) 77 399838
Salah Hiari	Director, Environmental Health Department	Ministry of Health	env@moh.gov.jo	+962 6 5685396/ +962 6 5666147
Mohamad Abadi	Head, Water Section	Ministry of Health	mohd_abadi@yahoo.com	+962 6 5685396/ +962 6 5666147
Bashar Smadi	Assistant Professor	University of Jordan	alsmadib@yahoo.com	+962 (0) 79 5575246
Fayez Abdullah	Assistant Professor	Jordan University for Science and Technology	fabdulla@just.edu.jo	+962 (0) 79 588016
Mohamad Khalaf	Researcher	Department of Statistics	Khalaf30@yahoo.com	+962 (0) 79 5880413
Mohamad Saidam	Director, EMARCU, UNICEF Consultant	Environment Monitoring & Research Central Unit (EMARCU), Royal Scientific Society	m.saidam@emarcu.gov.jo	+962 (0) 79 5157267
Amal Hijazi	Environment Officer	USAID	ahijazi@usaid.gov	+962 6 592 0101
Fida'a A. Jibril	Assistant to Dr Saidam	EMARCU	fida@emarcu.gov.jo	+962 6 5344701

Annex 2 RADWQ project team in Jordan

Role	Name	Job title	Organization	E-mail
Coordinator	Nawal Sunna'	Director , Laboratories and Quality Department	Water Authority of Jordan	nawalborgan@yahoo.com
International consultant	Federico Properzi	Short Term Consultant	World Health Organization	properzif@who.int
Statistician	Mohamad Khalaf	Researcher	Department of Statistics	Khalaf30@yahoo.com
Data manager	Rania Shaban	Head, Information Section	Water Authority of Jordan	r_m_shaban@hotmail.com
Field staff	Maher Hreishat	Head, Water Monitoring Section	Water Authority of Jordan	maher-h64@yahoo.com
Field staff	Louai Ilan	Technician	Water Authority of Jordan	
Field staff	Taha Samara	Technician	Water Authority of Jordan	
Field staff	Shawgi Marsouq	Engineer	Ministry of Health	sh_marzouq@hotmail.com
Field staff	Atta Mahmoud	Technician	Ministry of Health	
Field staff	Abdallah rawabdeh	Technician	Ministry of Health	
Field staff	Mahmoud Darwish	Technician	Ministry of Health	
Field staff	Zakaria Tarawneh	Assistant Secretary General	Water Authority of Jordan	
Field staff	Riffat Bani Khalaf	Extra staff	Water Authority of Jordan	
Field staff	Saleh Abu El-Heija	Extra staff	Water Authority of Jordan	

Annex 3 Map of Jordan and the eastern Mediterranean[a]

Map No. 4102 Rev. 3 UNITED NATIONS
August 2004

Department of Peacekeeping Operations
Cartographic Section

[a] Source: United Nations Cartographic Section. The designations do not imply any opinion whatsoever on the part of the United Nations or the World Health Organization concerning the legal status of any country, territory, city or area; or of their authorities; or concerning the delimitation of frontiers or boundaries.

Annex 4 Microbiological guidelines for Jordan

The Microbiological Guidelines for the quality of surface and ground drinking-water resources under the direct influence of surface contamination and the minimum treatment requirements for using them

Prepared by
The Higher Committee for Water Quality

July 2001

1- Scope:

These guidelines are concerned with the minimum requirements for treatment of public and private surface and ground water resources under the direct surface contamination, and are intended to be used for drinking domestic purposes. However these guidelines are not applicable to protected underground water resources.

2- Definitions:

2-1 Surface waters:

These are the running waters or waters of lakes, dams and ponds.

2-2 Underground waters under the direct surface contamination:

The underground waters of wells or springs whose physical and chemical properties change according to surface waters quality affecting them, and whose microbiological properties indicate the possibility of existence of pathogens therein by containing:

- ***Escherichia coli*** **(*E. Coli*)** counts of more than 20/100m1.

2-3 Disinfection:

This is the process of eliminating pathogenic microbes as well as the microbes indicating contamination through application of disinfectants such as chlorine, chlorine dioxide, ultraviolet rays, ozone or any other disinfectants approved by the official concerned parties.

2-4 Filtration:

Passing water through filtration barrier to remove pathogens and materials attached in water.

2-5 Protected underground resources:

These are wells and springs that the laboratory results of the samples thereof tested within one year indicate the stability of the microbiological, physical and chemical properties, provided that the *E. Coli* count shall be no more than 20/100m1 in any sample, and provided that such resources be subjected to microbiological test once every four months.

3- Water Resources Classification:

The water resources subject to these guidelines and requirements shall be classified into three categories:

3-1 First Category:

Water resources that can be exploited for drinking purposes by using the disinfection process only.

A. ***Criteria:***

1- ***E. Coli*** counts shall be no more than 20/100 ml in more than 20% of the tested samples within one year.
2- Turbidity concentration must not exceed (5) five units in any individual sample.
3- Hydrogen ion concentration must not be less than 6.5 and must not exceed 8.5 units.

B. ***Operation Procedures:***

Resource operation exploitation must be stopped in any of the following cases:

1- When any of the two guidelines mentioned in items 2,3 of A above is exceeded.
And operation of the resource shall not be resumed unless the results of all samples have met the guidelines mentioned above for two consecutive days.
2- If the ***E. Coli*** counts amount to 50/100 ml in any single sample.
And operation of the resource shall not be resumed unless the ***E. Coli*** counts are reduced to less than 50/100 ml in all samples tested for three consecutive days, at 2 samples / day minimum and at least at two hours intervals between one sample, and the other.
3- If the number of samples that contain more than 20 ***E. Coli*** per 100 ml exceeded 20% of the samples assumed to the tested within one year (except for the samples tested during the suspension period).

Operation of the resource shall not be resumed unless treatment station including necessary treatment processes is established according to guidelines stated for categories two or three of water resources.

3-2 ***Second Category:***

These are water sources that can be used for drinking purposes provided that they are subjected to both filtration and disinfection processes.

A. ***Criteria:***

These are the resources in which ***E. Coli*** counts exceed 20/100 ml in more than 20% of the samples and do not exceed 2000/100 in more than 20% of the tested samples within one year.

B. ***Treatment required***

These resources shall undergo treatment processes in any of the following methods prior to the final disinfection process, provided that the treatment processes as a whole shall include elimination of viruses at 99.99% (4 logarithms), ***Giardia*** and ***Cryptosporidium*** at 99.99% (4 logarithms).

1. rapid filtration
2. Membrane Filtration (Microfiltration, ultrafiltration and nano- Filtration .
3. Reverse Osmosis (RO).
4. Slow sand filtration preceded by mixing, coagulating and Settling.
5. Filtration with any other method approved by the Official concerned parties.

C. ***Operational procedures***

Resource operation must be discontinued in any of the following cases:

1. If the ***E.Coli*** counts in the resource amount to 5000 coli or more per 100ml in any single sample.
   And operation of the resource shall not be resumed unless the results of all tested samples within the suspension period were less than 5000/ 100 ml for three consecutive days, at 2 samples per day minimum, with at least two hours intervals between one sample and the other.
2. If the number of samples that contained more than 2000 ***E. Coli*** per 100 ml exceeded 20% of the samples assumed to be tested within one year (except for the samples tested during the suspension period).

Resource operation shall not be resumed, unless the said resources has been subjected to intensive treatment processes performed according to criteria approved for category three.

3-3 ***Third category:***

These are water resources that can be used for drinking purposes, provided that they are subjected to intensive treatment processes.

A. ***Criteria***

These are the resources in which ***E. Coli*** counts exceed 2000/ 100 ml in more than 20% of the samples tested within one year.

B. ***Treatment***

These resources shall undergo treatment processes further to what have been mentioned in the second category, provided that the treatment processes as a whole shall guarantee elimination of viruses at 99.99% (4 logarithms), and cryptosporidium at 99.99% (4 logarithms).

C. ***Operation procedures:***

Resource operation shall be stopped if ***E. Coli*** counts exceeded 2000/ 100 ml in any sample.
And operation of the resource shall not be resumed, unless the results of all tested samples within the suspension period were less than 20000/ 100 ml for three consecutive days, at 2 samples per day minimum, with at least two hours intervals between are sample and the other.

4- ***General Rules:***

1. In case no technical capacity for *E. Coli* test is available, then the total Thermotolerant coliform count (TTCC) shall be applied with the same guidelines.
2. Water resources classified within these guidelines shall be subjected to quality control at two samples per week minimum for raw water prior to treatment.
3. The owner of the water resource shall submit the necessary documents to the official water monitoring party, to ensure the efficiency of the treatment units proposed or used.

References

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Annex 5 Jordanian national standards for drinking-water[a]

Parameter	Acceptable level	Maximum allowable level
Microbiological		
Free-living organisms	Free	
Fungi	Free	
Total coliform count	<1.1/100 ml	
Membrane filtration	Negative	
Pathogenic enteric viruses and bacteria	<0/100 ml	
Pathogenic intestinal parasites	Free	
Pathogenic protozoa	Free	
Thermotolerant bacteria	<0/100 ml	
Physical		
Color	10 units	15 units
Taste and odour	acceptable to most consumers	
Turbidity	1 NTU	5 NTUs
Chemical		
Detergents (linear alkyl sulfonate)	0.2 mg/l	0.5 mg/l
pH	6.5–8.5 units	
Residual chlorine	0.2–1.0 mg/l	
Total dissolved solids	500 mg/l	1500 mg/l
Total hardness	300 mg/l	500 mg/l
Total trihalomethanes	0.15 mg/l	
Ag	0.1 mg/l	
Al	0.1 mg/l	0.2 mg/l
As	0.01 mg/l	
B	2 mg/l	
Ba	1.5 mg/l	
Cd	0.003 mg/l	
Cl	200 mg/l	500 mg/l
CN	0.07 mg/l	
Cr	0.05 mg/l	
Cu	1.0 mg/l	1.5 mg/l
F	2 mg/l	
Fe	0.3 mg/l	1.0 mg/l
Hg	0.002 mg/l	
Mn	0.1 mg/l	0.2 mg/l
Na	200 mg/l	400 mg/l
NH_4	0.5 mg/l	
Ni	0.07 mg/l	
NO_2	2 mg/l	
NO_3	50 mg/l	70 mg/l if there is no better resource
Pb	0.01 mg/l	
Sb	0.005 mg/l	
Se	0.05 mg/l	
SO_4	200 mg/l	500 mg/l
Zn	3 mg/l	5.0 mg/l

		Pesticides
Aldrin	0.03 µg/l	
Benzene	10.0 µg/l	
DDT	2.0 µg/l	
Dieldrin	0.03 µg/l	
Endrin	2.0 µg/l	
Ethylbenzene	500 µg/l	
Heptachlor epoxide and Heptchor	0.03 µg/l	
Lindane	4.0 µg/l	
Parathion	0.035 mg/l	
Tetrachloroethylene (PCE)	5.0 µg/l	
Toluene	300 µg/l	
Trichloroethylene (TCE)	5.0 µg/l	
Xylene	700 µg/l	
2,4-D	90 µg/l	
2,4,5-T	9.5 µg/l	

[a] Source: Jordan Ministry of Health., 2005

Annex 6 List of clusters used in the RADWQ survey for Jordan

Cluster No.	Governorate	Name of community	HH+FS[a]
1	Amman	Aljofeeh, Alnatheef, Um Tinah, Almanarah, Almareekh, Alqsoor, Alqalaa, Ain Qazal	+
2	Amman	Wadi Saqrah, Almohajreen, Nazal, Althraa. Alakhder	
3	Amman	Alashrafiyeh	
4	Amman	Sport City, Tlaa Alali, Alshmesani	+
5	Amman	Shfa Bdran, Soilh	
6	Amman	Al-Weibdeh, Al-Hussein, Jabal Amman	
7	Amman	Al-Radwan, Abdoon and Um Utheina	+
8	Amman	Altaj	
9	Amman	Alwehadat	
10	Amman	Alhashmie (North and South)	+
11	Amman	Marka 1 (Zahra')	
12	Amman	Marka 2 (Wadi Al-Esh)	
13	Amman	Marka 3 (Amir Hamza)	+
14	Amman	Marka 4 (Al-Nazir)	+
15	Amman	Almahta	
16	Amman	Tabrboor 1 (Abu Alia)	+
17	Amman	Tabrboor 2 (Tariq)	
18	Amman	Tabrboor 3 (Al-Shaheed)	
19	Amman	Tabrboor 4 (Al-Khazna)	+
20	Amman	Wadi Alseer	+
21	Amman	Medical City	
22	Amman	Alfisleeh, Sahib, Almoqar	+
23	Amman	Hammam Alshmot, Alnasreeh, Aljezah, West Arenba	
24	Amman	Aljezeeh, Alqastal	
25	Amman	Alqwesmeeh	+
26	Albalqaa	Alsaro Area, Alsaro Housing, Alyazedeeh, Armemeen, Um Jozeeh, Alsobihi, Arqwb Alrashed, Misrah, Batna, Naqb Aldboor, Wadi Alsalt, Aira, Yarqa	+
27	Albalqaa	W&N Biodah, Haqaweh, Jreesh, Alqaseeb, Wadi Alazab, Sihan, Aaleqoon. Somia, Alfhees, Mahes, Alhommer, Alhashmeeh, Daboq	
28	Albalqaa	Alsalt, Zay, Alawamleeh, Wadi Alnaqah, Daam, Salaoof, Kofer Houd, Mohammad Rasol Area, Arqweb, South Lmaslah	
29	Albalqaa	Abu Nseer, Mobas, Um Injasah, Um Alsandianah, Alsleehi, Um Aldananeer, Alhanoo, Aljaedeeh, Ain Albasha	+
30	Albalqaa	Albqaa Camp, Alshoihi	
31	Albalqaa	Dir Alaa Net, South Shonah, Aljoasreeh, Alkaramah, Wadi Albidd, Alrodah, Alkaramah, Wadi Alabidd, Alroiha, Drar, Abualzeqan, New Shoneih, Aljoofeh, Alrodeeh, Alkafreen, Alnahdah, Soima and hotels, Alloaa Net from South Maadi	
32	Alzarqa	New Zarqa	+
33	Alzarqa	Prince Mohammed Area	
34	Alzarqa	Alhouseen, Maasoum	
35	Alzarqa	Abed Allah	+
36	Alzarqa	Barzekh Area	+

37	Alzarqa	Shakeer	
38	Alzarqa	East and West Alhalabat, Alabdleeh and Main Aldleel, Alhashmeeh (Alnaser, Prince Mohammed area, Alhashmeeh housing, Alharareeh, Alsokhneeh, and the Alsokhneeh camp), Saroot Village, Alalook and Masrat	+
39	Alzarqa	Alraseefah	
40	Alzarqa	Awajan	
41	Alzarqa	Shniller, Jabal, Prince Faisal	+
42	Madaba	Alareed and its villages, Madaba, Jrent Hanita, Main, Alfaisaleeh, Theeban and its villages	+
43	Irbed	Jdeta, Bit Ibdes, Alkorah-Dir Abi Said and its villages, Altaibah, Dir Alsaanah, Kofer Youba, Jahfiah, Samad	+
44	Irbed	Kharja, Alzawiah, Hreema, Breshta, Alsilah, Alqasfah, Alyarmouk, Alkhreebah, Abu Alloqas, Mekhrba, Dir Alsaanah, Zebdah, Hofa Samad	+
45	Irbed	Almkheer, Marw, Alaal, Albiadah	
46	Irbed	Irbid City	+
47	Irbed	Irbid East area	
48	Irbed	Hekmah, Sal, Boshra, Doqra, Foaara	
49	Irbed	Alnaaemah, Kitm, Almofti camp	+
50	Irbed	Alhusn, Idoon, Sareh	+
51	Irbed	Alramtha, Alshajrah, Amrawah & Thneebah, Altorah	
52	Irbed	Almasharaa, Alrayan, Abusiedo, Sofrah, Kraimah, Abuhabeel, Abusiedo, Albaqorah, Wqas, Alsheekh Huseen, Alzamaliah	+
53	Irbed	Alshonah, Almansheeh, Upper Mkheeba, Lower Mkheeba	
54	Almafraq	Almafraq City, Somia, Rabaa, Sma Sarhan, Alkaieber, Mqeer Alsarahan, Jabber Pump Station (sometimes), Alaelemat Rahab, Ain, Alzafranah, Almamareeh, Dir Warq, West Boidah, Alkhanasry, Faa, Alhorsh, Hosha, Briqa and East Irbid and the line to Ramtha, Balaama, Hian Alroibed, Manshit Aalian, Alnmreh, Altarha, Alzneeh, Alzaitoonah, Almizraah, Althahreeh, The Prince Mohammad, Albostan, Hamnannah, Um Soioneeh, Khrisan, Almarajem	+
55	Almafraq	Authority, Albaaj, Alfehaleeh, Alboadi, Alnasreeh, Abu Alhial, Aljob, Alkhaldeeh Station, Um Allolo Station, Almafraq City, Alqadeer, Rojeb Sabaa, Um Alnaam, Boidt Alhoamdah, Khoo Station, Alzaraqa	
56	Almafraq	Jabber (downtown), Jabber (border), Alarqoob, Um Alsarb, Army, Alrooiai and Alnahda, Alsoilmah, Aldandanieh, Alhamraa, Aldrizi, Almoshref, Alakider, Aldaqmasah, Nadrah, Almjoy, Um Btemah, Hoeshan, Ain Alnabi, Alkhaldeeh, Almfrdat, Almabroukah, Almaherfeeh, Aldleel Farmers, Hammamt Alamoush, Alsahah, West Jarash, Aldajanieh, Almounifa, Alqadam, Almdour, Alkaram, Hmeed, Khatlah, Dahal, Um Hasmasah, Basmah, Alaqeeb, Amra and Aamerah, Kom Alraf, Sabea Seer, Abed Allah Prince area, Hmediat Almasaaid, Alshabar, Alaqeeb, Altaibah, Sabha, Sobhiah, Alhararah, Almanarah, Hamzah Prince area, Rahbet Rakad, Alhamidiah, Alashrafeeh, Alsaadah, Almanarah, Alhathem, Aljbeeh, Althalaj, Dir Alkahef, Khshaa Alqin, Dir Alqin, Almansorah, Aljadaah, Mathnat Rajel, Um Aljamal, Almakiftah/Alqano/Omqutain, Omqutain/Seleteen, Red Koom/Rasm, Alhiesan/Alrahmat/Albaag/Almshrfh/Alkmes, Alrafaaiat/Um Huseen/Arenbah/Qaseem, Albostanah, Rahbeeh, Rakad	

57	Jarash	Soof camp, Meqblah, Alshoahed, Asfoorah, Soof, Dir Allyat, Sakib	+
58	Jarash	Alkafeir, Jarash, Um Qantera, Alhazeeh, Alabbareh, Alnabi Houd	
59	Jarash	Debeen, Aljazazah, Jamla, Almajdel, Hamta and Aalimon, Alhadadah, Alketah, Manshet Bny Hasheem, Qazah Camp, Alfoareh, Alhoneeh, Borma, Khsheebah, Dibeen, Almajdal, Jamla, Talaat Alroz, Marsaa, Khofor Khall, Qafqafa, Nahleh, Balila, Mastabeh, Jipeh	
60	Ajloun	Baaoun which supplies Baaoun/Arjan/Rason/Osrah, and Ashtafiena which supplies Ajloon/Koferanjah/Anjarah/Ain Janah/Abeen/Lahna Altiearah	+
61	Ajloun	Rajeb and Thoqreet Zbeid, Zqeeq pump station 2/Zaqeeq reserve ware to Halawah Zqeeq reserve ware 4/Alwahadnieh/Alhashemeeh/Ashtfeena, the Law Kofrenjah area	
62	Alkarak	Alrayah/Alyaroot/Alhamaidah/Alamro/Alsamakeih/Hmoud, Alkarak/Almarj/Wadi Alkarak, Alqutranah	+
63	Alkarak	Almazar and Mouta, Alyaroot, Alqaser and Fqoa, Shahabieah	
64	Alkarak	Viva, Qour Alsafi, Qour Almazraah, South Mazar	
65	Altafielah	Alfosfat Min, Alqadisiah, Albaidaa Spring, Qasbet Altafielah, Alais, Abubena, Shethum, Alhasah, Alfosfat Housing City well	+
66	Ma'an	Ail, Alqaah, Bassta, Alzahraa, Alfardekh, Aljathah, Abualatham, Alshoubik, Alhashmieah, Aniezah, Tel Borma, Aldaajanieah, Border Station, Old Village, Almoudorah,Alshiedieah, Almoudoura New Village, Alhosinieah, Alfajij, Ail, Alrajef, Altaibah, Aljafir, Bair, Alanab, Almashash, Alshohibaa, Kbidah, Sahb, Kabad, Alshidiah, Maan, Athroh, Bigal Jarbaa, Small Jarbaa, Alarjah, Altmieaah, Alshobouk, Aljaiah, Almeqaraeah, Almansourah, Aljhier, Shamakh, Aljneinah, Alrmelat, Hoalah Bdbedah, Albaqaah, Alhadadah, Almothalth, Alnahdah, Alzietonah, Mthiebeeh, Maqdas and Om Soan, Almrieqah, Wadi Mousa	+
67	Aqaba	Alquiera, Alaqaba City, Alrieshah, Alatehad and Alrashdieh, Alshakreeh, drum and drinking-water tankers	+

[a] Household and faecal streptococci assessments were carried out for 32 of 67 clusters (indicated by "+").

Annex 7 RADWQ survey budget for Jordan[a]

No.	Category	Institute	Cost (US$/person-hour)	Total person-hours	Subtotal (US$)	Remarks
1	Project coordinator	WAJ	4.05	204	826	
2	Field coordinator	WAJ	8.11	272	2 206	
3	Data Manager	WAJ	3.60	408	1 469	
4	Technician-1	WAJ	3.60	272	979	
5	Technician-2	WAJ	2.25	544	1 224	
6	Technician-3	WAJ	2.70	544	1 469	
7	MOH coordinator	MOH	4.51	170	767	
8	Field coordinator	MOH	3.60	170	612	
9	Technician-1	MOH	3.60	272	979	
10	Technician-2	MOH	2.25	544	1 224	
11	Technician-3	MOH	2.25	544	1 224	
12	Technician-4	MOH	2.25	544	1 224	
13	Transportation	All			3 425	Two vehicles @ 15–20 JD per day, depending on sampling location.
14	Consumables	All			280	Glass bottles
15	Accommodation	All			565	In Aqaba
	Total cost				18 473	

[a] UNICEF provided the summary of costs incurred by the Water Authority of Jordan (WAJ) and the Ministry of Health (MOH) for personnel, transportation, consumables and accomodation. Of the total budget, UNICEF provided US$ 13 786.80, and the balance (US$ 4686.20) was provided by WAJ and MOH. The WHO Regional Centre for Environmental Health Activities provided secretarial support to the steering committee, and financial and logistical support during the missions of the international consultant.

Annex 8 RADWQ field workplan

RADWQ field workplan – week 1

(10/10/2004 to 14/10/2004)

ID	Cluster / Name of Community / Sampling Areas	October 10, 2004 Sun Oct 10	Mon Oct 11	Tue Oct 12	Wed Oct 13	Thu Oct 14
0	RADWQ Field Workplan Modified - W1					
1	Cluster 60: Ajloun					
2	Baaoun, Arjan, Osrah + (Q.C for chemical analysis + 1 Q.C for TTC)	WAJ1+MOH1				
3	Ashtafiena, Koferanjah + (5 HH Samples + 1 Q.C for TTC)		WAJ1+MOH1			
4	Anjarah, Ain Janah, Rason + (1 Q.C for TTC)			WAJ1+MOH1		
5	Abeen/ Lahna Altiearah + (5 FS samples + 1 Q.C for TTC)				WAJ1+MOH1	
6	Cluster 61: Ajloun					
7	Rajeb & Thoqreet Zbeid + (Q.C for chemical analysis + 1 Q.C for TTC)	WAJ2+MOH2				
8	Zqeeq Pump Station 2/ Zaqeeq Reservoir + (1 Q.C for TTC)		WAJ2+MOH2			
9	Alwahadnieh & Alhashemeeh + (1 Q.C for TTC)			WAJ2+MOH2		
10	Ashtfeena & The Low Kofrenjah Area + (1 Q.C for TTC)				WAJ2+MOH2	
11	Cluster 43: Irbid					
12	Jdeta & Bit Ibdes + (Q.C for chemical analysis + 1 Q.C for TTC)	WAJ3+MOH3				
13	Alkorah- Dir Abi Said & Its Villages + (5 HH Samples + 1 Q.C for TTC)		WAJ3+MOH3			
14	Altaibah, Dir Alsaanah & Kofer Youba + (1 Q.C for TTC)			WAJ3+MOH3		
15	Jahfiah & Samad + (5 FS samples + 1 Q.C for TTC)				WAJ3+MOH3	
16	Cluster 44: Irbid					
17	Kharja, Alzawiah & Hreema + (Q.C for chemical analysis + 1 Q.C for TTC)	WAJ4+MOH4				
18	Breshta, Alsilah & Alqasfah + (5 HH Samples + 1 Q.C for TTC)		WAJ4+MOH4			
19	Alyarmouk, Alkhreebah & Abu Alloqas + (1 Q.C for TTC)			WAJ4+MOH4		
20	Mekhrba, Dir Alsaanah, Zebdah & Hofa Samad + (5 FS samples + 1 Q.C for				WAJ4+MOH4	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 2

(21/11/2004 to 25/11/2004)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Nov 21 Sun Nov 21	Mon Nov 22	Tue Nov 23	Wed Nov 24	Thu Nov 25
1	Cluster 45: Irbid					
2	Almkheer + (QC for chemical analysis + 1QC for TT	WAJ-T1+MOH-T1				
3	Marw + (1 QC for TTC)		WAJ-T1+MOH-T1			
4	Alaal + (1 QC for TTC)			WAJ-T1+MOH-T1		
5	Albiadah + (1 QC for TTC)				WAJ-T1+MOH-T1	
6	Cluster 46: Irbid					
7	Irbid City - 1 + (QC for chemical analysis + 1QC for T	WAJ-T2+MOH-T2				
8	Irbid City - 2 + (5HH sample + 1 QC for TTC))		WAJ-T2+MOH-T2			
9	Irbid City - 3 + (1 QC for TTC)			WAJ-T2+MOH-T2		
10	Irbid City - 4 + (5 FS analysis + 1 QC for TTC))				WAJ-T2+MOH-T2	
11	Cluster 47: Irbid					
12	Irbid East Area - 1+ (QC for chemical analysis + 1QC	WAJ-T1+MOH-T1				
13	Irbid East Area - 2 + (1 QC for TTC)		WAJ-T1+MOH-T1			
14	Irbid East Area - 3 + (1 QC for TTC)			WAJ-T1+MOH-T1		
15	Irbid East Area - 4 + (1 QC for TTC)				WAJ-T1+MOH-T1	
16	Cluster 48: Irbid					
17	Hekmah + (QC for chemical analysis + 1QC for TTC)	WAJ-T2+MOH-T2				
18	Sal + (1 QC for TTC)		WAJ-T2+MOH-T2			
19	Boshra + (1 QC for TTC)			WAJ-T2+MOH-T2		
20	Dogra & Foaara + (1 QC for TTC)				WAJ-T2+MOH-T2	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 3

(28/11/2004 to 2/12/2004)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Nov 28	Mon Nov 29	Tue Nov 30	Wed Dec 1	Thu Dec 2
		Sun Nov 28				
1	Cluster 49: Irbid					
2	Alnaaemah+ (QC for chemical analysis + 1QC for T	WAJ				
3	Kitm + (5HH sample + 1 QC for TTC)		WAJ			
4	Almofti Camp-1 + (1 QC for TTC)			WAJ		
5	Almofti Camp-2 + (5 FS analysis + 1 QC for TTC)				WAJ	
6	Cluster 50: Irbid					
7	Alhusn - 1 + (QC for chemical analysis + 1QC for TT	MOH				
8	Alhusn - 2 + (5HH sample + 1 QC for TTC)		MOH			
9	Idoon + (1 QC for TTC)			MOH		
10	Sareh + (5 FS analysis + 1 QC for TTC))				MOH	
11	Cluster 51: Irbid					
12	Alramtha + (QC for chemical analysis + 1QC for TTC	WAJ				
13	Alshajarah + (1 QC for TTC)		WAJ			
14	Amrawah + (1 QC for TTC)			WAJ		
15	Thneebah & Altorah + (1 QC for TTC)				WAJ	
16	Cluster 52: Irbid					
17	Almasharaa, Alrayan + (QC for chemical analysis +	MOH				
18	Sofrah, Kraimah, Abuhabeel + (5HH sample + 1 QC f		MOH			
19	Abusiedo, Albaqorah & Alsheekh Huseen,+ (1 QC f			MOH		
20	Wqas, Alzamaliah+ (5 FS analysis + 1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 4

(5/12/2004 to 9/12/2004)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Dec 5	Mon Dec 6	Tue Dec 7	Wed Dec 8	Thu Dec 9
		Sun Dec 5				
1	Cluster 53: Irbid					
2	Alshonah + (QC for chemical analysis +1 QC for TTC)	WAJ				
3	Almansheeh (1QC for TTC)		WAJ			
4	Upper Mkheeba + (1QC for TTC)			WAJ		
5	Lower Mkheeba + (1 QC for TTCC)				WAJ	
6	Cluster 54: Almafraq					
7	Almafraq City- Somia, Rabaa, Sma Sarhan. Alkaieber, Mqeer Alsarahan,, & Jabb PS (QC for chemical analysis + (1QC for TTC)	MOH				
8	Alaelemat Rahab, Ain, Alzafranah, Almamareeh, Dir Warq, West Boidah, Alkhanasry, Faa, Alhorsh, Hosha, Briqa & East Irbid & Line To Ramtha + (5HH sample + 1 QC for TTC)		MOH			
9	Balaama, Hian Alroibed, Manshit Aalian, Alnmreh, Altarha.Alzneeh, Alzaitoonah, Almizraah + (1 QC for TTC)			MOH		
10	Althahreeh, The Prince Mohammad, Albostan, Hamnannah, Um Soioneeh, Khrisan, Almarajem + (5 FS analysis + 1 QC for TTC))				MOH	
11	Cluster 55: Almafraq					
12	Authority, Albaaj, Alfehaleeh, Alboadi, + (QC for chemical analysis + 1QC for TTC	WAJ				
13	Alnasreeh, Abu Alhial, Aljob, Alkhaldeeh Station + (1 QC for TTC)		WAJ			
14	Um Allolo Station, Almafraq City, Alqadeer, Rojeb Sabaa + (1 QC for TTC)			WAJ		
15	Um Alnaam, Boidt Alhoamdah, Khoo Station, Alzaraqa + (1 QC for TTC)				WAJ	
16	Cluster 56: Almafraq					
17	Jabber Down Town, Jabber Border, Alarqoob, Um Alsarb, Army, Alrooiai & Alnahda, Alsoilmah, Aldandanieh, Alhamraa, Aldrizi, Almoshref, Alakider, Aldaqmasah, Nadrah, Almjoy, Um Btemah, Hoeshan, Ain Alnabi, Alkhald + (QC for chemical analysis + 1QC for TTC)	MOH				
18	Almabroukah, Almaherfeeh, Aldleel Farmers, Hammamt Alamoush, Alsahah, We Jarash, Aldajanieh, Almounifa, Alqadam, Almdour, Alkaram, Hmeed, Khatlah, Dahal, Um Hasmasah, Basmah, Alaqeeb, Amra & Aamerah, Kom Alraf, Sabea Seer, + (1 QC for TTC)		MOH			
19	Hmediat Almasaaid, Alshabar, Alaqeeb, Altaibah, Sabha, Sobhiah, Alhararah, Almanarah, Hamzah Princs Area, Rahbet Rakad, Alhamidiah, Alashrafeeh, Alsaadah, Almanarah, Alhathem, Aljbeeh, Althalaj, Dir Alkahef, Khshaa Alqin, Di Alqin. Almans+ (1 QC for TTC)			MOH		
20	Aljadaah. Mathnat Rajel, Um Aljamal, Almakiftah/Alqano/Omqutain, Omqutain/Seleteen, Red Koom/ Rasm Alhiesan/Alrahmat/Albaag/Almshrfh/Alkme Alrafaaiat/ Um Huseen/Arenbah/ Qaseem, Albostanah , Rahbeeh, Rakad+ (1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 5

(12/12/2004 to 16/12/2004)

ID	Cluster Name / Name of Community / Sampling Areas	
1	Cluster 57: Jarash	
2	Soof Camp, Meqbliah, Sakib PS (QC for chemical analysis + (1QC for TTC)	WAJ
3	Alhoshied, Arfoorah + (5HH sample + 1 QC for TTC)	WAJ
4	Soof, Dir Alyat + (1 QC for TTC)	WAJ
5	Sakib + (5 FS analysis + 1 QC for TTC))	WAJ
6	Cluster 58: Jarash	
7	Alkafeir + (QC for chemical analysis + (1QC for TTC)	MOH
8	Jarash + (1 QC for TTC)	MOH
9	Um Qantera, Alhazeeh + (1 QC for TTC)	MOH
10	Alabbareh, Alnabi Houd + (1 QC for TTC)	MOH
11	Cluster 59: Jarash	
12	Debeen, Aljazazah, Jamla, Almajdel, Hamta & Aslimon, Alhadadah, Alketah,+ (QC for chemical analysis + 1QC for TTC)	WAJ
13	Manshet Bny Hasheem, Gazah Camp, Alfoarah * Alhoneeh, Borma, Khsheebah, + (	WAJ
14	Dibeen. Almajdal, Jamla, Talaat Alroz, Marssa, Khofor + (1 QC for TTC)	WAJ
15	Khalil, Qafqafa, Nahleh, Balila, Mastabeh, Jipeh + (1 QC for TTC)	WAJ
16	Cluster 30: Albalqaa	
17	Down Albqaa Camp 1 + (QC for chemical analysis + 1QC for TTC)	MOH
18	Down Albqaa Camp 2 + (1 QC for TTC)	MOH
19	Down Albqaa Camp 3 + (1 QC for TTC)	MOH
20	Alholli + (1 QC for TTC)	MOH
21	Planning & Organizational Meetings	

RADWQ field workplan – week 6

(19/12/2004 to 23/12/2004)

ID	Cluster Name / Name of Community / Sampling Areas	
1	Cluster 26: Albalqaa	
2	Alsaro Area, Alsaro Housing, Alyazedeeh, (QC for chemical analysis + (1QC for TTC)	WAJ
3	Armemeen, Um Jozeeh, Alsobihi, + (5HH sample + 1 QC for TTC)	WAJ
4	Arqwb Alrashed, Misrah, Batna + (1 QC for TTC)	WAJ
5	Naqb Aldboor, Wadi Alsalt, Aira, Yarqa+ (5 FS analysis + 1 QC for TTC))	WAJ
6	Cluster 27: Albalqaa	
7	W&N Biodah, Haqaweh, Jreesh + (QC for chemical analysis + (1QC for TTC)	MOH
8	Alqaseeb, Wadi Alazab, Sihan + (1 QC for TTC)	MOH
9	Aaleqoon. Somia, Alfhees, Mahes + (1 QC for TTC)	MOH
10	Alhommer, Alhashmeeh, Daboq + (1 QC for TTC)	MOH
11	Cluster 28: Albalqaa	
12	Alsalt + (QC for chemical analysis + 1QC for TTC)	WAJ
13	Zay, Alawamleeh, Wadi Alnaqah + (1 QC for TTC)	WAJ
14	Daam, Salaoof, Kofer Houd + (1 QC for TTC)	WAJ
15	Mohammad Rasol Area, Arqweb, S.Lmaslah + (1 QC for TTC)	WAJ
16	Cluster 29: Albalqaa	
17	Abu Nseer + (QC for chemical analysis + (1QC for TTC)	MOH
18	Mobas, Um Injasah, Um Alsandianah + (5HH sample + 1 QC for TTC)	MOH
19	Alsleehi, Um Aldananeer, Alhanoo + (1 QC for TTC)	MOH
20	Aljaedeeh, Ain Albasha + (5 FS analysis + 1 QC for TTC))	MOH
21	Planning & Organizational Meetings	

RADWQ field workplan – week 7

(26/12/2004 to 30/12/2004)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Dec 26	Mon Dec 27	Tue Dec 28	Wed Dec 29	Thu Dec 30
1	Cluster 31: Albalqaa					
2	Dir Alaa Net, S, Shonah, Aljoasreeh, Alkaramah, + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Wadi Albidd, Alrodah, Alkaramah, Wadi Alabidd, Alroiha + (1 QC for TTC)		WAJ			
4	Drar, Abualzeqan, New Shoneih, Aljoofeh, Alrodeeh, + (1 QC for TTC)			WAJ		
5	Alkafreen, Alnahdah, Soima And Hotels, Alloaa Net From South Maadi + (1 QC for TTC)				WAJ	
6	Cluster 32: Alzarqa					
7	New Zarqa -1 + (QC for chemical analysis + (1QC for TTC)	MOH				
8	New Zarqa - 2 + (5HH sample + 1 QC for TTC)		MOH			
9	New Zarqa - 3 + (1 QC for TTC)			MOH		
10	New Zarqa - 4 + (5 FS analysis + 1 QC for TTC))				MOH	
11	Cluster 33: Alzarqa					
12	Prince Mohammed Area - 1+ (QC for chemical analysis + 1QC for TTC)	WAJ				
13	Prince Mohammed Area - 2 + (1 QC for TTC)		WAJ			
14	Prince Mohammed Area - 3 + (1 QC for TTC)			WAJ		
15	Prince Mohammed Area - 4 + (1 QC for TTC)				WAJ	
16	Cluster 34: Alzarqa					
17	Alhouseen - 1 + (QC for chemical analysis + (1QC for TTC)	MOH				
18	Alhouseen - 2 + (1 QC for TTC)		MOH			
19	Maasoum - 1 + (1 QC for TTC)			MOH		
20	Maasoum - 2 + (1 QC for TTC)				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 8

(02/01/2004 to 06/01/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Jan 2	Mon Jan 3	Tue Jan 4	Wed Jan 5	Thu Jan 6
1	Cluster 35:Alzarqa					
2	Abed Allah -1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Abed Allah- 2 + (5HH sample + 1 QC for TTC)		WAJ			
4	Abed Allah - 3 + (1 QC for TTC)			WAJ		
5	Abed Allah - 4 + (5 FS analysis + 1 QC for TTC))				WAJ	
6	Cluster 36: Alzarqa					
7	Barzekh Area -1 + (QC for chemical analysis + (1QC for TTC)	MOH				
8	Barzekh Area- 2 + (5HH sample + 1 QC for TTC)		MOH			
9	Barzekh Area- 3 + (1 QC for TTC)			MOH		
10	Barzekh Area - 4 + (5 FS analysis + 1 QC for TTC))				MOH	
11	Cluster 37: Alzarqa					
12	Shakeer - 1+ (QC for chemical analysis + 1QC for TTC)	WAJ				
13	Shakeer - 2 + (1 QC for TTC)		WAJ			
14	Shakeer - 3 + (1 QC for TTC)			WAJ		
15	Shakeer - 4 + (1 QC for TTC)				WAJ	
16	Cluster 38: Alzarqa					
17	East And West Alhalabat, Alabdleeh And Main Aldleel+ (QC for chemical analysis +	MOH				
18	Alhashmeeh Alnaser+ Prince Mohammed Area+ Alhashmeeh Housing+ Alhararee		MOH			
19	Alsokhneeh+ Alsokhneeh Camp + (1 QC for TTC)			MOH		
20	Saroot Village, Alalook And Masrat + (5 FS analysis + 1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 9
(09/01/2005 to 13/01/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Jan 9	Mon Jan 10	Tue Jan 11	Wed Jan 12	Thu Jan 13
1	Cluster 39:Alzarqa					
2	Alraseefah-1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Alraseefah-2+ (1 QC for TTC)		WAJ			
4	Alraseefah-3 + (1 QC for TTC)			WAJ		
5	Alraseefah-4 + (1 QC for TTC))				WAJ	
6	Cluster 40: Alzarqa					
7	Awajan-1+ (QC for chemical analysis + (1QC for TTC)	MOH				
8	Awajan-2 + (1 QC for TTC)		MOH			
9	Awajan-3 + (1 QC for TTC)			MOH		
10	Awajan-4+ (1 QC for TTC))				MOH	
11	Cluster 41: Alzarqa					
12	Shniller -1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
13	Shniller- 2 + (5HH sample + 1 QC for TTC)		WAJ			
14	Jabal Prince Faisal- 1 + (1 QC for TTC)			WAJ		
15	Jabal Prince Faisal - 2 + (5 FS analysis + 1 QC for TTC))				WAJ	
16	Cluster 42: Madaba					
17	Alareed And Its Villages + (QC for chemical analysis + (1QC for TTC)	MOH				
18	Madaba and Jrent Hanita + (5HH sample + 1 QC for TTC)		MOH			
19	Jrent Hanita and Main + (1 QC for TTC)			MOH		
20	Alfaisaleeh and Theeban + Its Villages + (5 FS analysis + 1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 10
(16/01/2005 to 20/01/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Jan 16	Mon Jan 17	Tue Jan 18	Wed Jan 19	Thu Jan 20
1	Cluster 62:Alkarak					
2	Alrayah, Alyaroot and Alhamaidah + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Alamro, Alsamakeih and Hmoud + (5HH sample + 1 QC for TTC)		WAJ			
4	Alkarak and Almarj + (1 QC for TTC)			WAJ		
5	Wadi Alkarak and Alqutranah + (5 FS analysis + 1 QC for TTC))				WAJ	
6	Cluster 63: Alkarak					
7	Almazar & Mouta + (QC for chemical analysis + (1QC for TTC)	MOH				
8	Alyaroot + (1 QC for TTC)		MOH			
9	Alqaser + (1 QC for TTC)			MOH		
10	Fqoa, Shahabieah + (1 QC for TTC))				MOH	
11	Cluster 64: Alkarak					
12	Viva + (QC for chemical analysis + (1QC for TTC)	WAJ				
13	Qour Alsafi + (1 QC for TTC)		WAJ			
14	Qour Almazraah + (1 QC for TTC)			WAJ		
15	South Mazar + (1 QC for TTC))				WAJ	
16	Cluster 65: Altafielah					
17	Alfosfat Min and Alqadisiah + (QC for chemical analysis + (1QC for TTC)	MOH				
18	Albaidaa Spring and Qasbet Altafielah + (5HH sample + 1 QC for TTC)		MOH			
19	Alais, Abubena and Shethum + (1 QC for TTC)			MOH		
20	Alhasah and Alfosfat Housing City Well + (5 FS analysis + 1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 11

(23/01/2005 to 27/01/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Jan 23	Mon Jan 24	Tue Jan 25	Wed Jan 26	Thu Jan 27
1	Cluster 66:Maan					
2	Ail, Alqaah, Bassta, Alzahraa, Alfardekh, Aljathah, Abualatham, Alshoubik, Alhashmieah, Aniezah, Tel Borma, Aldaajanieah, Border Station, Old Village, Almoudorah, + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Alshiedieah, Almoudoura New Village, Alhosinieah, Alfajij, Ail, Alrajef, Altaibah, Aljafir, Bair, Alanab. Almashash, Alshohibaa, Kbidah, Sahb, + (5HH sample + 1 QC for TTC)		WAJ			
4	Kabad, Alshidiah, Maan, Athroh, Bigal Jarbaa, Small Jarbaa. Alarjah, Altmieaah, Alshobouk, Aljaiah, Almeqaraeah, Almansourah, Aljhier + (1 QC for TTC)			WAJ		
5	Shamakh, Aljneinah, Alrmelat, Hoalah Bdbedah, Albaqaah, Alhadadah, Almothalth, Alnahdah, Alzietonah, Mthiebeeh, Maqdas And Om Soan, Almrieqah, Wadi Mousa+ (5 FS analysis + 1 QC for TTC))				WAJ	
6	Cluster 67: Aqaba					
7	Alquiera and Alaqaba City + (QC for chemical analysis + (1QC for TTC)	MOH				
8	Alrieshah Alatehad and Alrashdieh + (5HH sample + 1 QC for TTC)		MOH			
9	Alshakreeh + (1 QC for TTC)			MOH		
10	Rum & Drinking Water Tankers + (5 FS analysis + 1 QC for TTC))				MOH	
11	Cluster 1: Amman					
12	Aljofeeh and Alnatheef + (QC for chemical analysis + (1QC for TTC)	WAJ				
13	Um Tinah and Almanarah + (5HH sample + 1 QC for TTC)		WAJ			
14	Almareekh and Alqsoor + (1 QC for TTC)			WAJ		
15	Alqalaa and Ain Qazal + (5 FS analysis + 1 QC for TTC))				WAJ	
16	Cluster 2: Amman					
17	Wadi Saqrah + (QC for chemical analysis + (1QC for TTC)	MOH				
18	Almohajreen + (1 QC for TTC)		MOH			
19	Nazal and Althraa+ (1 QC for TTC)			MOH		
20	Alakhder + (1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					
22	Planning & Organizational Meetings 4					

RADWQ field workplan – week 12

(30/01/2005 to 03/02/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Jan 30	Mon Jan 31	Tue Feb 1	Wed Feb 2	Thu Feb 3
1	Cluster 3: Amman					
2	Alashrafiyeh-1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Alashrafiyeh-2 + (1 QC for TTC)		WAJ			
4	Alashrafiyeh-3 + (1 QC for TTC)			WAJ		
5	Alashrafiyeh-4 + (1 QC for TTC))				WAJ	
6	Cluster 4: Amman					
7	Sport City-1 + (QC for chemical analysis + (1QC for TTC)	MOH				
8	Sport City-2 + (5HH sample + 1 QC for TTC)		MOH			
9	Tlaa Alali + (1 QC for TTC)			MOH		
10	Alshmesani + (5 FS analysis + 1 QC for TTC))				MOH	
11	Cluster 5: Amman					
12	Shafa Badran-1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
13	Shafa Badran-2 + (1 QC for TTC)		WAJ			
14	Sweileh-1 + (1 QC for TTC)			WAJ		
15	Sweileh-2 + (1 QC for TTC))				WAJ	
16	Cluster 6: Amman					
17	Al-Weibdeh + (QC for chemical analysis + (1QC for TTC)	MOH				
18	Al-Hussein-1 + (1 QC for TTC)		MOH			
19	Al-Hussein-2 + (1 QC for TTC)			MOH		
20	Jabal Amman + (1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 13

(6/02/2005 to 10/02/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Feb 6	Mon Feb 7	Tue Feb 8	Wed Feb 9	Thu Feb 10
1	Cluster 7: Amman					
2	Al-Radwan + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Abdoon + (5HH sample + 1 QC for TTC)		WAJ			
4	Um Utheina-1 + (1 QC for TTC)			WAJ		
5	Um Utheina-2 + (5 FS analysis + 1 QC for TTC))				WAJ	
6	Cluster 8: Amman					
7	Altaj-1 + (QC for chemical analysis + (1QC for TTC)	MOH				
8	Altaj-2 + (1 QC for TTC)		MOH			
9	Altaj-3 + (1 QC for TTC)			MOH		
10	Altaj-4 + (1 QC for TTC))				MOH	
11	Cluster 9: Amman					
12	Alwehadat -1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
13	Alwehadat -2 + (1 QC for TTC)		WAJ			
14	Alwehadat -3 + (1 QC for TTC)			WAJ		
15	Alwehadat -4 + (1 QC for TTC))				WAJ	
16	Cluster 10: Amman					
17	Alhashmie N - 1 + (QC for chemical analysis + (1QC for TTC)	MOH				
18	Alhashmie N - 2 + (5HH sample + 1 QC for TTC)		MOH			
19	Alhashmie S - 1+ (1 QC for TTC)			MOH		
20	Alhashmie S - 2 + (5 FS analysis + 1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 14

(13/02/2005 to 17/02/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Feb 13	Mon Feb 14	Tue Feb 15	Wed Feb 16	Thu Feb 17
1	Cluster 11: Amman					
2	Marka 1 (Zahra') -1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
3	Marka 1 (Zahra') -2 + (1 QC for TTC)		WAJ			
4	Marka 1 (Zahra') -3 + (1 QC for TTC)			WAJ		
5	Marka 1 (Zahra')-4 + (1 QC for TTC))				WAJ	
6	Cluster 12: Amman					
7	Marka 2 (Wadi Al-Esh) -1 + (QC for chemical analysis + (1QC for TTC)	MOH				
8	Marka 2 (Wadi Al-Esh) -2 + (1 QC for TTC)		MOH			
9	Marka 2 (Wadi Al-Esh) -3 + (1 QC for TTC)			MOH		
10	Marka 2 (Wadi Al-Esh) -4 + (1 QC for TTC)				MOH	
11	Cluster 13: Amman					
12	Marka 3 (Amir Hamza) - 1 + (QC for chemical analysis + (1QC for TTC)	WAJ				
13	Marka 3 (Amir Hamza) - 2 + (5HH sample + 1 QC for TTC)		WAJ			
14	Marka 3 (Amir Hamza) - 3 + (1 QC for TTC)			WAJ		
15	Marka 3 (Amir Hamza) - 4 + (5 FS analysis + 1 QC for TTC))				WAJ	
16	Cluster 14: Amman					
17	Marka 4 (Amir Hamza) - 1 + (QC for chemical analysis + (1QC for TTC)	MOH				
18	Marka 4 (Amir Hamza) - 2 + (5HH sample + 1 QC for TTC)		MOH			
19	Marka 4 (Amir Hamza) - 3 + (1 QC for TTC)			MOH		
20	Marka 4 (Amir Hamza) - 4 + (5 FS analysis + 1 QC for TTC))				MOH	
21	Planning & Organizational Meetings					

RADWQ field workplan – week 15
(20/02/2005 to 25/02/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Feb 20 – Thu Feb 24
1	Cluster 15: Amman	
2	Almahta -1 + (QC for chemical analysis + (1QC for TTC)	WAJ
3	Almahta - 2 + (1 QC for TTC)	WAJ
4	Almahta - 3 + (1 QC for TTC)	WAJ
5	Almahta- 4 + (1 QC for TTC))	WAJ
6	Cluster 16: Amman	
7	Tabrboor 1 (Abu Alia) - 1 + (QC for chemical analysis + (1QC for TTC)	MOH
8	Tabrboor 1 (Abu Alia) - 2 + (5HH sample + 1 QC for TTC)	MOH
9	Tabrboor 1 (Abu Alia) 3 + (1 QC for TTC)	MOH
10	Tabrboor 1 (Abu Alia) - 4 + (5 FS analysis + 1 QC for TTC))	MOH
11	Cluster 17: Amman	
12	Tabrboor 2 (Tariq) -1 + (QC for chemical analysis + (1QC for TTC)	WAJ
13	Tabrboor 2 (Tariq) - 2 + (1 QC for TTC)	WAJ
14	Tabrboor 2 (Tariq) - 3 + (1 QC for TTC)	WAJ
15	Tabrboor 2 (Tariq) - 4 + (1 QC for TTC))	WAJ
16	Cluster 18: Amman	
17	Tabrboor 3 (Al-Shaheed) - 1 + (QC for chemical analysis + (1QC for TTC)	MOH
18	Tabrboor 3 (Al-Shaheed) - 2 + (1 QC for TTC)	MOH
19	Tabrboor 3 (Al-Shaheed) - 3 + (1 QC for TTC)	MOH
20	Tabrboor 3 (Al-Shaheed)- 4 + (1 QC for TTC))	MOH
21	Planning & Organizational Meetings	

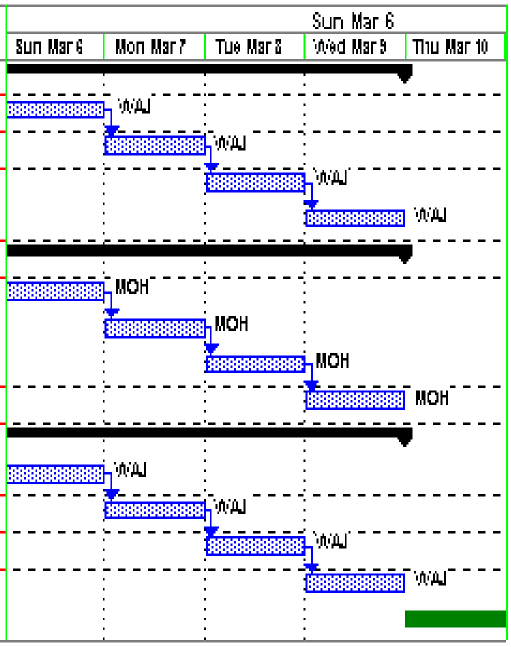
RADWQ field workplan – week 16
(27/02/2005 to 3/03/2005)

ID	Cluster Name / Name of Community / Sampling Areas	Sun Feb 27 – Thu Mar 3
1	Cluster 19: Amman	
2	Tabrboor 4 (Al-Khazna) - 1 + (QC for chemical analysis + (1QC for TTC)	WAJ
3	Tabrboor 4 (Al-Khazna) - 2 + (5HH sample + 1 QC for TTC)	WAJ
4	Tabrboor 4 (Al-Khazna) - 3 + (1 QC for TTC)	WAJ
5	Tabrboor 4 (Al-Khazna) - 4 + (5 FS analysis + 1 QC for TTC))	WAJ
6	Cluster 20: Amman	
7	Wadi Alseer - 1 + (QC for chemical analysis + (1QC for TTC)	MOH
8	Wadi Alseer - 2 + (5HH sample + 1 QC for TTC)	MOH
9	Wadi Alseer - 3 + (1 QC for TTC)	MOH
10	Wadi Alseer - 4 + (5 FS analysis + 1 QC for TTC))	MOH
11	Cluster 21: Amman	
12	Medical City -1 + (QC for chemical analysis + (1QC for TTC)	WAJ
13	Medical City - 2 + (1 QC for TTC)	WAJ
14	Medical City - 3 + (1 QC for TTC)	WAJ
15	Medical City - 4 + (1 QC for TTC))	WAJ
16	Cluster 22: Amman	
17	Alfisleeh + (QC for chemical analysis + (1QC for TTC)	MOH
18	Sahab - 1 + (5HH sample + 1 QC for TTC)	MOH
19	Sahab - 2 (Abu Alia) 3 + (1 QC for TTC)	MOH
20	Almoqar + (5 FS analysis + 1 QC for TTC))	MOH
21	Planning & Organizational Meetings	

RADWQ field workplan – FINAL WEEK (week 17)

(06/03/2005 to 10/03/2005)

ID	Cluster Name / Name of Community / Sampling Areas
1	Cluster 23: Amman
2	Hammam Alshmot + (QC for chemical analysis + (1QC for TTC)
3	Alnasreeh + (1 QC for TTC)
4	Aljezah + (1 QC for TTC)
5	W.Arenba + (1 QC for TTC))
6	Cluster 24: Amman
7	Aljezeeh - 1 + (QC for chemical analysis + (1QC for TTC)
8	Aljezeeh - 2 + (1 QC for TTC)
9	Alqastal - 1 + (1 QC for TTC)
10	Alqastal - 2 + (1 QC for TTC))
11	Cluster 25: Amman
12	Alqwesmeeh- 1 + (QC for chemical analysis + (1QC for TTC)
13	Alqwesmeeh - 2 + (5HH sample + 1 QC for TTC)
14	Alqwesmeeh - 3 + (1 QC for TTC)
15	Alqwesmeeh - 4 + (5 FS analysis + 1 QC for TTC))
16	Planning & Organizational Meetings



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Annex 9 Record sheet for a RADWQ sanitary inspection

		WSS No. [1]
Governorate [2]		JO __ __ __ __ __ __
Cluster No.		
Sample Site No. [3]		

1. WSS No. = unique code identifying a sample site (Water Supply Scheme Number;)
2. Broad Area: Amman = 11, Albalqa = 12, Alzarqa = 13, Madaba = 14, Irbid = 21, Almafraq = 22, Jarash = 23, Ajloun = 24, Alkarak = 31, Altafiela = 32, Ma'an = 33, Aqaba = 34;
3. Sample Site No. = 1–24 (NB: Sample Site No. where household samples are collected = 90, household samples = 91–95).

Name of Community (Town/Village):	
WSS Type: (a) **- Piped Water Treatment Process** ĺ **- Piped Water Distribution System** ĺ **- Household Piped Water** ĺ	**Chlorinated supply?** Y ĺ N ĺ
Name of Inspector/Analyst:	
Date of visit (inspection date):	**Time:**

1. Sanitary Risk Inspection (CHOOSE APPROPRIATE FORM)

PIPED WATER TREATMENT PROCESS	Risk
1. Are cracks evident in the pre-filters?	Y ĺ N ĺ
2. Are there leaks in the mixing tank?	Y ĺ N ĺ
3. Is the mixing tank in an insanitary condition?	Y ĺ N ĺ
4. Are hydraulic surges evident at the intake?	Y ĺ N ĺ
5. Is any sedimentation tank in an insanitary condition?	Y ĺ N ĺ
6. Is the air and water supply distribution in any sand bed uneven?	Y ĺ N ĺ
7. Are there mud balls or cracks in any of the filters, or is the filter performance not good?	Y ĺ N ĺ
8. Are cross-connections evident between backwashed and treated water?	Y ĺ N ĺ
9. Is there evidence that insufficient doses of coagulant (e.g. alum) are being used?	Y ĺ N ĺ
10. Are free residual chlorine concentrations (minimum 0.2 mg/l) not being achieved, or is the retention tank missing?	Y ĺ N ĺ
Total Score of Risks:	/10

PIPED WATER DISTRIBUTION SYSTEM	Risk
1. Do any taps or pipes leak at the sample site?	Y ĺ N ĺ
2. Does water collect around the sample site?	Y ĺ N ĺ
3. Is the area around the tap insanitary?	Y ĺ N ĺ
4. Is there a sewer or latrine within 30 m of any tap?	Y ĺ N ĺ
5. Has there been discontinuity in the water service in the last 10 days?	Y ĺ N ĺ
6. Is the supply main exposed in the sampling area?	Y ĺ N ĺ
7. Do users report any pipe breaks within the last week?	Y ĺ N ĺ
8. Is the supply tank cracked or leaking?	Y ĺ N ĺ
9. Are the vents and covers on the tank damaged or open?	Y ĺ N ĺ
10. Is the inspection cover or concrete around the cover damaged or corroded?	Y ĺ N ĺ

Total Score of Risks:	**/10**

HOUSEHOLD PIPED WATER	**Risk**
1. Is the main source tap sited outside the house (e.g. in the yard)?	**Y ☐ N ☐**
2. Is the water stored in a container (including rooftop or underground tanks) inside the house/building?	**Y ☐ N ☐**
3. Are any taps leaking or damaged?	**Y ☐ N ☐**
4. Are any taps shared with other households?	**Y ☐ N ☐**
5. Is the area around the main source tap insanitary?	**Y ☐ N ☐**
6. Are there any leaks in the household pipes?	**Y ☐ N ☐**
7. Do animals have access to the area around the pipe?	**Y ☐ N ☐**
8. Have users reported pipe breaks in the last week?	**Y ☐ N ☐**
9. Has there been discontinuity in the water supply in the last 10 days?	**Y ☐ N ☐**
10. Is the water obtained from more than one source?	**Y ☐ N ☐**
Total Score of Risks:	**/10**

Notes/Comments on Sanitary Inspection:

2. Water Quality Parameters **(WSS No.: ____________________)**

Sample point: **(location where sample is collected)**	**Appearance:**	**Clear** **Clear and coloured** **Slightly cloudy** **Cloudy** **Dirty**
Notes/Comments on the Water Quality Analysis:		

	Count No. 1	**Count No. 2**
Thermotolerant coliforms (TTC) (cfu/100 ml)		
Faecal streptococci (FS) (cfu/100 ml)		**a) X**
pH		
Turbidity (NTU)		
Conductivity (µS/cm)		
Free Chlorine (mg/l)		
Total Chlorine (mg/l)		**b) X**
Nitrate (mg/l)		
Arsenic (mg/l)		
Iron (mg/l)		
Fluoride (mg/l)		
Copper (mg/l)		

Count No. 2, or Quality Control (QC) Count, should be:

- ***TTC: 1st sample of the day**, use 95% confidence level*
- ***Chemicals: Once a week**, use 10% precision (± 0.1)*

Signature of Inspector/Analyst: ________________________________

Annex 10 Level 1 parameters for RADWQ surveys

Bacteriological parameters

A variety of microorganisms are found in water, including both pathogenic and nonpathogenic species. Some nonpathogenic microorganisms can cause problems with the taste and odour of water supplies, which consumers see as important indicators of water safety, and which may determine whether they drink the water. The principle concern for drinking-water quality, however, is contamination by pathogenic microorganisms, most of which derive from faeces. To determine whether drinking-water is contaminated by such pathogens, usually the levels of indicator microorganisms are measured. These indicator microorganisms are normally bacteria and several types are used by programmes that monitor drinking-water quality. The most commonly used is *Escherichia coli*, but thermotolerant coliforms are also frequently used as a surrogate for *E. coli.*

In the RADWQ project for Jordan, thermotolerant coliform levels were used to assay drinking-water quality, rather than *E.* coli levels, because tests for the former microorganisms are rapid and widely used. Whenever possible, however, it is recommended that confirmatory tests for *E. coli* be undertaken for each type of water source. The usefulness of faecal streptococci as indicator microorganisms of drinking-water quality was also examined in a small-scale within-study investigation, by testing 10% of all water sources for these bacteria.

Thermotolerant coliforms

The thermotolerant coliforms are a group of coliform bacteria that grow at 44 °C, and they include *E. coli* as well as other species that may derive from environmental sources. Thermotolerant coliform analysis can be performed using a number of relatively inexpensive techniques, and the results can be obtained within 14–24 hours. In temperate climates, approximately 95% of thermotolerant coliforms are thought to be *E. coli*, but in tropical climates this proportion may be significant lower. This indicates that the results of a thermotolerant coliform analysis should be interpreted cautiously and highlights the need for other assay methods.

E. coli contamination derives almost exclusively from human and animal faeces. Some strains of *E. coli* are pathogenic (e.g. *E. coli* O157:H7). There is evidence that *E. coli* can multiply in nutrient-rich tropical soils, although it is generally recognized that this ability is limited, and in most cases the indigenous bacteria would out-compete the *E. coli.* The identification of *E. coli* is simple, but time consuming, as it typically requires a two-stage process of presumptive and confirmative testing.

Faecal streptococci

Faecal streptococci may also be used as microbiological indicators of drinking-water quality. Evidence indicates that these bacteria have a stronger relationship to diarrhoeal disease than does *E. coli*, and a closer relationship to indicator bacteria known to derive from human faeces. Generally, faecal streptococci have a greater resistance in the environment than *E. coli* or thermotolerant coliforms, and it has been recommended that they be used to assay groundwater receiving contaminated recharge water, and to assay chlorinated distribution systems. Several simple methods are available for detecting faecal streptococci, but they are time-consuming and results cannot be obtained for 48 hours. This may limit the usefulness of faecal streptococci for routine monitoring, but it would have a limited impact on their value in assessments.

Chemical parameters

The third edition of the WHO *Guidelines for drinking-water quality* lists many chemicals that are relevant to drinking-water quality, and guideline values are given for most of the chemicals. To test for all the chemicals listed in the guidelines would be difficult, prohibitively expensive and largely unnecessary, even within an assessment, and therefore the chemicals selected for analysis must be prioritized. Some chemicals are toxic (e.g. fluoride, arsenic and nitrate), pose a health hazard when found in drinking-water and should therefore be included in an assessment. Other chemicals are not toxic *per se*, but contribute to the palatability or appearance of drinking-water, and thus influence whether people use a water source. Examples include salts and iron (see following section, *Aesthetic parameters*). Water properties that lead consumers to reject a safe, though aesthetically unappealing, source pose an indirect health risk, because the consumers may instead use a microbiologically contaminated source. Besides the chemical composition of drinking-water, certain physical characteristics of water (e.g. turbidity) are often cited by consumers as indicators of a change in water quality and as reasons for rejecting a source. Factors that influence the aesthetic properties of drinking-water should therefore also be included in an assessment of water quality.

Groundwater contamination may be natural or anthropogenic, and the levels of contamination can vary over time and by location. Contamination levels tend to vary more over time for surface waters and shallow groundwater than for deep groundwater. However, the microbiological quality of shallow groundwater and surface water is often poor, and this is the principal concern. The levels of chemical contamination in shallow groundwaters and surface waters tend to be related to human activity, but prevention measures are usually possible and the contamination may be relatively short-lived if there is a rapid flow of water in the shallow source. Naturally occurring chemicals in groundwater may affect the operational performance of drinking-water systems, but normally they do not pose an acute risk to health. Typically, long-term exposures to the low concentrations of the chemicals are required before clinical effects become apparent.

The microbiological quality of deeper groundwater is often very good and therefore chemical quality is usually a higher priority. Furthermore, the chemical contamination is more likely to be natural, and therefore removal, rather than prevention, may be required. However, if the water flow-rate in the deep groundwater source is slow, this could lead to long-term problems with contamination. The quality of deep groundwater is generally stable, so that the required frequency of monitoring is lower than that for shallow groundwater and surface water sources, which are both prone to natural (e.g. erosion, run-off) and anthropogenic contamination.

Nitrate

Nitrate is one of the most ubiquitous chemical contaminants of water bodies worldwide, as it is derived from human sources, particularly human wastes and inorganic fertilizers used in agriculture. Nitrate is of concern because of its link to methaemoglobinaemia in "blue-baby" syndrome, although the actual health burden for this syndrome is often considered to be relatively insignificant because of breast-feeding practices. It is likely, however, that the health burden is underreported.

Nitrate is also a concern because once it has entered a water body in which oxidation is occurring, only dilution and hydrodynamic dispersion are likely to significantly reduce nitrate concentrations until the input load is reduced. If nitrate is allowed to increase in source waters, long-term resource problems may result, leading to costly investments later. It is expensive and difficult to remove nitrate during treatment, and blending nitrate-rich waters with low-nitrate waters may be the only viable option. In reducing or nonoxidizing waters nitrate may not be formed, as organic nitrogen would be converted to ammonia by denitrifying bacteria.

Fluoride

Excess fluoride is associated with dental and skeletal fluorosis, which may cause severe deformation and disability in susceptible individuals. If no fluoride data are available for water supplies, and people have mottled teeth or skeletal deformities, fluorosis should be suspected. At the other extreme, a lack of fluoride also carries health risks and is associated with dental caries. In some countries, fluoride is added to drinking-water to improve dental health, but this remains a controversial issue and may not be the most effective mechanism to reduce the incidence of dental caries. Although fluoride may be released by industrial pollution, most fluoride contamination in drinking-water supplies at levels that pose a health concern derives from natural sources. Fluoride should always be analysed during the development of a water source, particularly groundwater sources.

Arsenic

Most arsenic in water is naturally occurring and derives from the dissolution of arsenic-bearing minerals associated with volcanic activity, but it may also originate from anthropogenic sources, such as mining and other industrial activities. Arsenic accumulates in humans (and is amplified in the food chain) and is associated with skin disease and cancers. Drinking from a water source contaminated by low arsenic concentrations (≤ 50 µg/l) over many years can result in toxic concentrations in humans, and carcinogenic effects may develop in some individuals.

Arsenic became one of the principal water-quality issues in the late 1990s because of the rising levels of arsenic in groundwaters in Bangladesh and neighbouring countries. Prior to this, few data on arsenic levels in water supplies were available, mainly because of a lack of the laboratory equipment needed to assay arsenic at low concentrations. Recently, new laboratory and field methods have been developed and these are helping to clarify the extent of arsenic contamination in water bodies worldwide, which appears to be extensive in Asia and Latin America.

Aesthetic parameters

Iron

Iron contamination of water sources is mainly of aesthetic concern, because in its oxidized ferric form iron can discolour clothes and sanitaryware, which may cause consumers to reject the water source. The ferric iron mostly comes from the oxidation of ferrous iron in the water itself, but it may also come from the corrosion of galvanized iron or cast-iron pipes, and from the action of iron bacteria (Howard, Ince & Smith, 2003; WHO, 2004). Iron contamination is a particular problem for groundwater supplies, but surface waters can also have iron problems, especially with colloidal iron.

Iron and manganese (which also causes discolouring problems with water supplies) are normally found together in nature, and if a water supply has an elevated level of one element this could indicate that the level of the other element is also high. Fortunately, treatments that remove iron from water also remove manganese. Given the impact of iron on the aesthetic quality of water, and the problems it can cause in rising mains and pipes, iron is a primary parameter for a RADWQ assessment.

Turbidity

Turbidity is a key parameter for describing the microbiological quality of drinking-water, and it is recommended that this parameter, together with pH and chlorine residuals, be included in surveys of water quality, as they either directly influence microbiological quality (in the case of chlorine), or influence disinfection efficiency and microbial survival (pH and turbidity). Turbidity is also the key parameter in a minimal monitoring of water quality. Very high turbidity, even in the absence of faecal indicator bacteria, may be cause for concern, as it indicates that sanitary integrity has been compromised.

Conductivity

Conductivity, the ability of water to carry an electric charge, can be considered a proxy indicator of dissolved solids (a conductivity of 1400 µS/cm is equivalent to 1000 µg/l of dissolved solids) and is, therefore, an indicator of the taste and salinity of the water. Although there is little direct health risk associated with high conductivity values, such values are associated with poor-tasting water and customer dissatisfaction and complaints. Changes in conductivity with time, or high conductivity values, can both indicate that the water has become contaminated (e.g. from saline intrusion, faecal pollution, or nitrate pollution). Over time, the contamination can cause corrosion in rising mains and pipes.

Sanitary risk factors

In addition to the analysis of microbial, chemical and aesthetic parameters, sanitary inspections were carried out at all supply points visited during the RADWQ study. Sanitary inspections are visual assessments of the infrastructure and environment surrounding a water supply, taking into account the condition, devices, and practices in the water-supply system that pose an actual or potential danger to drinking-water quality, and thus to the health and well-being of the consumers. The most effective way to undertake sanitary inspections is a semiquantitative, standardized approach using logical questions and a simple scoring system. Sanitary inspections complement water-quality analyses by providing a longer-term perspective on the risks of microbiological contamination, rather than the "snapshot" view of water-quality analyses, and there is an increase in the power of analysis when both types of data are available.

In the RADWQ survey in Jordan, special questionnaires were used in the sanitary inspections of all water supplies (Annex 9). The questionnaires comprised sets of 10 questions with only "yes" or "no" responses allowed, which enabled the interviewer to quickly and easily mark the answer. Sanitary inspection scores were then derived from the results of the sanitary inspections.

Risk-to-health analysis

A relative health risk for a water supply can be calculated by combining the sanitary inspection score with data on thermotolerant coliform counts (e.g. see Table 3.18). The sanitary inspections provide a longer-term perspective on the risks of microbiological contamination, while the coliform data privide more of a "snapshot" of current conditions. Ranking water supplies in such a way allows interventions aimed at improving water safety to be prioritized, and supports effective and rational decision-making.

Analysis of proxy parameters

The purpose of a proxy analysis in RADWQ surveys is to quantify correlations between pairs of selected water-quality parameters, and determine if one parameter could be used to approximate the result that would be given by the direct measurement of a second parameter (which might be more difficult, expensive or time-consuming to measure). Most commonly, a proxy analysis is used to investigate the correlations between:

- faecal contamination (measured as the thermotolerant coliform count) and turbidity;
- thermotolerant coliform count and faecal streptococci level; and
- conductivity and nitrate, fluoride or arsenic.

The strength of association between two water-quality parameters in RADWQ surveys is measured by calculating Pearson's r, a linear correlation coefficient. If the paired data lie exactly along a straight line with a positive slope, then $r = 1$; if they lie exactly along a straight line with a negative slope, $r = -1$; and if there is no correlation, then $r = 0$. The main limitations of Pearson's r are that the method assumes a linear association between two variables, and would not approximate well a non-linear relationship; it assumes the data are distributed normally; and the value of r is disproportionately influenced by outlier data. The justifications for using Pearson's r are that it can be easily calculated in Microsoft's Excel spreadsheet, and that the snapshot nature of RADWQ surveys does not justify using a more complicated analysis, such as Spearman's *rho*.

World Health Organization
Avenue Appia 20
1211 Geneva 27, Switzerland

United Nations Children's Fund
3 UN Plaza
New York, NY 10017, USA

9 789241 500579