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MITIGATING ARSENIC IN DRINKING WATER

UNICEF supports countries in providing safe drinking water for children as a fundamental right stipulated by Article 24 of the Convention on the Rights of the Child and the UN General Assembly resolutions on the human right to safe drinking water as a component of the right to an adequate standard of living that is essential for the full enjoyment of all human rights. The consumption of unsafe drinking water is one of the leading global health risks with children being disproportionately affected by associated chronic and acute health impacts.

The *Sustainable Development Goal target 6.1* aims for *universal and equitable access to safe and affordable drinking water for all by 2030.*[1] The SDG definition of a safely managed water service is one that is accessible on premises, available when needed and free of faecal and priority chemical contamination. The 4th Edition of the World Health Organization's *Guidelines for Drinking-Water Quality* recommends a risk-based approach to managing water safety within a framework of health-based targets and independent surveillance.

This Framework for Safe Drinking Water (FSW) enables the prioritization of management actions identified by water safety plans (WSPs) that maximize the health benefits of reducing exposure to microbial and chemical contaminants.

Naturally occurring arsenic contamination of groundwater presents a serious chronic public health risk. It has been found in at least 70 countries and could affect more than 140 million people, most of whom live in Asia. Arsenic contamination of drinking water is invisible, tasteless and odorless and the effects of ingestion are not apparent in the short term. Continued exposure to high levels of arsenic from drinking water and food can give rise to arsenicosis which is a painful and debilitating skin condition. Continuous exposure to arsenic also dramatically increases the risks of morbidity and mortality from cancers and heart, lung, kidney and liver disease that are not necessarily preceded by arsenicosis. Arsenic is readily absorbed *in utero* increasing the risk of stillbirth and the intake of arsenic by children (per unit body mass) is higher than that of adults increasing the risk of impaired intellectual development and associated impacts later in life.

As there is no medical cure for arsenic poisoning and as the health risk increases with the cumulative exposure any form of mitigation should seek to reduce the concentration and duration of arsenic exposure as soon as possible.

Short-term actions that can reduce arsenic-exposure risks include the use of rainwater for drinking during the wet season, the changing of cooking habits, the switching to alternate proximate safe sources, and the application of arsenic removal devices.

Long-term effective solutions require concerted action led by governments, based on solid knowledge of local conditions, involving communities and systematic information management systems with partners across all sectors related to water supply (e.g. agriculture) and public health (e.g. nutrition).

Undertaking arsenic-mitigation actions within a framework of health-based targets and independent surveillance seeks to ensure that the exposure to arsenic through all possible routes is minimized while also avoiding potential risk substitution (i.e. mitigation measures that reduce arsenic risks but increase exposure to microbial or other priority chemical risks).

UNICEF support is based on tenets of: assisting governments in establishing targets for drinking water quality and undertaking surveillance to monitor improvements; working with water service providers to proactively manage risks to drinking water safety; helping change knowledge, attitudes and practices so that the most vulnerable can protect themselves; undertaking research, supporting innovation and promoting the sustainable management of drinking-water resources.

In extending support to countries in assessing and mitigating the potential risk of arsenic contamination of groundwater, the following risk-response matrix may act as a guide for UNICEF country offices to identify response that is suited to their context.

	RISK	SCENARIO	RESPONSE
ASSESSMENT PHASE	**Low Risk**	• No previous evidence of arsenic in groundwater • No contamination risk on **www.gapmaps.net**	• Laboratory testing of priority natural contaminants (i.e. As, F, U, Cr, Cd, Pb) in <1% of wells at different depths
	Suspected Risk	• No previous evidence of arsenic in groundwater • Some contamination risk on **www.gapmaps.net**	• Laboratory testing for priority natural contaminants (i.e. As, F, U, Cr, Cd, Pb) including in >5% of wells in areas identified by **www.gapmaps.net**
	Identified Risk	• Some reports of arsenic in groundwater, not yet confirmed	• Establish a multi-disciplinary team to undertake arsenic contamination validation (testing & analysis) exercises
	Confirmed Risk	• Sample surveys have confirmed the presence of arsenic in the ground or surface water	• Set health-based targets (including arsenic standards) • Prepare arsenic testing, marking and monitoring plans • Develop communications strategy based on KAP analysis • Identify priority arsenic mitigation options
MANAGEMENT PHASE	**Quantified Risk**	• Data on the nature and scale of the problem has been presented in detailed maps	• Undertake blanket survey of wells in high risk areas • Upgrade capacities for field testing & lab verification • Introduce unique coding system for all wells • Initiate priority arsenic mitigation options
	Mitigated Risk	• Blanket surveys have identified all the safe and contaminated wells (public & private) • Alternative sources have been identified/provided for at risk populations	• Establish health/agriculture/water surveillance system • Support public/private arsenic mitigation at scale • Enforce QA/QC process for all mitigation options (incl. arsenic testing & coding standards for all new wells) • Research anomalies in health/agriculture/water data
	Secondary Risk	• Anomalies in arsenic exposure and health impacts have been identified	• Test/mark arsenic contamination of irrigation wells • Open access data-base on arsenic contamination • Support academic research to address anomalies
	Prospective Risk	• Foreseen yet unquantified risk of exposure to arsenic	• Research latent burden of disease, intergenerational effects, arsenic mobilisation/migration, consequences on food & water security, trust in public agencies

The Human Right to Safe Water

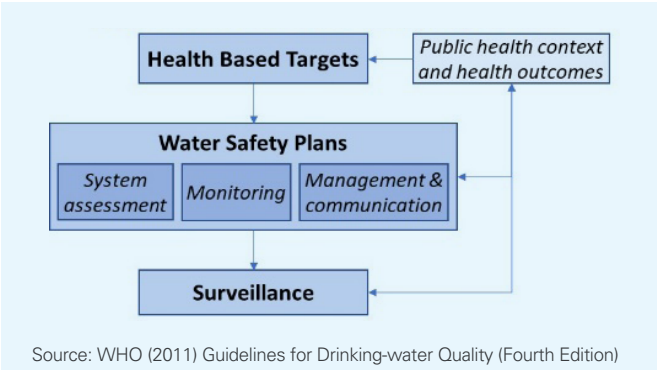
Drinking-water quality is a major concern in countries throughout the world. Safe water must be free from pathogens and dangerous concentrations of chemical contaminants such as arsenic or fluoride. Safe drinking water has been recognized as a fundamental human right essential to the full enjoyment of life and all other human rights.[2] Article 24 of the Convention on the Rights of the Child also outlines the responsibility of signatory states to support the highest attainable standard of health for children, and to provide "clean drinking-water, taking into consideration the dangers and risks of environmental pollution.[3]"

Sustainable Development Goals

Where the MDGs sought to halve the population without access to an improved water source, the SDGs target universal access to safe and affordable water services and the reduction of inequalities. The Sustainable Development Goal target 6.1 aims for universal and equitable access to safe and affordable drinking water for all by 2030. The new global SDG indicator of a "safely managed drinking water service' is defined as the use of an improved drinking-water source which is accessible on the premises, available when needed, and free of faecal and priority chemical contamination.

Framework for Safe Drinking Water

The 4th Edition of the World Health Organization *Guidelines for Drinking-Water Quality* situates the management of drinking-water safety within a framework of health-based targets and independent surveillance. Control of the microbial and the chemical quality of drinking water requires the development of water safety plans (WSPs) that, when implemented, provide the basis for system protection and process control to ensure that drinking water is acceptable to consumers and presents a negligible risk to public health. The Framework for Safe Drinking-water (FSW) prioritizes water safety plan (WSP) management actions that maximize the overall health benefits of reducing exposure to microbial and chemical contaminants.



Source: WHO (2011) Guidelines for Drinking-water Quality (Fourth Edition)

Extent of Arsenic Contamination

Some arsenic is naturally present in most rocks and sediments that form aquifers. There are four main geochemical processes that trigger the natural release of arsenic into groundwater. These processes occur in a wide range of geological and climatic environments. Where reductive dissolution tends to occur in unconsolidated sediments in humid climates; alkali desorption and sulfide oxidation tend to occur in hard rocks in drier climates; and geothermal activity occurs in specific volcanic settings.

Naturally occurring arsenic contamination of groundwater has been discovered in at least 70 countries half of which were discovered within the last 20 years. In terms of human exposure, the alluvial aquifers adjacent to young mountain ranges (i.e. the Himalayas, the Alps and the Andes) and fluvio-glacial aquifers in general present the highest risk, particularly affecting the middle and lower reaches of the Indus, Ganges-Brahmaputra, Irrawaddy, Mekong, Red and Yellow rivers.

Though arsenic occurrence in groundwater is subject to considerable uncertainty, UNICEF and EAWAG have developed maps to assist in predicting the risk of arsenic contamination that are freely available on the Groundwater Assessment Platform website (www.gapmaps.net). Estimates from 2009 suggest that arsenic contamination could affect more than 140 million people globally.

Arsenic contamination of drinking water is invisible, tasteless and odorless and so the detection of arsenic in groundwater requires specific testing. Due to the highly variable distribution of arsenic in groundwater, it cannot be assumed that all wells in high-risk areas are contaminated. In alluvial soils, safe wells can occur right alongside contaminated wells which means that some safe wells may be present even in highly arsenic contaminated areas. The movement of arsenic in groundwater is relatively slow, travelling metres per year horizontally and metres per decade vertically. The presence of arsenic contamination in previously tested safe wells (often due to faults in the well casing or testing regimes) does however mean that testing for arsenic in contaminated areas should be repeated every few years.

Mechanisms of Arsenic Exposure

The use of contaminated groundwater for drinking and cooking is the main conduit for human exposure to arsenic. The World Health Organization (WHO) guideline value for arsenic in drinking water was set at 50 parts per billion (ppb)[4] over a lifetime of exposure but this was revised downward in 1993 when it was estimated to pose an unacceptably high risk of death by cancer. The current WHO guideline value has been provisionally set

at 10 ppb due to the limits on the detection and removal of arsenic even though this is still considered to pose an unacceptably high health risk. Since the setting of water-quality standards is the responsibility of nation states, acceptable levels of arsenic in drinking water ranging from 50 ppb to less than 10 ppb have been progressively adopted by different countries.

Other avenues of arsenic exposure include food (from crops irrigated with water contaminated with arsenic that is then transferred into the food) or air (from the burning of contaminated coal or plant matter that has been irrigated with arsenic contaminated water). Top soil irrigated with arsenic- contaminated water acts as an arsenic sink that can affect crops even after irrigation has ceased. As arsenic is also toxic to plants (phytotoxicity), increasing levels of arsenic in the soil also have a significant negative effect on crop yields. While human activities such as mining and geothermal changes such as volcanic activity may also cause severe arsenic contamination, their extent is generally limited.

Assessments of the maximum Tolerable Daily Intake (TDI) of arsenic therefore needs to consider exposure from food, water and air. While assessments of exposure through water are relatively straightforward, exposure through food varies enormously with dietary habits (i.e. inorganic concentrations of arsenic in food are dependent on the variety of crops, as well as the methods used to cook and produce those crops). While arsenic is readily absorbed by ingestion, inhalation and *in utero,* the use of arsenic-contaminated water for bathing or laundry does not present a significant risk, as arsenic is not absorbed through the skin.

Consequences of Arsenic Exposure

The detection of arsenic poisoning is often challenging because the effects of ingestion are not apparent in the short term. Constant exposure to high levels of arsenic dramatically increases the likelihood of contracting cancers as well as heart, lung, kidney and liver diseases. Arsenic-induced cancer has particularly long latency periods, exhibiting up to 40 years after exposure has ended. In only a small percentage of cases will arsenic poisoning present as skin lesions (*arsenicosis*) in the form of changes in skin colour (*melanosis*) or the hardening of the skin into nodules (*keratosis*). While skin legions can assist in detection, they also have serious negative social consequences such as social exclusion, particularly for young women.

The risks of arsenic poisoning increase with higher levels and/or longer periods of exposure, especially when it occurs earlier in life or among individuals with lower levels of nutrition. As there is no medical cure for arsenic poisoning, the only solution is to reduce exposure as soon as possible. Once a person has been exposed to arsenic, the health risks remain for decades, even after the exposure to arsenic has ceased.[5] Arsenic is readily absorbed *in utero* presenting serious risks of stillbirth.[6] Children are also at a greater risk of arsenic poisoning from food as their intake per unit body mass is higher than that of adults. Exposure of children to arsenic can impair cognitive development, intelligence and memory[7] as well as increasing their risk of mortality from heart and lung disease later in life.[8]

Assessments of Arsenic Exposure

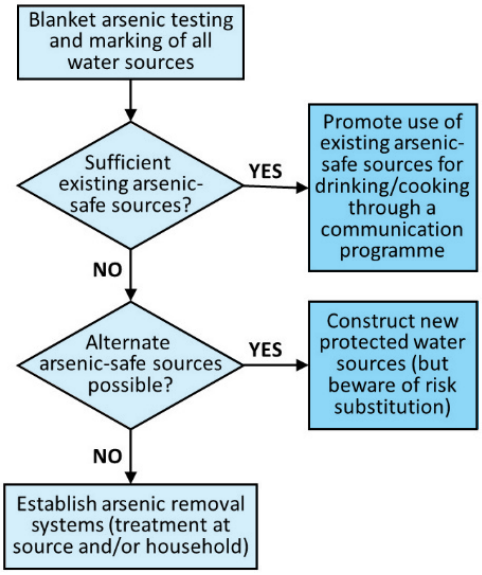
Tackling groundwater arsenic contamination requires immediate action to identify the extent of the arsenic risk and reduce exposure as soon as possible. In the short term, actions can include the use of rainwater for drinking during the wet season, the changing of cooking habits, the switching to alternate proximate safe sources and the application of arsenic removal devices. Caution must be exercised to prevent risk substitution (i.e. implementing actions that reduce arsenic but inadvertently increase microbial exposure risks) and avoid unsustainable alternatives (i.e. arsenic- removal devices that fail due to poor O&M). In the long term, the Framework for Safe Drinking-water (FSW) proposes the establishment (and independent surveillance) of health-based targets for drinking-water quality and human exposure. These health-based targets are designed to ensure that the implementation of mitigation measures to reduce arsenic exposure to safe levels via drinking water are delivering the desired health outcomes.

Assessing the extent and the severity of arsenic contamination in groundwater is possible through specific sample surveys. The use of a unique coding system for referencing the depth of the screen and the GPS location of groundwater sources is extremely important in generating models of the hydrogeology of arsenic contamination. Testing for arsenic can be undertaken either using laboratory equipment which produces more accurate results or using field test kits which are faster, lower cost and provide immediate feedback on the presence of arsenic in water sources. In practice, most water-quality control systems comprise a combination of bulk testing using field test kits and quality control using laboratories.

Response to Arsenic Exposure

In areas identified as prone to arsenic contamination, sample surveys will need to be followed by blanket screening (i.e. the testing and marking of all existing public and private water sources). Due to the unpredictability of arsenic contamination in groundwater, blanket screening along with GPS mapping of arsenic in all the water sources enables the locations with the lowest coverage of safe sources to be identified and prioritized

(i.e. to target populations most at risk and to reduce the elite capture of arsenic mitigation measures). Blanket screening has also been known to enable households to immediately reduce their arsenic exposure by switching from sources marked unsafe to proximate wells marked safe. The decision on whether to mark or to close arsenic-contaminated wells is an important policy decision because while contaminated wells can still be safely used for cleaning or bathing, there is a risk that they may also be used for drinking, cooking or irrigation.



Experience suggests that the identification and abstraction of water from alternate safe aquifers will tend to dominate arsenic mitigation activities because groundwater is generally more likely to be proximate, reliable and carry lower bacterial risks than the other alternatives. For instance:

- While surface water carries low risks of arsenicontamination, it carries higher risks of bacterial, agricultural and industrial pollution.
- While rainwater is generally free of arsenic and bacterial contamination, its seasonality does pose higher reliability risks that necessitate expensive storage which increases bacterial risks.
- While arsenic removal devices can treat contaminated groundwater, the increased maintenance requirements and the disposal of arsenic-rich sludge presents higher operational risks to sustainability

Following blanket testing, the unique coding system developed for recording well depth and location will need to be expanded to manage the data of all new wells, after they are drilled and cased and before they are equipped. This should enable the creation of a single database that allows the arsenic status of wells to be monitored (against screen depth and location). Professionalization of water-source testing by public and private sector providers (in addition to the drilling and equipping of wells) is essential to generate the necessary data on arsenic safety to ensure that water is safe and that changes in groundwater contamination risks can be predicted and managed.

One of the most underestimated, yet essential, aspects of arsenic mitigation is the understanding and changing of existing knowledge, attitudes and practices. The choice and the use of different water sources for different purposes is deeply embedded in cultural beliefs and significantly alters the risk profiles of different households and their members. Understanding those beliefs, expanding awareness of arsenic and enabling households to access drinking-water testing services, are essential to changing behavior and empowering households to hold local authorities and service providers accountable for providing safe drinking water.

Multi-Sectoral Response to Arsenic Exposure

Due to the invisible and complex nature of arsenic contamination, arsenic mitigation activities need to be situated within a framework where the health impacts of alternate mitigation options can be evaluated. This means that monitoring should not only address the quality of drinking water, but should also include biomarkers of exposure, diagnosable features of arsenicosis and trends in cancer and heart disease. With time, monitoring should be expanded to track the risks of arsenic exposure from groundwater irrigation entering the food chain. Where widespread arsenic contamination has occurred, matching the data sets generated by agriculture, drinking water and health sectors can enable anomalies in mitigation to be identified (i.e. where levels of high exposure via drinking water or food are not correlated with health impact).

Effective arsenic mitigation requires coordination across all the sectors associated with water supply and public health, including central and local government policy makers and agencies, public and private service providers, non-governmental organizations and international development agencies, local and international researchers, local communities and users themselves. Undertaking arsenic mitigation actions within a framework of health-based targets and independent surveillance seeks to ensure that the exposure to arsenic through all possible routes is sufficiently mitigated and the potential substitution of arsenic with other risks is adequately managed. Harmonized approaches, communication strategies, short-term priority actions and long-term strategic actions within National Implementation Plans are all critical for scaling up arsenic mitigation.

Experience of UNICEF in Arsenic Mitigation

While governments are ultimately responsible for securing universal access to drinking water that is accessible in sufficient quantities and quality to achieve public health objectives, UNICEF is a committed partner in arsenic mitigation efforts. To this end, UNICEF supports: National and local policy makers to define health-based targets for drinking water quality, assign responsibilities for drinking-water safety and protect drinking water resources;

- Water-service providers (public and private) to develop and manage drinking-water safety plans to meet drinking-water standards and safeguard supplies against potential risks;
- User communities to hold drinking-water service providers and policy makers accountable for the delivery of safe, sufficient, proximate, affordable, reliable and sustainable drinking water;
- Independent surveillance agencies to assess the relationships and performance of sector institutions in meeting health-based targets.

UNICEF seeks to achieve this through:

- Undertaking advocacy on policy and regulatory reforms with national and local decision makers;
- Extending capacity in the management of service delivery with government departments;
- Generating data with public knowledge agencies and undertaking research with academia;
- Piloting innovative models with non-government organizations;
- Strengthening communication systems to improve access to information with civil society.

UNICEF has extensive experience in arsenic mitigation, commencing with its engagement in Bangladesh and India in the 1990s. In addition, UNICEF has supported arsenic mitigation efforts to varying extents in Afghanistan, Burkina Faso, Cambodia, China, the Democratic People's Republic of Korea, the Lao People's Democratic Republic, Mongolia, Myanmar, Nepal, Nicaragua, Nigeria, Pakistan, Thailand, and Viet Nam. As a result, UNICEF can make available services to strengthen the enabling environment, build capacity of implementing agencies, undertake formative research and provide education and advocacy around solutions for arsenic mitigation. UNICEF supports learning from experiences among arsenic-affected countries and promotes regional dialogue among policymakers, academia and technical experts. UNICEF collaborates with the UN Food and Agriculture Organization (FAO) and the World Health Organization (WHO) to leverage their experience and expertise in the health aspects of arsenic and implications for food security and nutrition.

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Sources

The UNICEF Policy Brief on Arsenic in Drinking Water summarizes key elements of the Arsenic Primer updated by UNICEF & WHO in 2018[9]. All references to the original sources are contained in the Arsenic Primer.

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