ARSENIC PRIMER

GUIDANCE FOR UNICEF COUNTRY OFFICES ON THE INVESTIGATION AND MITIGATION OF ARSENIC CONTAMINATION

Water, Environment and Sanitation Section
Programme Division
UNICEF New York

unicef

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UNICEF Arsenic Primer

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2008

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Cover Photo:

A boy pumps water from a tube-well, the spout of which is painted green to indicate that its water has been tested and is arsenic free and safe to be used for any purpose, in the town of Sonargaon in Narayanganj District, Bangladesh.

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PREFACE

The contamination of drinking water supplies with naturally-occurring arsenic is major health problem. Even low concentrations of arsenic, when ingested over a period of years, can result in a range of serious conditions – known collectively as arsenicosis – that include skin lesions, cancer of the skin, lung and bladder, and gastro-intestinal and pulmonary conditions. Chronic arsenic poisoning has also been found to affect children's cognitive development. There is no medical cure for arsenicosis. The only solution is to stop drinking arsenic-contaminated water.

In Bangladesh and parts of China and India the problem is widespread. Many people are already suffering from arsenicosis and long-running testing programmes indicate that tens of millions of people are at risk. Testing has also confirmed major occurrences in other regions, notably in East and Southeast Asia. However, the global extent of the arsenic problem is still unknown.

In an effort to clarify the situation, UNICEF commissioned Dr. Peter Ravenscroft, a leading arsenic researcher at Cambridge University, to develop a model to predict arsenic occurrence around the world. This work was successfully completed and one of the outputs is a listing of world regions where the risk of naturally-occurring arsenic in groundwater aquifers is high. This list and other findings from the study are included in the report *Predicting the Global Extent of Arsenic Pollution of Groundwater and its Potential Impact on Human Health*.

The *Arsenic Primer* was written as a companion document to that report. It is a synthesis of the knowledge UNICEF and its partners have gained over the last ten years in arsenic mitigation programmes in Asia, including information on the occurrence and effects of arsenic, mitigation programme design, testing, communication, and water supply options. It also includes references to additional sources of information for each subject area.

In countries where there is a risk of arsenic contamination, the *Arsenic Primer* will help UNICEF, governments and other stakeholders take the necessary steps to help ensure the safety of water supplies for children and their families.

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ACKNOWLEGEMENTS

UNICEF would like to acknowledge with thanks the authors of the Arsenic Primer:
Rick Johnston, from UNICEF Bangladesh; Ross Nickson, previously from UNICEF India; and Greg Keast, consultant.

They were guided by Clarissa Brocklehurst and Oluwafemi Odediran from the WES Section of UNICEF Programme Division and received valuable inputs from other UNICEF staff active in the area of arsenic and water quality, and from Jane Springer, who edited the document.

UNICEF would also like to thank Dr. Guy Howard from the UK Department for International Development for reviewing parts of the document.

MODULE 1: INTRODUCTION

Background

In the 1990s it became clear that groundwater in parts of India and Bangladesh was contaminated with naturally occurring arsenic at concentrations posing a threat to human health. Testing programmes showed the extent of the problem: tens of millions of people were at risk in the two countries. This led to a paradigm shift in the general assumption in the sector that groundwater was always "safe" for human consumption. Testing for arsenic was subsequently undertaken in other countries and it became apparent that the problem was not confined to the Indian sub-continent. Arsenic at concentrations above the World Health Organization guideline value (see box) has now been found around the world, including major occurrences in other South Asia countries, countries in East and Southeast Asia and occurrences on other continents.

Globally, over 130 million people are now estimated to be potentially exposed to arsenic in drinking water at concentrations above the WHO guideline value of 10 ppb, a number that is likely to grow as more areas are tested. These people are at risk of developing serious long term health effects as a result of this exposure, collectively known as arsenicosis or chronic arsenic poisoning. These effects are likely to continue and increase in the future even though exposure is being reduced through mitigation programmes.

Mitigation of the problem is now well advanced in some countries, including Bangladesh, India, China, and some Southeast Asian countries. As a result, there has been considerable experience gained and lessons learned. Some countries are at a nascent stage in tackling a known problem of arsenic contamination while others are only now discovering that a problem exists. This primer is based on the experience gained in ongoing mitigation programmes and is intended as a guide for countries at an earlier stage in the mitigation process.

Arsenic Standards

The World Health Organization's *Guidelines for Drinking-Water Quality* recommends guideline values (GVs) for a range of drinking water contaminants including arsenic. GVs are health-based targets defined using risk factor analysis (see Module 3 for more information). Countries set their own standards for drinking water contaminants, which may be different from the WHO GVs.

The arsenic GV is 10 ppb (parts per billion), also expressed as 10 µg/L (micrograms per liter). National standards for arsenic vary, in many countries it is the same as the WHO GV but in others – including in China, India and Bangladesh – it is 50 ppb.

Predicting the extent of arsenic in groundwater

In 2008 UNICEF New York commissioned Peter Ravenscroft, a researcher at the University of Cambridge, to develop a Geographical Information System (GIS) model to predict the global extent of arsenic contamination of groundwater based on his previous work on the geology of arsenic contamination. The model predicts potential for occurrence of arsenic in groundwater and has correctly identified many areas where arsenic contamination of groundwater is known to occur. The results also indicated several areas where arsenic in groundwater is not known, but based on this modeling, can be suspected to occur. It is important to note that the model only predicts the likelihood of occurrence of arsenic in groundwater. It does not identify whether that groundwater is used for drinking and thus whether people are exposed to arsenic. The report, report *Predicting the Global Extent of Arsenic Pollution of Groundwater and its Potential Impact on Human Health* should be consulted alongside this primer.

Using the *Arsenic Primer*

The Arsenic Primer is meant to provide advice and guidance on all aspects of arsenic mitigation programming from testing methods to treatment of arsenic patients. It is for UNICEF staff and other field workers tackling a problem of arsenic in groundwater used for drinking. It consists of ten modules, each of which highlights key issues and points the reader towards more detailed sources of information.

Additional Resources

Arsenic Crisis Information Centre. http://bicn.com/acic/

IRC (2007). Thematic Overview Paper 17 “Arsenic in Drinking Water”. The Hague: IRC. http://www.irc.nl/page/33113

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MODULE 2: ARSENIC OCCURRENCE IN GROUNDWATER

Introduction

This section focuses on how groundwater used for drinking, cooking and irrigation becomes contaminated with arsenic. Worldwide this is the most prevalent route of exposure and the primary cause of arsenicosis.

Surface water contaminated by arsenic as a result of human activities (e.g., mining) or from natural sources has also been reported in some countries, but it is much less common. Arsenicosis as a result of consumption of arsenic-contaminated rainwater has not been reported, and is unlikely, although there may be some exposure in the immediate vicinity of coal-fired power plants and some types of mineral smelters.

Arsenic in groundwater may be a result of natural geochemical processes or pollution from human activities (known as anthropogenic pollution). It is naturally-occurring arsenic that affects the largest geographical areas and, if groundwater is used for drinking, exposes the greatest numbers of people to contamination. Arsenic found in the Ganges-Meghna-Brahmaputra basin in South Asia is an example of this type of contamination.

Potential diffuse anthropogenic sources (e.g. arsenical pesticides) are not known to have caused groundwater pollution, but they can cause extensive soil pollution. Point-sources of pollution – such as industrial spillage, landfills or mining wastes – are usually limited and therefore affect a relatively small number of people, but may have severe impacts.

Sources of arsenic

Some arsenic is naturally present in all rocks and sediments that form aquifers tapped for drinking (see Table 2.1).

To be a public health risk, arsenic must be released from the aquifer rock or sediment into groundwater and that groundwater must be subsequently used for drinking. In most cases, the arsenic found in rock and sediment is immobile; as a result, only trace levels of arsenic are found in groundwater. However, certain natural geochemical conditions and processes can lead to high levels of arsenic in groundwater. It is these geochemical *triggers*, more than the arsenic content in aquifer media, which create the risk of drinking water contamination.

Table 2.1 Arsenic in rock and sediment

Rock or sediment type	**Arsenic content (mg/kg)**	
	Average	**Range**
Sandstone	4.1	0.6 - 120
Limestone	2.6	0.4 – 20
Granite	1.3	0.2 - 15
Basalt	2.3	0.2 – 113
Alluvial sand (Bengal)	2.9	1.0 – 6.2
Alluvial silt (Bengal)	6.5	2.7 – 15
Loess (Argentina)	-	5.4 – 18

There are four main geochemical processes that trigger the natural release of arsenic from aquifer materials into groundwater, as shown in Table 2.2. As the table shows, these processes can occur in a wide range of geological environments, but the most serious occurrences (in terms of the numbers of people affected) are located predominantly in young alluvial basins adjacent to active mountain belts.

Table 2.2. Natural geochemical processes that release arsenic to groundwater

Process	**Characteristic geochemical conditions**	**Generalized geological environment**	**Countries where this process is known to operate**	**Additional information**
Reductive dissolution	Anoxic groundwater; low levels of dissolved oxygen, nitrate (NO_3) and sulfate (SO_4); pH~7; high iron (Fe); also high manganese (Mn), ammonia (NH_4) and bi-carbonate (HCO_3).	Holocene sediments deposited in floodplain areas of rivers draining geologically-recent mountain chains.	Bangladesh, India, Vietnam, China, Cambodia, Hungary	May affect large areas. 64% of known occurrences of arsenic due to this process.
Alkali desorption	Oxic groundwater; pH ~ 8; low levels of iron (Fe). Possible elevated levels of other toxic ions such as F, B, Mo, Se.	Alluvium and bedrock aquifers.	Argentina, USA, Spain, China	May affect large areas.
Sulfide oxidation	Oxic groundwater; pH < 7 (sometimes extremely acidic); high levels of sulfate (SO_4).	Areas where mineralization has taken place, often associated with rare metals, e.g., gold, tin.	Ghana, Thailand, USA	Usually localized, may be associated with lowering of water table due to extraction of groundwater.
Geothermal	High temperature groundwater; high chloride (Cl).	Areas of geothermal activity, i.e., geologically active, often associated with volcanic rocks.	Chile, China, Nicaragua	Usually localized.

With the exception of sulfide oxidation in some cases, there is no evidence that these processes are dependent on human-induced changes in the sub-surface environment (e.g., by extraction of groundwater). However, pumping out groundwater may lead to *movement* of dissolved arsenic in the sub-surface and therefore has the potential to exacerbate the problem in specific wells or localized areas.

Understanding the geological environment

A sound understanding of the geological environment and the processes leading to elevated arsenic in groundwater is a crucial first step in tackling the problem. It also provides the basis for designing a programme of further investigation and mitigation. Different processes responsible for arsenic occurrence have different implications.

For example, in the Ganges-Meghna-Brahmaputra basin, where reductive dissolution is the key process, arsenic is generally found only in the Holocene sediments of the floodplain areas of the river systems of the basin. Geologically older, terraced areas are free from arsenic. Arsenic is also found in groundwater at an average of between 10m and 60m depth and deeper groundwater is generally free from arsenic.

In Uttar Pradesh state in India it was suspected that arsenic would be found in Holocene sediments of the active river systems of the state, similar to the situation further downstream in West Bengal and Bangladesh. This was confirmed in one District (Figure 2.1 and 2.2) and used to focus further testing for arsenic in selected "at risk" Blocks (Figure 2.3).

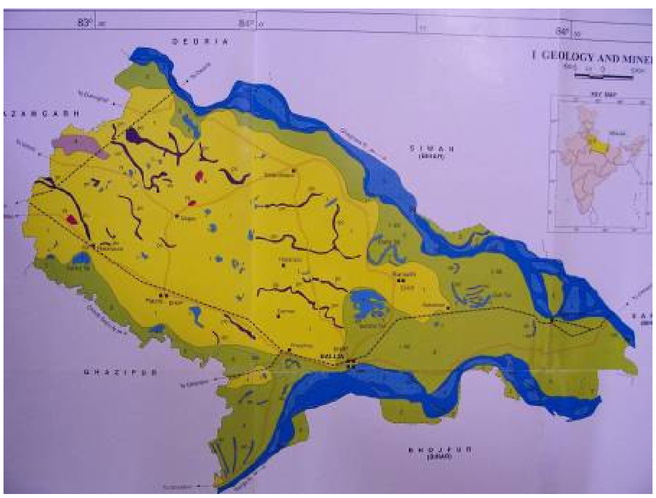

Figure 2.1. Geological map of Ballia District of Uttar Pradesh. Green is younger Holocene alluvium and yellow is older alluvium.
Source: District Resource Map, Geological Survey of India.

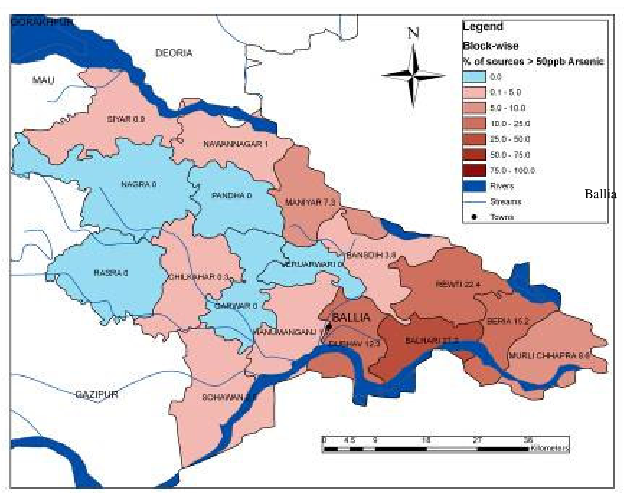

Figure 2.2. Percentage of blocks affected by arsenic >50 ppb in Ballia District. In Chilkahar Block one source was affected in the south of the Block.

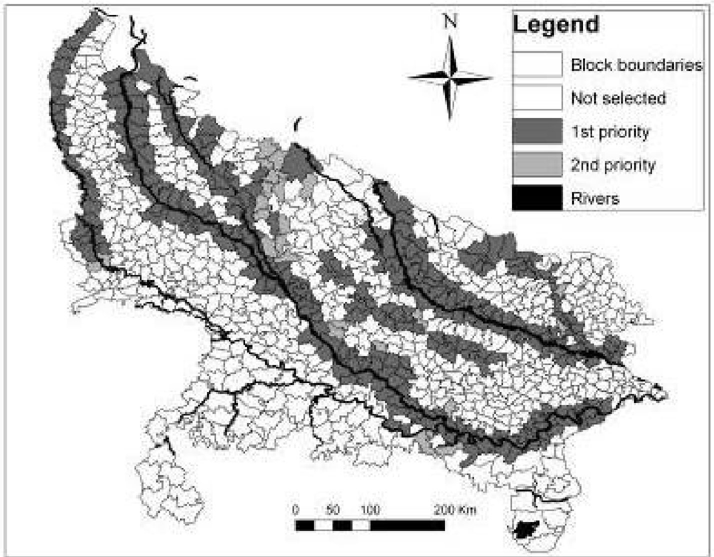

Figure 2.3 "At risk" Blocks selected for testing on the basis of data from Ballia District

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Berg, M., C. Stengel, P.T.K. Trang and 5 others (2006). Magnitude of arsenic pollution in the Mekong and Red River Deltas Cambodia and Vietnam. *Science of the Total Environment*; 372, 2-3, 413-425.

Bhattacharya, P., M. Claesson, J. Bundschuh and 6 others (2006). Distribution and mobility of arsenic in the Río Dulce alluvial aquifers in Santiago del Estero Province, Argentina. *Science of the Total Environment*; 358(1-3), 97-120.

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MODULE 3: HEALTH EFFECTS

Introduction

Arsenic is a systemic poison, and chronic ingestion of arsenic can lead to a wide range of health problems, which are collectively called *arsenicosis* or chronic arsenic poisoning. The effects include skin lesions, cancer of the skin, lung and bladder, and gastro-intestinal and pulmonary conditions. Chronic arsenic poisoning has also been found to have slowed children's cognitive development.

Not everyone exposed to excess arsenic will develop arsenic-related disease. Exposure to arsenic is a *hazard* – something that can cause harm. The likelihood that this exposure will lead to health effects is the *risk*. The *risk* of arsenic health effects increases with arsenic concentration and with duration of exposure. In addition there are many other contributory factors that are not yet fully understood (e.g., diet, smoking and genetic susceptibility).

Setting a standard for exposure to arsenic (e.g., a drinking water quality standard) involves *risk management*: choosing a point on a spectrum of risk that is acceptable given the socio-economic scenario of the country in question. It is important to point out that a drinking water standard or guideline value does not represent a threshold value below which consumption of arsenic is safe and above which it is unsafe (see box).

Setting the Arsenic Guideline Value

WHO has set a guideline value of 10 parts per billion (ppb) for arsenic in drinking water. This guideline value is considered provisional, because of uncertainties about the health effects of low-level exposure to arsenic, and the practical difficulties in measuring or removing arsenic to levels below 10 ppb. At low doses, the risk of cancer is assumed to be linear and lifetime exposure at 10 ppb is predicted to result in 6 excess skin cancer cases per 10,000 people exposed (6 x 10^{4}). This is a relatively high risk for drinking water; risk targets are usually fixed at one additional death per 100,000 people exposed (1 x 10^{5}). However, this level of risk would require a concentration of 0.17 ppb, which is not practical.

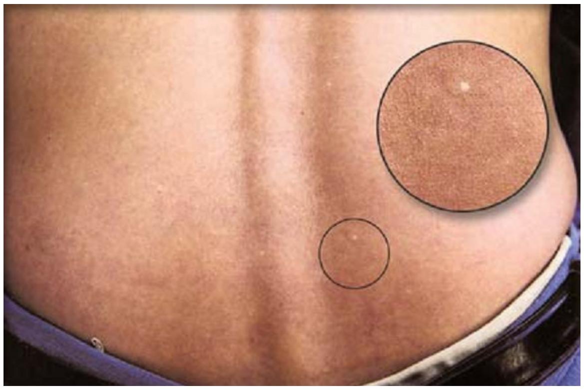
The WHO assessment does not consider lung or bladder cancers, though these are likely to dominate arsenic-induced mortality. The US National Academy of Sciences has noted that as many as 1 in 100 (1 x 10^{2}) additional cancer deaths could be expected from a lifetime exposure to drinking water containing 50 ppb arsenic, although this estimate, like the WHO guideline value, relies on a linear extrapolation to low-dose effects that remains somewhat controversial.

Skin lesions

The most widely recognized signs of chronic arsenic poisoning are *melanosis* (changes in skin colour) and *keratosis* (hardening and thickening of skin into nodules).

Melanosis occurs mainly on unexposed parts of the body such as the chest, abdomen and back. Small patches of skin (from the size of a pinhead to a grain of corn) become darker (hyper-pigmentation) or lighter (hypo-pigmentation or leukomelanosis) than surrounding skin. A "raindrop" pigmentation pattern of both hyper- and hypo-pigmentation is characteristic of high exposure to arsenic.

Keratosis, and the more advanced hyperkeratosis, occur mainly on the palms and soles. In early stages, small nodules form that can be felt when touched. In hyperkeratosis, these nodules grow and coalesce into wart-like bumps. As the nodules thicken, skin can become cracked and vulnerable to secondary infections, leading to debilitation and pain. Keratosis is approximately half as common as melanosis.



Melanosis and leukomelanosis
Source: *Endemic Arsenicosis*

Hyperkeratosis on the palm
Source: *Endemic Arsenicosis*

The risk of skin lesions increases both with duration of exposure and arsenic concentration. At very high concentrations, melanosis and keratosis can develop in a few years, but in most cases ten to twenty years are required. Keratosis often develops after melanosis. In rare cases, skin lesions have been reported even at concentrations below 50 ppb, though this may reflect an incomplete exposure history. Prevalence increases sharply above about 300 ppb.

At a given dose, men are more likely than women to develop skin lesions. Skin lesions often appear in clusters of people within a household or village – this may be due to localized hot-spots (e.g., one highly contaminated well shared by a household), genetic factors or the fact that malnourished people are roughly twice as likely to develop skin lesions as those having better diets.

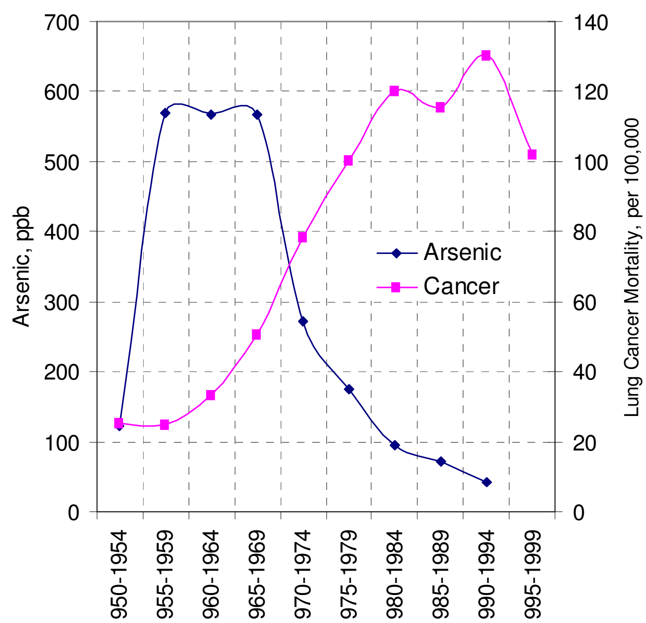


Figure 3.1 Arsenic exposure and male lung cancer mortality, Region II, Chile
Source: Marshall et al. J Natl Cancer Inst 99:920-928, 2007

Cancer

While skin lesions are among the most recognized symptoms of arsenicosis, it is cancer that poses the greatest health threat. Arsenic is a known carcinogen, with skin, lung and bladder cancers causing the greatest disease burden. Internal cancers can occur without any development of skin lesions, so simply relying on early onset symptoms to estimate the likely disease burden is not reliable.

Cancers have a long latency period, and can occur even several decades after exposure has ceased. In a region of Chile, the total population was exposed to high levels of arsenic (average 570 ppb) for more than twelve years. The cancer burden continued to increase after arsenic removal plants were installed, and peaked more than twenty years later (see Figure 3.1). At the peak, arsenic-induced cancers were responsible for the deaths of one in twenty adult females, and nearly one in ten adult males. This high level of risk is unique among environmental carcinogens.

The lung cancer risk of drinking water having 500 ppb arsenic is comparable to that of smoking cigarettes regularly, while the risk of consuming arsenic at 50 ppb is roughly equivalent to that posed by second-hand smoke.

Arsenicosis sufferer, Bangladesh
Source: Dr. Richard Wilson, Harvard University (from the Chronic Arsenic Poisoning website www.physics.harvard.edu/~wilson/arsenic/arsenic_project_introduction.html)

Other effects

Besides skin lesions and cancers, arsenic has been linked to a wide range of other health problems. One symptom is peripheral neuritis, or a tingling sensation in the fingers and toes. Gastro-intestinal disturbances are also frequently reported. The vascular system can be affected and lead to gangrene; in Taiwan a form of gangrene called “black-foot disease” is associated with arsenic.

Pulmonary effects are also common, and range from mild bronchitis to bronchiectasis and Chronic Obstructive Pulmonary Disease, which can be fatal. Arsenic-exposed populations have been reported to be at higher risk of developing diabetes, hypertension, hepatomegaly (abnormal enlargement of the liver), conjunctivitis and heart attacks than those who are not exposed.

Recently it has been shown that arsenic has special effects on children. Several studies have reported that arsenic-exposed children have slower cognitive development. Arsenic has also been linked to an increased risk of fetal loss and still birth in pregnant women.

The stigma of arsenicosis symptoms has a significant impact on the lives of some of its victims, especially women. In some areas arsenicosis sufferers have been shunned by spouses and community members due to a mistaken belief that arsenicosis is a contagious disease and other factors.

Medical care

In many countries, medical workers have been the first to identify arsenic contamination because of patients presenting with skin lesions. However, most health workers are not trained in identification and management of arsenicosis, and training courses are an important component in responding to a discovery of arsenic in drinking water. WHO has developed a Field Guide for health workers, which includes a valuable algorithm for case classification of arsenicosis.

While acute arsenic poisoning can be treated using chelation therapy (a treatment for toxic metal poisoning), this is not recommended for chronic arsenic poisoning. One challenge for medical professionals in caring for arsenicosis patients is that there is in fact no medicine that can “cure” them. Skin cancers can be removed through excision, and keratosis can be lessened by application of ointments (particularly containing salicylic acid), but there is no comprehensive treatment for arsenicosis.

The only effective remedy is to stop arsenic intake, generally by finding a safe alternative source of drinking water. In fact this is the primary “prescription” that can be given by doctors upon discovery of a case of arsenicosis. Once patients switch to a safe source of drinking water, skin lesions improve, and this improvement may be accelerated by taking anti-oxidant supplements (e.g., Vitamins A, C and E; selenium). However, the long-term risk of developing internal cancers remains, even if visible symptoms fade away.

Additional Resources

Guifan, Sun (2004). *Endemic Arsenicosis: A Clinical Diagnostic Manual with Photo Illustrations*. Jointly published by UNICEF; China Medical University, College of Public Health and Division of Endemic & Parasitic Disease Control, Department of Disease Control, Ministry of Health, People's Republic of China.
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University of California, Berkeley. Arsenic Health Effects Research Program
(many papers can be downloaded here including the source of the graph in Figure 3.1)
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MODULE 4: THE UNICEF ROLE IN ARSENIC MITIGATION

Introduction

UNICEF has promoted the use of groundwater as an alternative to microbiologically contaminated surface water sources in drilling and handpump installation programmes in many countries. In the overwhelming majority of cases groundwater has proven to be a safe source. However, in some areas, chemical contaminants such as arsenic have been found to be present, presenting risks to public health over the longer term. Although the responsibility for public health ultimately rests with national governments, when arsenic contamination is an issue, UNICEF can and should support government in prevention and mitigation efforts.

Arsenic mitigation falls within the UNICEF mandate to contribute to the global effort to fulfill the Millennium Development Goals, and specifically Target 7C: to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation. If drinking water is contaminated with arsenic at concentrations above the national standard, then it is not a source safe drinking water. The fact that exposure to arsenic has special effects on children (cognitive impairment and higher infant mortality rates – see Module 3), is another reason for UNICEF action.

UNICEF and Arsenic Mitigation

In addition to support for arsenic programming from Headquarters and Regional Offices, UNICEF is or has been involved in national mitigation programmes in several countries. These efforts vary from limited testing (e.g. in DPR Korea) to major support programmes (e.g. Bangladesh). In recent years, the following country offices have supported arsenic-related activities (see the UNICEF WASH Annual Report for additional information on arsenic-related activities):

Afghanistan	Mongolia
Bangladesh	Myanmar
Burkina Faso	Nepal
Cambodia	Nicaragua
China	Nigeria
DPR Korea	Pakistan
India	Thailand
Lao PDR	Viet Nam

UNICEF's organizational competency

There are several reasons why UNICEF has the organizational competency to deal with arsenic mitigation. UNICEF has more than a decade of experience of arsenic testing and mitigation in Asia, Africa and the Americas (see box). In some of these countries, UNICEF has taken a leading role in support to comprehensive mitigation programmes involving testing, communication, health aspects and provision of arsenic-safe water. No other international agency has this depth of experience globally. The lessons learned in these countries provide a valuable learning opportunity for other countries facing the problem.
This primer is one way that this experience is being disseminated, as is the arsenic sections in the UNICEF Water Quality Handbook. Another way is through the arsenic module of the UNICEF WASH International Learning Exchange programme run by the India Country Office, which provides an opportunity for UNICEF staff and partners to visit ongoing mitigation programmes in India.

In many regions UNICEF has the technical background and capacity in the programmatic areas important to arsenic mitigation and can provide technical support for capacity building of development partners (see Module 9: Partnerships and Advocacy). UNICEF supports comprehensive WASH programmes in many countries and arsenic testing, provision of alternative water supplies, arsenic removal and wider water safety programming is a logical extension to such programmes. The UNICEF Health Programme contributes by strengthening government health services in patient diagnosis, management and treatment. Perhaps overlooked in the past, but essential, is UNICEF's capacity to engage communities through the Behaviour Change Communication (BCC) Programme or Information Education Communication (IEC), as it is sometimes known. Arsenic mitigation involves a change in behaviour of the affected community to seek arsenic-safe water sources, so advocacy and communication are critical to success (see Module 6: Programme Communication).

UNICEF also has long-established relationships of trust with national and local governments. This means that a UNICEF alert about potential arsenic problems will be given due consideration by government and other partners working on a crowded development agenda. The field presence of UNICEF (or its partners) means on-the-ground arsenic testing can be undertaken to provide an evidence base for further advocacy. Its multi-national reach means that lessons learned in arsenic mitigation from other countries can benefit government agencies and communities in newly affected areas.

Areas outside of UNICEF expertise

UNICEF does not have sufficient technical capacity or resources to become heavily involved in assessing and mitigating the risks to human health from arsenic in the food chain. This is relevant in countries where arsenic in irrigation water has been demonstrated to lead to arsenic entering crops grown for food, and where consumption of these crops causes a threat to human health (see Module 8: Other Routes of Exposure). In this scenario the Food and Agriculture Organization (FAO) has the mandate and technical background to be the obvious UN partner.

UNICEF country offices may not feel they have sufficient technical capacity to assist government partners to establish standards for drinking water quality. In these cases, the World Health Organization (WHO), which publishes the Guidelines for Drinking Water Quality, is the obvious UN partner. The WHO may also be a key UN partner for tackling the health effects of arsenic in the population and has published an arsenicosis field guide for the Southeast Asia region (see Module 3: Health Effects).

Additional Resources

UNICEF India Country Office. International Learning Exchange. (contact the Child's Environment Section, India Country Office or the WES Section in NYHQ for further information).

UNICEF WES Section, Headquarters (2008, 2007, 2006). Water, Sanitation and Hygiene Annual Report. New York: UNICEF. (available from the WES Section, NYHQ upon request).

MODULE 5: MEASURING ARSENIC

Introduction

Testing for arsenic is a key component of any arsenic mitigation programme. Testing is carried out to find arsenic-affected areas on a large scale (screening testing) and also to determine which sources are contaminated within individual communities (blanket testing). Testing is not a one-off activity, periodic testing is an important part of understanding the nature of the arsenic contamination problem and assessing mitigating efforts. See Module 10 for more information on the role of testing within overall mitigation programmes.

It is more difficult to test for arsenic than for other contaminants in water, for which a simple strip test or a meter give an instant result. However, the various methods available for testing for arsenic have improved in recent years. Both field and laboratory testing methodologies can be used.

Field testing for arsenic

In the past arsenic field tests were qualitative or semi-quantitative at best, but there has been substantial research and development in recent years, and the accuracy and precision of field test methods have improved dramatically. The most commonly used field test methods rely on the reduction of arsenic present in the sample to arsine gas, which then reacts with other chemicals on a test paper or in an indicator tube to produce a colour change. The tester then examines the colour change by eye and the degree of change indicates the arsenic reading. In some field-testing equipment a digital photometer is used to measure the colour change to eliminate the human error inherent in visual estimation by a field tester.

Examples of arsenic field-testing equipment
(see box at end of the module for details)

Laboratory testing for arsenic

There are a number of methods available for laboratory testing for arsenic. In order of increasing sophistication (and cost) these range from the Silver Diethyl-dithio-carbamate (SDDC) colorimetric method, using a photometer or spectrophotometer; Anodic Stripping Voltametry; Graphite Furnace Atomic Adsorption Spectrophotometry (GF-AAS); Flame AAS with Hydride Generation apparatus (HG-AAS); to inductively coupled plasma mass spectroscopy (ICP-MS).

The SDDC colorimetric method
UNICEF/2005/Nickson

An HG-AAS machine

Sampling procedure

It is important that correct sampling procedure is followed for both field and laboratory testing of arsenic. To ensure that the sample is freshly drawn from the aquifer and is representative, groundwater sources should be pumped to ensure that at least one well volume of water is removed before taking a sample. Preservation of the sample is essential where samples are to be transported to a laboratory for analysis. To avoid formation of iron oxyhdroxide in the sample (orange colour commonly seen in groundwater containing iron), which may remove arsenic from the solution, the pH of samples should be reduced to <2 by adding dilute acid. Nitric or hydrochloric acid is commonly used for this and it should be certified to contain low levels of arsenic.

Relative strengths and weaknesses of field and laboratory testing

The advantages and disadvantages of field and laboratory approaches are summarized in Table 5.1. If correctly operated and maintained by well-trained and dedicated staff, laboratory equipment will produce more accurate and precise results than field testing. But without good quality control measures, neither field nor laboratory results will be reliable.

Table 5.1. Field versus laboratory testing

Field testing	
Strengths	**Weaknesses**
• Rapid – large numbers of samples can be tested in a short period of time • Simple procedure – field testers can be minimally educated and are easy to train • Less costly • Result is obtained, recorded and reported to community on the spot – acts as a communication tool • Less chance of misreporting of results	• Overall accuracy is lower than properly conducted laboratory testing • More potential for human error as more people are physically carrying out the testing

Laboratory testing	
Strengths	**Weaknesses**
• When properly conducted, is more accurate overall than field testing • Can build longer term capacity for general water quality monitoring and surveillance • Laboratory provides a focus and a base for water quality work	• Requires equipment, trained staff and long-term support systems that may not be available in-country • Correct sample collection, labeling and preservation is required • Time required per sample is greater • More costly • Equipment requires maintenance and availability of spare parts • Results must be communicated back to community in a repeat visit with the potential for errors in data recording and reporting

For initial screening testing to determine if an area is affected by arsenic, field testing may be sufficient. If the purpose of the testing is to establish if the source exceeds a standard of 10 ppb or 50 ppb, a field test kit does not need to be able to reliably distinguish between 200 ppb and 300 ppb in order to identify the well as contaminated.

In India, Bangladesh, China and elsewhere surveys have used field test kits in a semi-quantitative way, to simply classify wells as above or below the national standard of 50 ppb. In practice, field test kits are very reliable when arsenic levels are well above or below the limit in question: very rarely would a well having 1 ppb be found unsafe, or a well with 1000 ppb be found safe. Figure 5.1, drawn from testing surveys in Bangladesh, shows that field kits were most likely to have errors in the 25-100 ppb range, as expected.

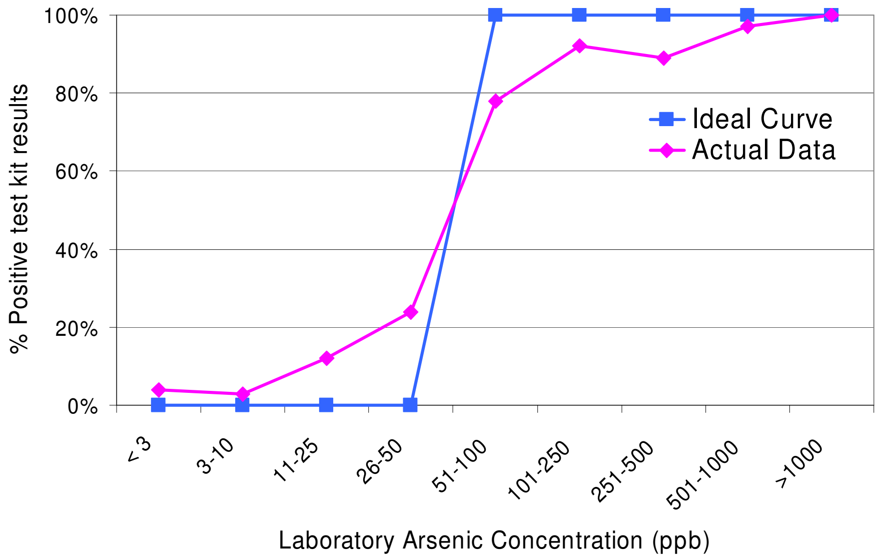


Figure 5.1 Test kit results surveys in Bangladesh
Source: Rosenboom, *Not Just Red or Green*

In the longer term, with the goal of building counterparts' water quality testing capacity, experience shows that it is beneficial to promote both field and laboratory methods. This allows the programme to capitalize on the strengths of each approach while minimizing the effects of the weaknesses on the overall quality of the testing programme. Country offices need to determine the best approach to take, given what is known about arsenic in drinking water and what risk can be reasonably expected. The availability of laboratory infrastructure and trained water quality testing staff is clearly a factor in this decision.

Faced with a large number of sources to be tested for arsenic in Uttar Pradesh in India a testing process using both field and laboratory methods was devised. This is a *tiered system* of testing which built laboratory capacity and improved the overall accuracy of the testing process, while covering a large number of sources in a reasonable time frame. In UP fourteen zonal laboratories were equipped with either the SDDC method with a photometer or a field kit with a colorimeter. Field testing with simple field kits progressed and where sources were found to contain >40 ppb they were sampled and confirmatory testing carried out at one of the zonal laboratories. In addition, 5 per cent of sources (i.e., every twentieth source) were sampled and tested in the laboratory as a quality control check for human error in the field-testing process.

Commercially available arsenic test kits*

- Acustrip Inc. (www.acustrip.com) markets five different arsenic test kits. The main product, the Arsenic Check test (#481396) has a range of 5-500 ppb, while the lower-priced, less sensitive version (#481298) has a range of 10-1000 ppb. The company also markets a low-range kit (#481297) with a range of 2-160 ppb and two "individual" kits for household use. The Acustrip kits have a reported reaction time of only 12 minutes.
- The Asia Arsenic Network (www.asia-arsenic.jp/en/ and aan-bangladesh.com), an early player in arsenic testing and kit development, continues to market an inexpensive kit with a range of 20-700 ppb in Bangladesh (through NIPSOM – National Institute of Preventative and Social Medicine – www.nipsom.org) and Nepal (through ENPHO - Environment and Public Health Organization, www.enpho.org). Kit specifications are available online.
- Hach (www.hach.com) produces two arsenic test kits. The EZ Arsenic Kit (# 2822800) has a range up to 4000 ppb, takes fewer steps, and is more economical. The Low Range Kit (# 800000) has a range up to 500 ppb and is best for samples containing sulfide or arsenic-iron particles.
- Merck (www.merck-chemicals.com) has produced arsenic test kits for many years. The company markets two colorimetric (colour chart) kits: the standard Merckoquant arsenic test kit (#117917) with a reported detection range of 20-3000 ppb and the newer, more sensitive kit (#117927) with a reported detection range of 5-500 ppb. Merck has also released a new digital optical photometer Spectroquant arsenic kit (#101747) with a reported range of 1-100 ppb. This kit is used with Merck's photometers to digitally measure colour results for better accuracy and precision. These photometers are typically used in a laboratory setting, but one model, the Nova 60A (# 1.09751.0001) comes with a battery pack and can be used as a "portable field station" (although it is much larger and heavier than the Arsenator, below).
- A joint project between UNICEF and the Rajiv Gandhi National Drinking Water Mission in India has developed specifications for a field kit that does not use the conventional mercuric-bromide paper. Instead, a detector tube is filled with a granular media coated with a secondary colour reagent that reacts with arsenic and mercuric bromide to produce a pink colour. Following completion of the test, arsenic concentration (10-110 ppb) is read directly by measuring the extent of pink colour penetration in the detector tube. Specifications for the kit are available from the Rural Water Supply Network (RWSN) at: www.rwsn.ch/documentation/skatdocumentation.2005-11-18.2902656953/file
- UNICEF also supported the development of locally manufactured arsenic test kits in China, Thailand and Vietnam, and the former two are still in use. The Thai kit, developed and marketed by Mahidol University (www.mahidol.ac.th), has a detection range of 5-500 ppb and is also used in other countries in the region.
- Wagtech International Ltd (www.wagtech.co.uk), produces the Digital Arsenator. Like the Merck photometer kit, it uses an optical photometer to measure the colour change on mercuric bromide filter paper; however, it is much more portable. It detects arsenic within a reported range of 2-100 ppb. The Arsenator is significantly more expensive than manual colour comparison kits, but is more accurate and precise. A recent UNICEF-commissioned study from India comparing the Arsenator with laboratory AAS-HG showed a very high correlation of 0.998 (Shriram Institute, 2006). Wagtech also produces a Visual Arsenic Detection Kit, which uses a visual reference colour chart instead of the optical photometer. It has a reported range of 10-500 ppb.

* *This list does not include all available kits, and it is not an endorsement of the companies or products listed.*

Additional Resources

APHA/AWWA/WEF (2005). Standard Methods for the Examination of Water and Wastewater. 21st Edition. American Public Health Association.

Jakariya, Md. et al. (2007). Screening of arsenic in tubewell water with field test kits: Evaluation of the method from public health perspective, Sci. Tot. Env., Vol. 379, Iss. 2-3, p167-175.

Rosenboom, J.W. (2004). *Not Just Red or Green: An Analysis of Arsenic Data from 15 Upazilas in Bangladesh*. Dhaka: Arsenic Policy Support Unit, Government of the People's Republic of Bangladesh, Department for International Development (UK) and UNICEF Bangladesh. http://www.physics.harvard.edu/~wilson/arsenic/remediation/not_just_red_or_green.pdf

Steinmaus, C. et al. (2006). Evaluation of Two New Arsenic Field Test Kits Capable of Detecting Arsenic Water Concentrations Close to 10 µg/L, Environ. Sci. Technol., 40 (10), p3362 -3366

Van Geen, A. et al. (2005). Reliability of a commercial kit to test groundwater for arsenic in Bangladesh, Environ. Sci. Tech., 39 (1), p299-303.

UNICEF (2008). *UNICEF Water Quality Handbook*. New York: UNICEF. http://www.unicef.org/wes/index_resources.html

United Nations (2002). Chapter 2: Environmental Health and Human Exposure Assessment in *Synthesis Report on Arsenic in Drinking Water*. Geneva: WHO. http://www.who.int/water_sanitation_health/dwq/arsenic3

MODULE 6: PROGRAMME COMMUNICATION

Introduction

Communication for behavioural change is a key component of arsenic mitigation programmes. If they are given the appropriate knowledge and encouragement, people can take proactive steps to protect themselves from arsenic poisoning and demand critical services from government and its partners. The importance of effective communication is underlined by the experience in Bangladesh, where blanket testing identified arsenic-contaminated sources and a communication programme encouraged millions of people to switch to safe sources. To date, a far greater number of people have gained access to safe water through well switching than through the construction of new sources or arsenic removal filters combined.

While this and other lessons learned are key resources for the design of communication programmes in other countries, local context is just as important. Thus programmes to encourage behavioural change should be designed from the ground up on the basis of sound communication principles.

Communication challenges

Promoting behavioural change is always a challenging process, and especially for arsenic mitigation. The first challenge is to convince people that arsenic is even present and that it poses a health risk. Arsenic in water is invisible and tasteless, and is a long-term hazard: convincing people that their apparently clean water source may cause cancer and other serious health problems many years in the future is difficult. This difficulty is compounded by the fact that the solutions to the problem often involve giving up private and/or nearby water sources for more distant communal sources, which represents a major loss of convenience and privacy and creates an extra burden, especially on women and girls. Finally, because of the long-term nature of the problem, such modified behaviour must be sustained for many years even though there may be no visible effects or benefits in the community.

Table 6.1. KAP goals of an arsenic communication programme

Knowledge	Attitudes	Practices
• Arsenic is a poison • Consistent drinking can be fatal • Know how to identify symptoms • Know proper use of arsenic-contaminated and safe drinking water • Know that arsenicosis is not contagious • Know that boiling water doesn’t work	• Community members can together work out a solution • Help people affected – do not reject them • Share responsibility for fetching water for drinking	• Demand water testing • Switch to a safe source and drink only safe water • Share the safe water sources • Men/boys should share burden of fetching safe drinking water

Programme design principles

Here are the key principles that should be taken into account when designing communication programmes for arsenic mitigation:

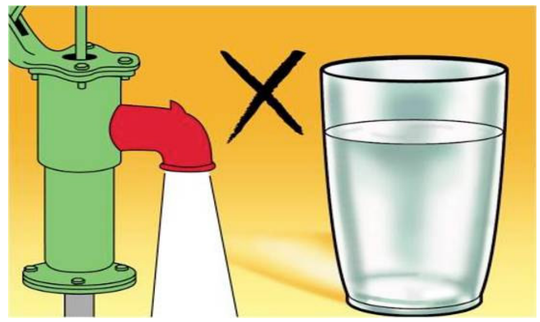
- Levels of knowledge can be raised, but may have little effect on behaviour.
- Beliefs and values influence how people behave.
- A behaviour is likely to be repeated if the benefit is rewarding, and less likely if the experience is punishing or unpleasant.
- Individuals are not passive responders, but have a proactive role in the behaviour change process.
- Social relations and social norms have a substantial and persistent influence on how people behave.
- Behaviour is not independent of context. People influence, and are influenced, by their physical and social environments.

(See the UN Synthesis Report on Arsenic in Drinking Water for more information.)

Programme design methodology

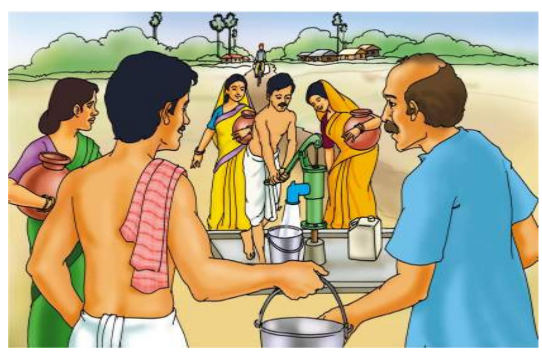
The programme design process begins with a situation assessment using existing and new information sources, including knowledge, attitudes and practices (KAP) studies, special surveys, and monitoring and evaluation reports. The situation assessment must collect disaggregated data to ensure that marginalized groups within the community – including women, children and the poor – are taken into account. The assessment must also include the best available knowledge of the extent and severity of the arsenic problem in the area. When the assessment is completed a detailed communication analysis is formulated that clearly defines the problem, analyzes actual practices and desirable behavioural changes, and develops clear communication objectives and strategies.

Ask for testing and mark the spout red or blue depending on the result.



Avoid water from a red-spout tubewell.

Do drink water from a blue-spout tubewell.



Drink only safe water even if it means carrying it back from a far-away blue-spout source.

Figure 6.1. Some key messages from the India arsenic communication programme

At this stage, screening and blanket testing should have been completed and policy decisions on the marking and/or sealing of contaminated sources must be made (see 7: Provision of Safe Water).

The communication analysis is the basis for the design of the communication campaign itself: the development of messages (see Figure 6.1 for examples from India) and choices of media and methodologies. Finally, the campaign material is developed, field tested, modified as necessary and launched. It is important to ensure that the persons using this material are properly trained, so that they impart the knowledge correctly. Monitoring and course corrections should be included in long-term plans.

Additional Resources

UNICEF India, UNICEF Bangladesh. Arsenic communication packages (available from the country offices upon request).

UNICEF (1999). Water*, Environment and Sanitation Guidelines: Water Handbook*. New York: UNICEF. http://www.unicef.org/wes/files/com_e.pdf

United Nations (2002). *Synthesis Report on Arsenic in Drinking Water*. Geneva: WHO. Chapter 7: Communication for Development (Michael Galway). http://www.who.int/water_sanitation_health/dwq/arsenic3

MODULE 7: PROVISION OF SAFE WATER

Introduction

The provision of arsenic-free water is the only way to protect people from arsenicosis. Arsenic-free water is provided by identifying safe existing sources, by constructing new sources or by removing arsenic from the contaminated sources, usually in that order of preference. Whatever option is chosen, it is important that the safety of the new water sources is assured. New sources must not only be arsenic-free, but must also be protected from faecal contamination to ensure that health risks from the new source are not greater than from the old source.

Water supply options and relative risk assessment

Because of the spatial variability of arsenic in groundwater aquifers, there are often some arsenic-free sources even in zones with high levels of arsenic contamination. These sources are identified through blanket testing programmes and marked accordingly – for example, by painting the spouts of handpumps green. In communities where there are a sufficient number of existing arsenic-free sources, it may not be necessary to construct new sources or introduce arsenic removal systems. People can instead use the arsenic-free sources for drinking and cooking water, at least in the short term. This option, known in South Asia as "well switching," is only viable when people are properly informed through a communication programme (see Module 6: Programme communication) and agree to use and share these sources.

If the blanket testing programme shows that there are not enough existing arsenic-free sources in a community, the next best option is source substitution: developing alternative safe sources of water such as groundwater at a different depth or using surface water. The type of source will depend on availability of water resources and the type of technologies commonly used in the country. For example, rainwater is an arsenic-free water source but if there is no experience using rainwater in-country, it may be best to consider another option.

Alternate water sources should be carefully chosen to ensure that the risks

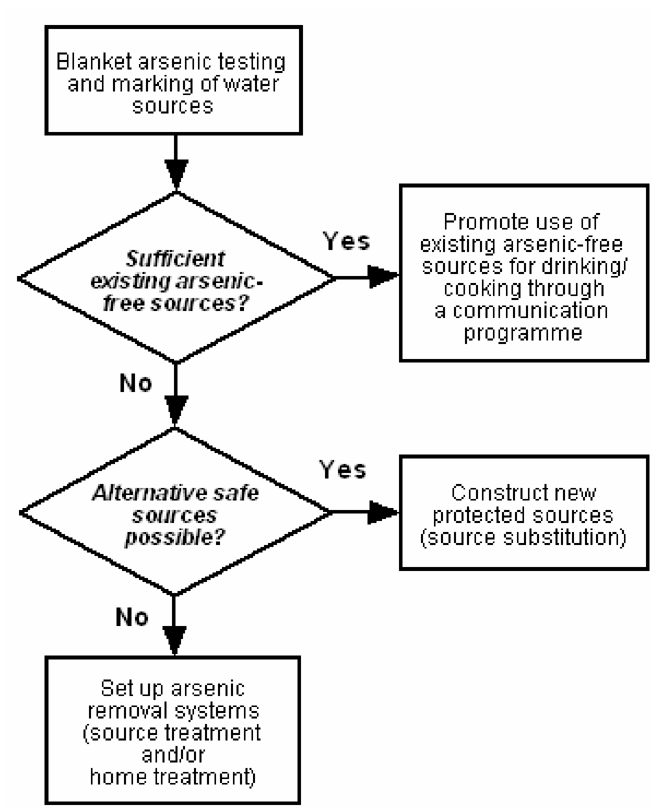


Figure 7.1. Decision tree for provision of safe water in arsenic contamination areas

Contaminated sources: mark or seal?

Arsenic-contaminated water can be safely used for bathing, washing and other household purposes, including washing dishes (see photo). If the well is left open, there is a risk that people will continue to drink the water, even with a communication campaign and proper marking -- such as the spout painted red. But this risk must be considered against the risks posed by closing the well.

If a contaminated well is closed, and the household needs to collect water from a more distant source, less water will be used and hygiene practices will probably suffer. The additional workload of collecting water will fall disproportionately on women and children.

When public wells are highly contaminated – above 200 ppb or 300 ppb, say – it may be prudent to close them because the health risks from exposure are more immediate and severe. Of course, the decision of whether or not to close private wells lies with the well owners.

These Bangladeshi women know the red spout means the water is arsenic-contaminated and cannot be used for drinking or cooking – but that it can be used for other purposes.
UNICEF/HQ98-0839/Noorani

from the new source are not greater than from the old source. Especially important is that new sources are not susceptible to faecal contamination. For example, a rigorous risk assessment was conducted for alternatives to arsenic-contaminated groundwater in Bangladesh in 2006 during both dry and wet seasons. One alternative water source (deep boreholes tapping arsenic-free aquifers) had a significantly lower potential disease burden than the other three sources (dug wells, filtered surface water and rainwater).

Experience and research shows that providing new arsenic-free water sources is a better option than removing arsenic from contaminated sources in most cases. Due to the costs and logistical complexity of arsenic removal – which involves treatment of arsenic-contaminated water at the source or in homes – it is the last option, to be considered only when the other options are exhausted.

Source substitution: alternative water options

The development of new water supplies is a subject that is beyond the scope of this module. For more information, readers should refer to local expertise and practices -- which will be the key determinant of technology and source options -- and to the recommended readings. Here is a broad overview of the three types of alternative water sources most likely to be viable options in rural areas of arsenic-affected zones.

Groundwater
In the alluvial areas where most arsenic occurrences have been found, it is common that only some aquifers are contaminated with arsenic. Typically, very shallow groundwater tends to be low in arsenic, middle aquifers are contaminated and deeper aquifers are low in arsenic. This means that dug wells and boreholes are viable options in some arsenic-contaminated areas. However, the depth of the low-arsenic aquifers can vary widely, and must be determined through local testing.

In areas where arsenic-free (or low-arsenic) groundwater is a viable option, it should be considered first over surface water. Groundwater is often more widely available and less expensive to extract in rural areas, and it is safer from faecal contamination. But it isn't always safe: population pressures and other factors can increase the possibility of faecal contamination and sources must be carefully constructed and protected.

Deeper aquifers are tapped by drilling boreholes and installing handpumps or motorized pumps. In the soft formations found in alluvial areas it is often possible to hand-drill boreholes, even to depths greater than 200m. Mechanized drilling rigs can also be used, but only in countries where there is an established water well-drilling industry.

The low/no-arsenic shallow aquifers are generally tapped with hand-dug wells. Properly constructed and protected, such wells can be safe from faecal contamination. However, all things being equal, they are more susceptible to contamination than deeper boreholes, and thus should only be considered if deeper sources cannot be tapped. A distinction should also be made between the private family dug wells that are common in many parts of the world and communal wells constructed through government-sponsored programmes. Household wells are usually outside of any national water quality regulatory and monitoring framework, are often poorly constructed and are rarely well-sealed against contamination. Exacerbating the problem is the fact that many household compounds, because of lack of space and knowledge, have family latrines and garbage pits dug close to the dug well or borehole.

Surface water
Surface water is widely used throughout the world as the source for domestic water systems, both for large piped systems and for smaller rural systems. In almost every case, surface water must be treated before reaching consumers because lakes and rivers are highly susceptible to faecal contamination. This treatment requirement increases costs and decreases sustainability, especially in poorer communities. Surface water is also increasingly susceptible to chemical contamination from a variety of sources ranging from industrial pollution in rivers to the chemicals used in small-scale fish-farming ponds. This means that simple, low-cost sand filters used to treat surface water in rural areas in some countries are becoming a less viable option.

Rainwater
In theory, rainwater is the safest of all water sources. Although rainwater can become contaminated through the absorption of atmospheric pollutants, it is usually very pure as it hits the earth. The problem with rainwater is that the surfaces that are used to collect it, such as rooftops, are often not clean. And more serious, the fact that rainwater must be stored for relatively long periods of time increases its susceptibility to contamination from a variety of

sources. This storage requirement can also make the technology unviable in areas with long dry seasons: the large tanks necessary can be too costly or will not fit in household yards. However, in some regions – notably Southeast Asia – there is a long and successful tradition of household rainwater harvesting and storage, making it a real option.

Household water treatment for faecal contamination
Householders throughout the developing world are increasingly using low-cost technologies to treat water to reduce faecal contamination. Studies show that with the right technologies and practices, this can be a highly effective way to improve the microbiological quality of water used for drinking and cooking. With household water treatment, surface water, water from dug wells and stored rainwater can become safer and thus more viable options.

The most common techniques used for home water treatment are boiling, chlorination, filtration, solar disinfection and combined flocculation/disinfection techniques. The best of these options is usually the one that is most widely practiced locally. Boiling, while widely practiced, is usually only an option for richer households, due to fuel costs. In some countries chlorination is widely used and is effective for low-turbidity water. Elsewhere, low-cost filters – such as ceramic filters– are increasingly well-made and available in local markets. Solar disinfection (SODIS) is growing in popularity because of its effectiveness when properly done and because it is ultra-low cost or free.

Other alternative water options
In some cases the best option is a combination of water sources and technologies. A common combination is the use of household rainwater harvesting systems during the rainy season and shared boreholes during the dry season. Another option is mixing arsenic-contaminated groundwater with water from another source (usually treated surface water) resulting in water with an arsenic concentration that meets national standards. However, this is only an option in areas with the resources to construct, operate and maintain the relatively sophisticated systems necessary.

The Nirmal combined arsenic and iron removal filter used in India
UNICEF/2003/Keast

Arsenic removal

Removing arsenic from water is considered the last option because it is technically challenging to remove arsenic from water, because it is difficult to ensure that arsenic removal units are correctly operated and maintained, and because of the need to keep costs low enough for poor communities and households.

Arsenic removal is technically challenging because the treatment target is so low: reducing concentrations in highly contaminated areas to national standards of 10 ppb or 50 ppb can mean target reduction rates of over 90 per cent. The most common low-cost removal techniques are *co-precipitation*, using agents such as alum or iron, and *adsorption* using alumina or metallic iron ore. Arsenic removal units using these and other techniques are available for municipal water systems, for attaching to handpumps, and for use by households. Due mainly to costs and logistical issues, household units are now considered by most to be the best option for wide-scale application in developing countries.

As the extent of the arsenic problem became clear, many different types of household arsenic removal filters were developed by a variety of organizations, public and private. So many, that in Bangladesh that it became necessary to implement a comprehensive assessment and certification programme to ensure that only the most effective, sustainable and safe technologies were released onto the market.

Despite these efforts and the availability of relatively effective low-cost units, arsenic removal still has a relatively limited impact on overall mitigation efforts. In Bangladesh, for example, the vast majority of people in arsenic-affected areas who now have access to safe water supplies through mitigation efforts have provided water through well-switching or deep boreholes.

Arsenic removal remains an important option in areas where other options are not available, and in some cases – such as in areas where contamination levels are very high – as a short-term solution until new sources can be constructed.

Additional Resources

Howard, G. et al. (2006). Risk Assessment of Arsenic Mitigation Options in Bangladesh. *Journal of Health, Population and Nutrition*, 24(3): 346-355.
http://www.icddrb.org/pub/publication.jsp?classificationID=30&pubID=7836

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United Nations Synthesis Report on Arsenic in Drinking Water (2002). Geneva: WHO. Chapter 6: Safe Water Technology (R. Johnston, H. Heijnen and P. Wurzel)
www.who.int/water_sanitation_health/dwq/arsenic3.

MODULE 8: OTHER ROUTES OF EXPOSURE

Introduction

The problem of arsenic contamination of drinking water is the main focus of this primer. However there are other exposure routes in addition to water, and these are introduced in this module.

Absorption of arsenic through skin is minimal, so handling of contaminated water – or washing with contaminated water – is not dangerous. However, exposure through arsenic-contaminated food and air dose pose a risk, especially when it is combined with arsenic from drinking water. Occupational exposure to arsenic can be significant (e.g., for mine and smelter workers), but it affects small numbers of people it is not discussed here.

Arsenic in agriculture

Far more groundwater is used for irrigation than is used for drinking and cooking. When arsenic-contaminated water is used for irrigation, it builds up in soils, particularly those containing significant amounts of clay. Plants grown in these soils can transport and accumulate arsenic. While some plants convert inorganic arsenic to less toxic organic forms, in others inorganic arsenic passes into the foodstuff. Arsenic uptake by plants is complex, and cannot easily be predicted.

Rice is a staple of the diet in the Asian countries most prone to arsenic contamination. The anaerobic conditions in rice paddies are favorable for arsenic mobilization, and studies have demonstrated significant uptake of arsenic by rice. In general, arsenic levels are highest in roots, followed by shoots, leaves and grains. One study found that 80 per cent of arsenic in rice samples from Bangladesh was in the toxic inorganic form, with a median concentration of 0.2 mg/kg. Bangladesh has set no standards for arsenic in foods, but the Chinese government in 2005 fixed a limit of 0.15 mg/kg inorganic arsenic in rice. WHO has established a provisional Maximum Tolerable Daily Intake (MTDI) of 0.0021 mg inorganic arsenic per kg body weight, which should include exposure from food and water together. Different strains of rice show different degrees of arsenic uptake, and arsenic levels in rice are affected by concentration in irrigation water and soils.

On a dry weight basis, some vegetables have much higher levels of arsenic than rice. However, a typical Asian diet includes much more rice than vegetables, so intake from rice remains the principal arsenic exposure through food.

Domestic animals may be fed crop residues containing elevated levels of arsenic, such as rice straw. While there is little data available, arsenic is not thought to accumulate to dangerous levels in meats or milk. Animal dung, which contains high levels of partially digested plant matter, can contain high levels of arsenic, and if this dung or arsenic-rich crop residues is used as a domestic fuel, arsenic could be released to the atmosphere and pose an inhalation threat.

Irrigation with arsenic-contaminated groundwater poses an additional hazard, which has received less attention, but may be of equal or greater significance: when arsenic levels in soils become concentrated enough, the soil becomes toxic to some crops. Studies in Bangladesh have shown a clear relationship between increasing arsenic levels in soils and decreasing crop yields. Thus, arsenic may pose a risk to both the incomes and the nutritional status of rural farmers.

Potential mitigation strategies include reducing reliance on groundwater for irrigation by changing cropping or irrigation patterns. Arsenic mitigation in agriculture requires a broader water resources management perspective. UNICEF may wish to discuss the issue with FAO and government counterparts.

Indoor coal-burning in China
Source: Environmental Health Perspectives Volume 102, Number 2, February 1994

Arsenic in coal

Coal can contain very high levels of arsenic – up to 3.5 per cent arsenic by weight. Hundreds of millions of people around the world burn coal in the household in non-ventilated stoves for heating, and in some cases for drying food. In southwest China, arsenic-rich coal is used to dry chili peppers and corn, exposing people to arsenic both through inhalation and by contaminating food. Coal-drying may also release high levels of fluoride, selenium or other toxins to foods and air. Thousands of cases of arsenicosis and millions of cases of fluorosis have been linked to coal-burning.

Additional Resources

An, D. et al. (2007). Unventilated Indoor Coal-Fired Stoves in Guizhou Province, China: Reduction of Arsenic Exposure through Behavior Changes Resulting from Mitigation and Health Education in Populations with Arsenicosis. *Environmental Health Perspectives. 115* (4): 659-662 .
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MODULE 9: PARTNERSHIPS AND ADVOCACY

Introduction

Arsenic exposure is a multi-sectoral problem that involves a number of different stakeholders. While national governments have overall responsibility for arsenic mitigation, UNICEF and other stakeholders can play an important supportive role. The experience in countries where arsenic mitigation programmes have been ongoing for the longest time demonstrates that involvement of the key stakeholders and the development of strong partnerships is key to the success of the programme.

Table 9.1. Potential stakeholders

Water supply and water safety	• Government water supply ministries and departments • Government health ministries and departments • Water resource agencies • Technical departments of academic institutions – e.g., in fields of civil engineering, chemistry, environmental science, hydrogeology • UNICEF WES specialists • Other UN agencies, including Water and Sanitation Programme (WSP), UNDP, World Bank • International NGOs such as WaterAid, Local NGOs
Health	• Government health ministries and departments • Health/medicine departments of academic institutions • UNICEF health specialists • Other UN agencies, such as WHO • International NGOs and local NGOs
Geo-science	• Geological surveys • Groundwater exploitation agencies • Geology departments of academic institutions
Agriculture/Irrigation	• Government agriculture/irrigation ministries and departments • Agriculture departments of academic institutions • Other UN agencies, such as FAO • International NGOs and local NGOs
Other key development partners	• Local government institutions • Donors

Arsenic Task Forces

In India, potential stakeholders in West Bengal state were drawn together with the formation of the state Arsenic Task Force. The full arsenic task force is a consultative, multi-sectoral advisory and networking body with 23 members, including representatives from the relevant government bodies, academic institutions, UN agencies and NGOs. The Core Committee of the task force is an executive of eight to ten members. Discussions and decisions taken in the meetings are recorded and minutes are circulated to all members and higher level officials (i.e., ministers and principle secretaries of relevant government departments). UNICEF supported the establishment and operational expenses of the Core Committee of the Arsenic Task Force.

This arrangement has several advantages. It ensures that the Government of West Bengal receives the best scientific advice and guidance available when formulating arsenic mitigation programmes. In addition, it ensures that all potential stakeholders are aware of the ongoing or planned arsenic mitigation activities, thereby encouraging collaboration and avoiding duplication. A similar arrangement has now been established in the states of Bihar, Uttar Pradesh and Assam.

Other countries also have coordination bodies. In China, UNICEF's ongoing work with government agencies in the area of both arsenic and fluoride has contributed to the recent establishment of a National Network for Arsenic and Fluoride. The network involves several government bodies, including the China Geological Survey, the Ministry of Water Resources and the Ministry of Health and carries out its work through a joint workplan.

In some cases these coordination bodies may be expanded in the future to tackle broader water quality issues. But what is crucial is that water safety is recognized as a multi-sectoral issue that requires inter-sectoral cooperation and coordination.

Evidence, advocacy, action: arsenic in Vietnam

As the extent of the arsenic contamination problem in Bangladesh and India became clearer in the 1990s, UNICEF and its partners began to investigate the possibility of the presence of arsenic in other regions with similar hydrology and geochemistry. In Vietnam, UNICEF sponsored arsenic testing in Hanoi and other areas in the Red River delta region that confirmed the arsenic in groundwater at levels higher than the national standard.

Based on this evidence, and using lessons learned from other countries, UNICEF launched an information sharing and advocacy programme with key government ministries and agencies. The programme used a variety of methods, including publishing an information brochure, raising the subject during regular sectoral coordination meetings and sponsoring visits of government officials to other arsenic-affected countries.

UNICEF also supported two national arsenic conferences in Vietnam, which led to the development and ratification of a national action plan and the formation of a national arsenic coordination committee. Arsenic-related activities are now incorporated into sectoral ministry plans of action, and a coordinated and comprehensive mitigation programme – with continued support from UNICEF and partners – is in place to address the problem.

Advocacy

Advocacy is a key step to encourage action by responsible government authorities and other relevant stakeholders. These stakeholders can include civil society organizations, funding agencies, other UN agencies and even other sectoral programmes within UNICEF.

A key to successful advocacy is having access to information and being able to present it effectively to different audiences. The types of advocacy that have been successful in arsenic mitigation programmes so far include raising awareness through international, national and local conferences and media events; placing articles in local media; briefing local medical and water sector professionals, leaders and educators; developing working groups of representatives from UNICEF, WHO and FAO; and strengthening convergence within a UNICEF field office by defining specific activities relating to arsenicosis in the UNICEF Health section workplan.

Additional Resources

UNICEF (2008). Chapter 6. Raising Awareness and Building Capacity in *UNICEF Water Quality Handbook*. New York: UNICEF.
http://www.unicef.org/wes/index_resources.html

World Bank/WSP (2005a). *Arsenic Contamination of Groundwater in South and East Asia: Towards a More Operational Response*. *Volume 1: Policy Report*. Washington: World Bank.
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MODULE 10: PROGRAMMING FOR ARSENIC MITIGATION

Introduction

This section offers guidance for UNICEF staff and partners on designing and executing a comprehensive arsenic mitigation programme. The decision about whether to implement a "single parameter" programme, or to build it into a broader "water safety" framework is discussed at the end of the module.

Experience in Bangladesh, India and elsewhere indicates that there are four main pillars to an effective programme of arsenic mitigation:

1. Arsenic testing
2. Behaviour-change communication on the results of testing and the implications for the community
3. Provision of alternative sources of arsenic-safe water where required
4. Support to health professionals in recognition, diagnosis and management of arsenicosis

Stages in the development of an arsenic mitigation programme

The main stages in the development of the programme are the following.

Desk investigation
In areas where arsenic exposure through groundwater used for drinking is suspected, but not confirmed, it may be beneficial to first conduct a brief search of the available literature to determine if any previous investigations have been made. Published national and international scientific literature is the obvious place to start, but good information may also exist in an unpublished form. This might include government water supply data, unpublished data of academic institutions (e.g., in MSc or PhD theses), or reports of development partners such as other UN agencies, international NGOs or NGOs. In a number of countries the first evidence of arsenic contamination has come from health workers, especially dermatologists.

Preliminary field investigations
Awareness about arsenic exposure as a risk to health often develops from a limited initial field investigation and reporting by an academic, non-governmental or governmental institution. This may take the form of an initial water quality test report or identification of arsenicosis patients. In many cases UNICEF has supported these initial investigations.

Media involvement if necessary
There may initially be reluctance on the part of government agencies and others to accept the problem and take action. This may stem from disbelief or a lack of understanding. Sometimes local or international media stories on arsenic contamination help raise the profile of the issue and generate sufficient pressure to ensure progress.

Proactive media management
National and international journalists sometimes sensationalize and incorrectly report the magnitude and science of the arsenic problem. It is important to maintain contacts with reliable journalists and provide them with detailed explanations, fact sheets and Q&A documents to ensure accurate reporting. UNICEF should also be sure to hold press conferences at critical junctures, highlighting the positive steps taken by UNICEF and partners in tackling the arsenic issue.

Awareness-raising of government/non-government counterparts and formation of a stakeholder group
As with any development programme, it is important to raise awareness and knowledge of development partners at a central/senior level, and engage their support, before progressing to lower levels. This is particularly important in the case of arsenic, because it is a multi-disciplinary problem requiring involvement of water supply providers, health professionals, geo-science institutions, academic researchers, communication experts, NGOs reflecting the affected community, other specialist stakeholder UN agencies, NGOs, agriculturalists and irrigation engineers.

Ensuring the involvement of representatives from these key stakeholder groups at the beginning will reduce confusion, spreading of misinformation and misdirection of activities later on. In several of the states of India this has been done through formation of an Arsenic Task Force (ATF) comprised of representatives from governmental, non-governmental and academic institutions and supported by UNICEF. Similar coordination mechanisms have been instituted in Bangladesh, Vietnam and other countries.

Development of plans of action
Arsenic task forces and similar coordination mechanisms are the ideal forums for the development of national and/or sub-national plans of action, which require government leadership and full stakeholder participation to be successful. While the strategic framework for most arsenic response programmes includes the four core elements of testing, communication, safe water supply and arsenicosis management, plans of action will vary from place to place, depending on the situation. Plans of action also need to be updated and modified periodically as data emerges from testing programmes and in response to new programming approaches and technologies.

Screening testing
Where the water supply is drawn from a large number of point sources (e.g., in Uttar Pradesh, India, there are about 1.45 million government-installed handpumps and many more private handpumps), it may be beneficial to conduct a round of screening testing to identify areas for more comprehensive blanket testing.

Here the term "screening testing" is used to mean testing of a sub-set of all of the water sources. Strategies such as testing one in ten sources or one source per village may be employed. It is also useful to consider a round of screening testing when availability of equipment, supplies or capacity are a limiting factor. In areas where arsenic levels are above (or approaching) the standard in use, more comprehensive

Screening testing using a field test kit in Uttar Pradesh state in India
UNICEF/2005/Nickson

blanket testing may be taken up. Ultimately, the aim should be to test all sources in areas where arsenic is known to be a problem; however, screening testing can be used to focus limited resources in the most affected areas, or areas considered to be at higher risk geologically, in the initial stages.

Development of communication strategy and materials
Where dispersed point sources such as handpumps provide the water supply, tackling a problem of arsenic exposure through groundwater used for drinking requires engagement of the community. It ultimately requires behaviour change by individuals to reduce their exposure to arsenic. It is essential that a strategy for communicating the results of testing and the implications to the people in the community is developed early in the mitigation process.

Example of a leaflet developed and used in Bihar state in India

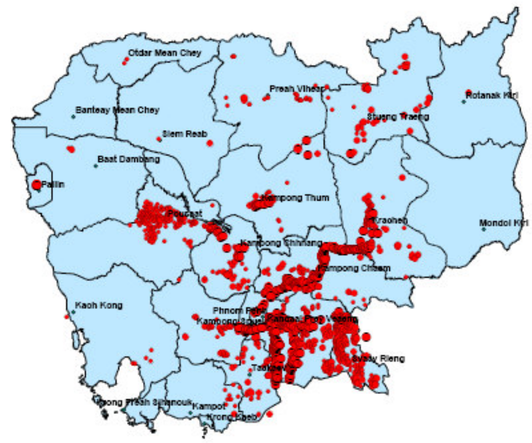
The key messages to be communicated and the channels of communication (e.g., TV and radio, newspapers, posters and flyers, interpersonal communication) need to be defined, keeping in mind the population's education level, rate of literacy and key languages and dialects. Communication messages should be directly linked to UNICEF or another stakeholder's programmes. Communication materials can then be developed and tested and rolled out for use.

Blanket testing and marking of sources coupled with behaviour change communication
In known affected areas, or areas where arsenic is strongly suspected, blanket testing of all sources may be taken up. Ideally this should include both government-installed and privately installed sources. Marking of sources as safe/unsafe from arsenic (e.g., with green/red paint or signboards) has been a successful strategy for informing people of the testing results in Bangladesh and elsewhere. This information provides people with the first and simplest option available to reduce their exposure to arsenic: well-switching – that is, changing behaviour to collect water from an alternative arsenic-safe source.

Sources marked as arsenic-safe must be safe for the entire range of possible contaminants, including microbiological contaminants. This may involve a review of the geological setting, testing of a sub-set of sources for other potential chemical contaminants, and verification of adequate source protection, for example, using sanitary surveillance and/or home treatment.

Collation of data and mapping of extent and magnitude of the problem
Once sufficient data are available it should be possible to summarize and analyze them, and ideally produce maps showing the extent and magnitude of the problem (which may be simply the percentage of sources affected in different geographical areas).

If sufficiently detailed, the summary data, analysis and maps may be used by water supply providers to prioritize provision of alternative sources. These data will also be useful to UNICEF as an advocacy tool with water supply providers, policy makers, planners and politicians.



Map of arsenic occurrence in Cambodia
(one output of a UNICEF-supported testing programme)

Provision of alternative sources
In areas where there are insufficient arsenic-safe sources or there are particular problems in sharing of water sources (e.g., communal differences, ownership issues) alternative sources of arsenic-safe water must be provided. Use of deeper groundwater, rainwater, treated shallow groundwater (e.g., from dug wells), treated surface water and arsenic removal are potential options.

This aspect of an arsenic mitigation programme requires the largest financial commitment and UNICEF is unlikely to have the technical capacity or the funding to undertake it alone. Government, NGOs, donors and other development partners will need to be engaged. In some cases UNICEF may demonstrate suitable technologies for replication by the government or other partners. Care must be taken to ensure that by encouraging a shift from one source of drinking water to another there is no risk substitution from long-term, chronic exposure to arsenic leading to arsenicosis, to more immediate risks of diarrhoeal disease from faecally contaminated water.

Support to health staff in affected areas
It is likely that there is limited knowledge about arsenicosis in the local medical community. Training on arsenicosis symptoms, diagnosis and management is often necessary. Production of health manuals in the local language have assisted in the awareness raising and training of medical professionals in Bangladesh, India and China.

The best available medical prescription for treatment of chronic arsenicosis is drinking arsenic-safe water and this should be stressed. Symptomatic treatment of arsenicosis symptoms such as keratosis and skin cancer can be taken up by health professionals where necessary.

Monitoring of provision of safe water and reduction in exposure of population
As arsenic mitigation progresses it is important to measure achievements in reducing the exposure of the target population to arsenic. Some information may be gathered from water supply status data but more comprehensive data is likely to come from questionnaire surveys of the population, water quality surveys, or epidemiological studies with direct or indirect measurement of arsenic exposure. These data can be used to make corrections in the mitigation programme strategy.

Building arsenic into a broader water safety programme

In certain areas where arsenic in groundwater used for drinking was unrecognized and large numbers of people were found to be exposed, a targeted approach was required. UNICEF thus supported activities with the sole aim of mitigating arsenic exposure. This focus has been successful in mitigating exposure to arsenic, but there is a danger that without a holistic consideration of water safety that other risks to health – especially from faecal contamination of drinking water – are overlooked. It may therefore be beneficial to incorporate arsenic mitigation into a broader water safety programme framework.

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