Notes:

• please add details of the date, time, place and sponsorship of the meeting for which you are using this presentation in the space indicated;

• this is a large set of slides from which the presenter should select the most relevant ones to use in a specific presentation. These slides cover many facets of the problem. Present only those slides that apply most directly to the local or regional situation. Where relevant, adapt the information, statistics and photos within each slide to the particular context in which this module is being presented. For instructions on how to use this module visit: https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19-12-02;

• Water is one module from a larger training package focused on children’s environmental health. Throughout Water, a number of different modules are suggested that contain additional relevant information. Consult these other modules where relevant. To see the full package visit: https://www.who.int/teams/environment-climate-change-and-health/settings-populations/children/capacity-building/training-modules;

• Water has a companion module titled Sanitation and hygiene, which covers many overlapping and relevant topics. Consult this module for relevant additions;

• the World Health Organization (WHO) reference number for the module Water: training for health care providers, second edition is WHO/HEP/ECH/CHE/23.13;

• for more information on WHO’s work on children’s environmental health, please visit: https://www.who.int/health-topics/children-environmental-health.
Access to water is vital for children’s health. This module discusses the global context of water, and the effects that poor or inadequate access to water can have on children’s health and development. The learning objectives for this module are to:

- understand the context of water access, availability, quality and safety;
- recognize the major categories of water pollutants and their sources;
- learn about the potential effects of exposure to these pollutants on children’s health;
- identify specific actions at the clinical and community level to promote water safety and access.
Note:
When selecting the slides to include in your presentation, please choose only those of relevance to the region and/or interests of your audience.

This training module includes the following sections:
• global water issues
• children’s special vulnerability to water issues
• main contaminants found in water: sources and effects
• the roles of health care professionals in protecting children from water-related hazards
• case studies on water and child health.

Photo:
• © WHO/SEARO/Joao Soares Gusman. A boy and a girl play at a water source, Timor-Leste.
This module starts with global water issues facing children around the world. It also includes details on the global disparity in water access and definitions relevant to this module.

**Photo:**
Life on earth exists only because planetary conditions allow for liquid water. All water currently on earth has been here for billions of years. Water is a finite resource that cycles and replenishes continuously through the hydrologic cycle of vapor, liquid, solid, saline and fresh states. This cycle is influenced by global weather and climatic conditions (1).

Pollution and climate change threaten water quality, availability and accessibility in a variety of ways. Representative examples of these threats will be given throughout this module.

Terrestrial life, including human life, cannot exist without fresh water. While fresh water is a renewable resource, it is also finite and limited (2).

Approximately 70% of the earth’s surface is covered with water (3), but:

- only 2.5% of that water is fresh (versus salt) water (1);
- only 0.75% of all of earth’s water is both fresh and accessible in non-frozen rivers, lakes and underground aquifers (1).

There are many reasons why liquid water is essential for life (1,2):

- humans need fresh, clean water for drinking, cooking, and hygiene;
- all forms of land-based agriculture require water which, ideally, is safe and clean;
- many industries that communities rely upon require high-quality fresh water;
- humans play in both fresh and salt water bodies;
- healthy oceans, rivers and lakes are critical sources of food for billions of people across the globe.

Protecting water quality is essential for ensuring healthy human populations.

References:
Photo:
• © NASA.
The World Health Organization (WHO) and United Nations Children’s Fund’s (UNICEF) Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP)’s ladder for water supply defines five categories of drinking water - the highest of which is “safely managed drinking water services (1)”.

**Safely managed drinking water services** are defined as:
- drinking water from an improved source that is accessible on premises, available when needed and free from faecal and priority contamination (1).

The map on this slide shows the **geographic distribution of the global population with access to safely managed drinking water.** Countries, areas and territories which have achieved universal access to safely managed drinking water across their populations are coloured in dark blue. The map shows that the majority of these countries, areas and territories are in the European Region and the Region of the Americas and are majority high-income countries (HICs), with few exceptions (1).

The map also illustrates the **distribution of data acquisition.** The countries, areas and territories coloured white did not have available data for 2020 to make an estimate of the proportion of the population using safely managed drinking water services. The African Region has a significant number of countries, areas and territories that do not have adequate data on drinking water. The most at risk populations for adverse water-related health outcomes tend to be in low-income countries and are rural rather than urban dwelling. In 2020, only 138 of 234 countries, areas and territories had data on safely managed drinking water, highlighting the need for better global monitoring to achieve universal access to safely managed drinking water services by 2030 (1).

Safe drinking water is critical to human health and wellness. Yet, in 2020, it was estimated that 26% of the world’s population lacked access to safe drinking water services at home. 2 billion people worldwide lacked safely managed drinking water services in 2020. Of these (1):
- 1.2 billion had only basic services;
- 489 million of these were using unimproved sources or surface water.

**Note:** for more information on how faecal matter contaminates water sources, please see the Sanitation and hygiene module.

**Reference:**
Map:
- © WHO.

The World Health Organization (WHO) and United Nations Children’s Fund’s (UNICEF) Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) defines “basic hygiene” as:
• the availability of a handwashing facility with soap and water at home (1).

Clean water for handwashing is as important for health and wellness as safely managed drinking water. The COVID-19 pandemic has highlighted the importance of access to hygiene services, as well as the global inequities in access. Children’s particular vulnerabilities related to lack of hand hygiene services are discussed later in this presentation.

The bar graph displayed on this slide represents the global population in 2015 (7.4 billion people) and 2020 (7.8 billion people). Between 2015 and 2020, 500 million people gained access to basic hygiene services. Globally, in 2020 (1):
• 1.6 billion people had only limited facilities (availability of a handwashing facility lacking soap and/or water at home), representing 29% of the global population without the capacity to appropriately wash their own, or their children’s, hands;
• 670 million people globally had no hand washing facilities at home.

Note: for more information on hygiene and child health, please see the Sanitation and hygiene module.

Reference:

Photos:
• Top: © WHO/ Liberia Office. A child attending a ceremony were washes her hands before entering the building, Liberia.
• Bottom: © WHO/ Diego Rodriguez. Women and child bathe and wash clothes in the canal that connects the village of Inthein with Inle lake, Myanmar.

Figure:
Children suffer disproportionately from inadequate access to safe water for drinking, cooking and hygiene needs. In 2019, diarrhoeal diseases were the fourth leading cause of deaths in children under 5 years of age globally, causing 9.1% of deaths in this category (1,2). The risk of developing diarrhoeal disease is greatly exacerbated by inadequate access to clean water (1,2). The majority of diarrhoeal-related deaths in children under 5 years of age occur in the African and South-East Asia Regions (1). Diarrhoeal diseases also contribute significantly to childhood stunting which can have lifelong consequences to health and wellbeing (3).

A large proportion of diarrhoeal diseases are caused by faecal-oral pathogens and can be prevented through access to safe and adequate drinking water, sanitation and hygiene, and by ending open defecation (4). The most recent World Health Organization (WHO) environmentally-attributable disease estimates found that, globally in 2016, more than 297,000 deaths in children under 5 years could have been prevented through increased access to safe drinking water, sanitation and hygiene (5).

The figure on this slide shows the age distribution of global disability-life adjusted-years (DALYs) from combined diarrhoeal diseases, typhoid, paratyphoid and invasive, non-typical salmonella in 2019. It is clear from this figure that newborns and children under 5 years of age in 2019 bore the greatest global burden, particularly in premature mortality (shown in light pink for females and blue for males) (6).

**Note on terminology:** disability-adjusted life years (DALYs) for a disease or health condition are the sum of years of healthy life lost due to disability and years of life lost due to premature mortality (YLLs) and the years lived with a disability (YLDs) (7).

**Note:** for more information on children’s special vulnerability to inadequate access to drinking water, please see the Children are note little adults and Why children modules. For more information on children exposure to inadequate sanitation and hygiene, please see Sanitation and hygiene.

**References:**


sheets/detail/malnutrition, accessed 15 December 2022).


Figure:
• © Institute for Health Metrics and Evaluation. Enteric infections – level 2 cause (https://www.healthdata.org/results/gbd_summaries/2019/enteric-infections-level-2-cause, accessed 15 December 2022). This work is available under the Creative Commons Attribution-NonCommercial-NonDerivatives 4.0 International licence (CC BY-NC-ND 4.0 IGO; https://creativecommons.org/licenses/by-nc-nd/4.0/).
Climate change and water

- **Warmer air:**
  - More water in atmosphere
- **Warmer oceans:**
  - More intense storms
- **Warmer planet:**
  - Less ice, higher sea levels
- **Changing weather patterns:**
  - More precipitation events
  - More flood events
  - More drought

**Climate change is a reality.** Global temperatures are rising and will continue to do so throughout the remainder of the 21st century.

**One of the major planetary systems affected by climate change is the water cycle** (1). Warmer air holds more moisture and warmer oceans feed more intense storms. The consequences of these changes are major disruptions in weather patterns, particularly as expressed in the distribution, timing and intensity of rainfall. Some areas, countries and regions will experience more extreme precipitation and flooding. On the other hand, other areas, countries and regions will experience more extreme drought (1). Some regions are facing both (2).

Water availability affects human migration as it is a crucial element for survival and health. Water scarcity may lead to conflict and political instability (1).

**Climate change can also affect water quality** by overwhelming water purification infrastructure and increasing runoff during extreme precipitation and flooding events. Melting glaciers and rising sea level can lead to saltwater intrusion in drinking water sources (3).

**Note:** for more information please see the module on *Global climate change and child health.*

**References:**

**Photos:**
- Top: © WHO / Mobeen Ansari. WHO surveillance officer speaks with children in a village affected by the 2022 flooding, Pakistan.
- Bottom: © WHO / Billy Miaron. A boy fetches water at Hula Hula Springs in Marsabit County, Kenya. With the ongoing drought in Marsabit, the spring is the only available water source for the whole community.
In simple terms, children’s health and wellness can be threatened by (1):

- **too much water** such as storms, floods and excess precipitation;
- **not enough water** for example from drought, glacier loss and poor access to water services;
- **poor quality water**, such as from biological contamination, chemical or physical pollution or salt water intrusion.

There are a variety of forces that combine in any given location to determine whether water is safe, plentiful and well managed. As the human population continues to grow, urbanize, industrialize, and migrate, and as the climate continues to change, the challenges to water security will develop differently in the various regions of the world. Children are often one of the most vulnerable groups to water security challenges.

The next section of this module will explore children’s special vulnerability to global water challenges.

**Reference:**


**Photo:**

- © WHO/Christopher Black. A woman bathes her baby, Democratic Republic of Congo.
The second section of this module discusses children's special vulnerability to water challenges.

Photo:
• © WHO/SEARO/Joao Soares Gusman. A boy and a girl play at a water source, Timor-Leste.
When discussing children’s environmental health, it is always important to discuss the premise that children are not little adults.

Children require special protection and considerations in both health care and public health policy. It is important to recognize that children (including the embryo, fetus, infant and all life stages until the completion of adolescence) are often at different and increased risk from environmental hazards compared to adults. There are four broad categories that explain these differences.

1. **Different and unique exposure** to environmental hazards compared to adults. Children can be exposed *in utero* to chemical (pollutants and pharmaceuticals), physical agents (radiation and heat) and biological (viral and parasitic) agents. They can also be exposed, after birth, to pollutants that pass into their mother’s breastmilk. Neither of these routes of exposure occur in adults or older children. Children also have pathways of exposure that differ from adults due to their size and developmental stage. For example, young children engage in normal exploratory behaviours including increased hand-to-mouth and object-to-mouth behaviours, and non-nutritive ingestion, including water that may be contaminated. Due to cognitive immaturity, children may have a more limited understanding and ability to move away from dangerous water-related situations, including from toxic agents and weather events, which could result in harm. This immaturity is often expressed in the younger years and in adolescence, when risk-taking behaviours are more common (1).

2. **Dynamic developmental physiology** children are often subjected to higher exposures to pollutants found in water than adults. As children are anabolic and rapidly growing, they drink more water per unit body weight than adults and often absorb nutrients more efficiently (2). Therefore, pollutants in water can result in higher internal doses in children compared to adults. These exposures may be metabolized and excreted quite differently by an immature set of systems to the way they are dealt with in fully mature, adult systems. Furthermore, the developmental component of a child’s physiology is changing; maturing, differentiating and growing in phases known as "developmental windows". These phases can be understood as "windows of vulnerability" and create unique risks for children exposed to hazards which can permanently alter normal function and structure in ways with no analogs in adults similarly exposed (1).

3. Children have **longer life expectancy**, they have longer to manifest a disease with a long latency period, and longer to live with toxic damage which may manifest during childhood or much later in life (1).

4. Finally, children are **dependent upon adults** to protect them and ensure a safe environment. The photo on this slide is a statue of a young child, gazing in wonder at the world with trust and curiosity. It was designed by the
artist to represent any ethnicity or race, and she is wearing a simple garment that could be from anywhere in the world. Children trust the adults in their lives to nurture and protect them through actions and decisions until they can protect themselves through their own individual, collective and political action (3).

**Note:** for more information on children’s special vulnerability please see the modules *Children are not little adults* and *Why children*.

**References:**

**Photo:**
Different and unique exposures

- **Intrauterine:**
  - Maternal diet and exposures
- **Ingestion:**
  - Breastmilk
  - Swallowing bath and recreational water
  - Food contaminated by polluted irrigation water
  - Mouthing behaviours

Children’s special vulnerabilities to environmental hazards vary by (1):
- environmental medium
- exposure route
- timing
- duration.

Water is a significant medium of exposure as it is the ultimate sink for many pollutants. There are many ways that water can carry pollutants to children; some of which are unique to them.

Neonates’ bodies are 80–90% water by weight, compared to adults’ bodies which are 55–60% water (2). Pollutants absorbed by pregnant women, may end up in the body’s circulation and some may be able to cross the placental and expose the developing fetus. Similarly, maternal ingestion of pollutants incorporated in foods from polluted water bodies, such as methylmercury, may be transmitted to the fetus where they can adversely affect development. Postnatally, children consume significant amounts of breastmilk, which can be contaminated by certain chemicals. Formula mixed with polluted water can expose children to both chemical and biological contaminants. The World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF) recommend exclusively breastfeeding for the first 6 months of life with continued breastfeeding along with complementary foods while continuing to breastfeed for up to two years and beyond (3).

Contaminated water is a threat to children when bathing or swimming as they often swallow water during these activities. Food grown or harvested with contaminated water can also represent a threat, particularly as children may have a restricted diet and eat large quantities of only a few types of food. Finally, children learn about the environment through exploration, particularly by putting things in their mouths. Non-nutrient ingestion, or simply mouthing contaminated objects and hands, can lead to many kinds of chemical and biological exposures. This highlights the need for safe drinking water, as well as for hygiene and routine cleaning (1,4).

**Note:** for more information on children’s special vulnerability please see the modules *Children are not little adults* and *Why children*.

**References:**

Photo:
• © WHO/ David Spitz. Pregnant women waiting for a medical consultation, Colombia.
From birth, children grow rapidly over the first 2 years of life and growth continues throughout puberty.

The youngest children are growing and developing most rapidly and are in an anabolic state. For example, a child 6 to 12 months old consume four times as much water per unit of body weight than an adult (1). While ingestion is the major route of exposure, contaminated water can aerosolize and carry pollutants into the lungs. Children breathe rapidly, inhaling more air per unit of body weight than adults. In young children, lungs are still developing and are more absorptive than in fully developed, adult lungs. Up to 50% of water-related volatile organic carbon pollution in water is inhaled when it becomes suspended in the air or on droplets during bathing and showering (1).

Similarly, children have a higher surface area to volume ratio than adults, so the potential to absorb higher levels of contaminants through the skin is greater (2).

Children’s metabolism changes and matures rapidly in the first year of life, but depending on the contaminant, they may absorb more of a given contaminant compared to adults and be less able to metabolize and eliminate it (1,2).

The bodies and physiology of the fetus and child have many periods of specific vulnerabilities as they transition to adult capacities. Depending on the pollutant, the amount, the life-stage and the duration of exposure, critical systems can be damaged before they are mature, potentially causing lifelong consequences (1,2). These periods are known as windows of vulnerability.

Note: for more information on children’s special vulnerability and windows of vulnerability please see the modules Children are not little adults and Why children.

References:
As children grow, they learn by experience and, often, by taking risks. Where water is concerned, risk-taking behaviour presents significant challenges. Adults need to monitor children's behaviors and minimize risk in order to protect them from injury, exposure to pathogens and hazardous chemicals that can cause illness, and even death.

While the primary concern of this module is access to adequate and safe drinking water, it is essential to remember that "children's work is to play" and that they may spend many hours swimming, bathing and playing in recreational waters. Children's cognitive immaturity may not allow them to understand or recognize the dangers of playing in contaminated water or playing in unsafe locations. The water quality of pools, lakes, rivers, ponds and coastal waters should be considered, as well as the many other risks that exist in water-related environments. By far the most serious injury risk to children's life is drowning. Storms, flooding and natural disasters involving excess precipitation also increase the risk of drowning, as children may require assistance from adults to keep them safe from harm, and some children may not know how to swim. Storms, flooding and natural disasters also increase the risk of microbial contamination and chemical contamination of surface waters. In 2019, drowning was one of the leading global unintentional injuries in children under the age of 5 years. In 2019, drowning caused an estimated 47,800 deaths globally in children under 5 years of age. Children under 5 years of age made up 20% of all global drowning deaths in 2019. In 2016, environmentally-attributable drowning factors caused the deaths of more than 46,000 children under the age of 5 globally. Risk factors for drowning include being male, lack of physical barriers between children and water, particularly close to the home, as well as lack of child supervision.

While the physical risk of drowning is associated with large amounts of water, children face different risks associated with inadequate amounts of water. Wherever there is a shortage of rain over a long period of time, there is drought. Drought affects plants, animals and people. It is a serious problem for farmers and for the people who depend on crops and livestock for food. Drought can lead to food and water insecurity, which can in turn lead to resource-related conflict. Estimates have suggested that 1 in 4 children globally (approximately 600 million children) will be living in extreme water stress by 2040.

Areas with low rainfall and areas with desert or desert-like conditions are more prone to drought. Changing climate patterns and increasing populations have the potential to cause unanticipated and serious drought conditions in the future. Children are especially vulnerable to a lack of water due to a number reasons:

- higher water requirement per kilogram of body weight, particularly infants and toddlers;
- higher susceptibility to waterborne diseases;
- direct correlation between water impurities in drought prone areas and diarrhoeal and intestinal parasitic diseases among children;
- drought increases food insecurity, leads to malnutrition, stunting and, in extreme cases, starvation.
Photo:
• © WHO/ Lindsay Mackenzie. Mashire brings her daughter Malaa for a consultation at the new health care centre in the village of Abu Gaw, Sudan.

References:
The third section of this module will discuss the main contaminations found in water, their sources and their potential health effects in children.

**Note:** additional water contaminants that may be of interest and local relevance, both chemical and biological, are discussed in the *Children and neurodevelopmental behavioural intellectual disorders (NDBID)* and *Sanitation and hygiene* modules.

**Photo:**
This section of the presentation will concentrate on threats to water quality. The graphic on the slide shows the four realms of water (1):

- air
- oceans
- fresh surface water
- fresh groundwater.

Water moves continuously around the world through evaporation, transpiration, precipitation and run-off. Some water becomes trapped for long periods of time in ice or deep underground aquifers. Deep ocean waters mix very slowly over centuries (2).

Much of the water that humans use circulates readily between upper oceans, the atmosphere, surface waters and shallow aquifers. The growing global human population and rapid industrialization are increasingly placing waters at risk of local contamination. Water contamination can expose human populations to contaminants on an international scale. Water forms the ultimate destination or sink for many contaminants, particularly chemicals derived from human activities, that are discharged into water, air and onto the earth’s surface (3).

References:

Figure:
Fresh water can be categorized by its source as either groundwater or surface water. The vulnerability to contamination and quality are different for both groundwater and surface water.

**Groundwater** comes from underground aquifers, has been filtered through a process known as percolation, and can remain in place from a few weeks up to as long as 10,000 years (1). The deeper the aquifer, the more likely it is that the water is pure and ancient. It is sometimes referred to as “fossil water”. Over-harvesting of this water can lead to unsustainable use that can threaten the survival of future generations. Groundwater represents about 90% of the world’s readily available freshwater sources available for human use (1). It is less likely to be polluted by human activity than surface water, but can be contaminated by minerals present in the rocks forming the aquifers. Some industrial processes such as fracking can also result in extreme pollution of groundwater (2).

**Fresh surface water** is found in rivers, lakes and artificial reservoirs. It has a much shorter residence time; from a few weeks up to a decade (1). It is much more susceptible to pollution than groundwater from human activities, such as agricultural run-off, industrial and sewage discharges, water treatment effluent, nutrient overload leading to ecosystem degradation, and other water related hazards. In drought conditions, surface water in lakes can become salinated due to excess evaporation, making it unusable for human consumption. Surface water is not distributed uniformly around the world and, in many areas, river flow is dependent upon glaciers. As climate change progresses, these glaciers are melting and shrinking, and communities dependent upon these rivers will experience increasing water insecurity (3).

**References:**
Water contaminants can be divided into three broad categories (1,2):

- **Biological**, such as bacteria, viruses, parasites and toxins;
- **Chemical**, including inorganic, organic, disinfection by-products and pharmaceuticals;
- **Physical**, such as particles and radioisotopes.

Each of these categories, and representative examples, will be discussed in the following slides.

A fourth category is included in the World Health Organization’s (WHO) guidelines for drinking water quality and relates to **taste, color, odor and clarity**. These are referred to as the “acceptability aspects” of water and are fully discussed in the WHO guidelines for drinking water quality. Many contaminants which adversely affect the acceptability aspects of water are not harmful to health, however the level of harm posed by these aspects may be difficult to tell without specialized technologies. Water that appears unacceptable should be evaluated before use. This aspect of drinking water quality is not covered in this presentation (1).

Note: modify the following sections of this module as appropriate by using examples that are pertinent to the region and circumstances in which it is being used.

**References**:  

**Photo**:  
- © WHO/SEARO/Walter Owens. Urban water pollution in New Delhi, India.
Biological contaminants are the most immediate threat to the majority of populations without access to safely managed drinking water. Surface waters can be contaminated by livestock and other domestic animals. Animal excrement and untreated human sewage that enters water sources can spread disease vectors such as insects and parasites. Water is a common reservoir for major human pathogens (1).

Water can also be contaminated when technology failure occurs. For example during times of high rainfall and storms, drinking water and sewage treatment facilities can become overwhelmed and result in outbreaks of gastroenteritis even in the most highly industrialized nations. Inadequate or unsafe distribution, storage or handling of drinking water and poorly protected well heads can result in the biological contamination of water sources (1,2).

References:

Photo:
• © WHO/ Andy Craggs. The Maasai pastoralists in the northern part of United Republic of Tanzania are particularly vulnerable to the combined effects of climate change and zoonotic diseases (diseases that can be passed from animals to humans) because they live close to large wildlife populations that can act as reservoirs of infection, and compete for access to water and food for their cattle.
The primary public health concern regarding water contamination is \textit{microbiological} contamination of drinking water (1).

Water-related infections can be classified into four categories (2):
- \textbf{waterborne diseases}, acquired directly from contaminated drinking water, such as diarrhoeal diseases;
- \textbf{water-washed diseases}, acquired through contact with skin or eyes due to lack of hygiene and access to safe water, such as scabies or trachoma;
- \textbf{water-based diseases}, caused by aquatic organisms that spend part of their life-cycle in the water and another part as animal parasites, such as schistosomiasis;
- \textbf{diseases transmitted by water-related vectors}, spread by vectors that breed or bite near water, such as African trypanosomiasis (vector: tse-tse fly) and leishmaniasis (vector: sandfly).

Microbial contamination usually results from the contamination of water with human or animal faeces. If drinking water is contaminated with faeces, pathogens are likely to be widely and rapidly dispersed. If the contamination is recent, and if the faeces are from carriers of communicable enteric diseases, the microorganisms (bacteria, viruses or protozoa) that cause these diseases may be present in the water (1). These diseases range from mild gastroenteritis to severe and sometimes fatal episodes of diarrhoea, dysentery, hepatitis, cholera and typhoid. Helminths (such as roundworm) and amoebae may also be transmitted in water and are common in poor-quality water supplies (3).

There are also some organisms in water that may cause disease in humans under certain circumstances, for example \textit{Legionella} bacteria may be transmitted through inhalation of contaminated aerosols from contaminated water supplies (4).

Adverse health effects arise primarily from the ingestion of pathogenic bacteria. People with low immunity, including infants, young children, the sick and the elderly are particularly vulnerable to microbial contamination even from ordinarily mild pathogens (5).

Outbreaks of waterborne diseases can lead to the spread of infection across a wide community. \textit{Cryptosporidium} and \textit{Giardia}, for instance, cause regular outbreaks of diarrhoea. These diseases cause problems due to the following factors (1):
- cyst formation (cysts are resistant in water environments);
- cysts have a small size (can evade filtration processes);
- no specific hosts;
- cysts are resistant to chlorine.
Additionally, risks are posed by some toxins that occur naturally in water, particularly in nutrient-rich surface waters where there is profuse algal growth (4).

**Note:** present the water-related diseases most relevant to the context in which this module is being used.

**Note:** for more information on sanitation, faecal contamination and diseases in children please see the module on *Sanitation and hygiene*.

### References:

Impact of biological contamination

<table>
<thead>
<tr>
<th>Disease</th>
<th>Drinking water</th>
<th>Sanitation</th>
<th>Handwashing</th>
<th>WASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrhoeal deaths*</td>
<td>35%</td>
<td>31%</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>Respiratory disease</td>
<td></td>
<td></td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Trachoma</td>
<td></td>
<td></td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

*Low- and middle-income countries

- Global prevalence of mortality due to diarrhoeal diseases could be decreased by up to 35% with increased access to clean drinking water
- Adequate handwashing with soap prevents respiratory disease, the leading cause of death in children under 5 years globally
  - Trachoma is responsible for visual impairment or blindness in about 1.9 million people worldwide

Biological contamination of drinking water can have profound consequences on child health.

Despite great advances made in recent years to reduce the number of people without access to water, sanitation and hygiene (WASH), many populations remain at high risk to WASH-related diseases. Estimates for 2016 in low- and middle-income countries (LMICs) found that (1):
- 35% of diarrhoeal deaths were attributed to poor quality drinking water;
- 31% of diarrhoeal deaths were attributed to lack of sanitation;
- 12% of diarrhoeal deaths were attributed to lack of handwashing.

Globally in 2016, an estimated 13% of the burden of disease from acute respiratory infections was associated with inadequate handwashing and an estimated 100% of the burden of trachoma was related to inadequate water, sanitation and hygiene (2). Trachoma is the leading cause of preventable blindness globally and affects the sight of approximately 1.9 million people worldwide (1). These are just some of examples of the many water-related biological threats to child health.

**Note:** for more information on sanitation, faecal contamination and diseases in children please see the module on **Sanitation and hygiene**.

**References:**
Naturally occurring toxins can also contaminate water sources. These are produced in fresh, brackish and saltwater depending upon environmental conditions (1).

When water is excessively warm or contains an overload of nutrients from agriculture or industry activities, the organisms that produce these toxins can reproduce and overwhelm the balance of an affected water ecosystem, producing toxins that can be harmful to children’s health (2). These toxins can cause a variety of neurological, gastrointestinal, respiratory, dermatological conditions through inhalation, ingestion or direct contact with the toxins in the water. Consumption of contaminated fish or shellfish from affected waters is also a source of exposure to natural toxins (3,4).

Both humans and animals can be affected, and children may be especially vulnerable due to their small size, their high surface area to volume ratio and their lack of understanding of the danger of playing near or in water that is unsafe (4,5).

References:
Chemicals are the next category of contaminants discussed in this presentation that can pollute water sources. Chemicals in water can be naturally occurring or as a result of human activities.

Water naturally contains many trace elements and minerals which, depending on their concentration, may be inert, beneficial or harmful to human health. Some minerals can be beneficial to human health at low concentrations, but harmful at high concentrations, such as fluoride (1).

Chemicals may contaminate water sources, particularly surface waters, through human activities. Examples of human activities that can cause chemical contamination of water sources include (1):

- agricultural chemicals, such as pesticides and fertilizers;
- urban run-off from roadways and other hard surfaces;
- industrial discharges directly into rivers and lakes;
- deposition of chemicals from air pollution;
- human sewage treated or untreated discharged into rivers or lakes;
- effluent from drinking water treatment plants.

Groundwater can be contaminated as well, particularly by deep water injection in processes such as fracking and chemicals leaching into ground (and surface) waters from landfills and dumps (1).

Oceans are vulnerable to both discharges from shipping and illegal ocean dumping as well as air pollution (1).

Plastic contamination is an emerging concern. Large masses of floating plastic have been identified in bodies of water and microplastics have been measured in both freshwater and marine environments, aquatic animals and human tissues. Plastics and microplastics are not further explored in this module, but more information can be found on the World Health Organization’s (WHO) website (2).

Exposure to chemicals in the environment is ubiquitous. There are thousands of manmade chemicals in use today and children may be exposed through the consumption of drinking water, washing and hygiene activities, or swimming in recreational water sources. Many chemicals are harmless or even beneficial to human health (3). However, some specific chemicals are known to cause serious health effects even at low concentrations, and treatment is needed to remove them or to reduce their concentration in drinking water (4). Brief reviews of a few example chemicals are discussed in the following slides.

**Note:** highlight the human activities that are the most common sources of water pollution in your community, region
or country.

Note: for more information on specific chemicals that can pollute water sources and their effects on children’s health please see the modules *Children and chemicals, Lead, Mercury, Persistent organic pollutants (POPs), Pesticides*.

References:

Photo:
Inorganic chemicals are naturally-occurring, and some of these may be found in some drinking water sources. Arsenic is one such example. Organic arsenic, mostly found in fish and seafood, is significantly less harmful to human health than inorganic arsenic (1).

Inorganic arsenic is present at high levels in the groundwater of some countries, such as Argentina, Bangladesh, Chile, China, India, Mexico and the United States of America (2). Bangladesh has particularly high levels of arsenic in groundwater. In Bangladesh, estimates suggest that tens of millions of people are exposed to unsafe levels of arsenic in drinking water from tube wells (3). In one estimate from 2012, consumption of drinking water in Bangladesh with arsenic levels greater than 50 micrograms per litre (µg/L) and 10–50 µg/L accounted for an annual 24 000 and perhaps as many as 19 000 adult deaths in the country, respectively (4).

Inorganic arsenic can also be introduced into the environment from the dissolution of minerals, from industrial effluent (for example, drainage from goldmines) and from atmospheric deposition (for example, burning of fossil fuels and wastes). These sources can make significant contributions to arsenic concentration in drinking water (1,3).

Inorganic arsenic in drinking water poses the most significant threat to public health, but some foods, particularly rice, cereals, and dairy products, and tobacco are other sources of inorganic arsenic in certain areas of the world (1,5). Arsenic compounds are readily absorbed from the gastrointestinal tract, bind to haemoglobin and are deposited in the liver, kidneys, lungs, spleen and skin. Inorganic arsenic can cross the placenta (1). Inorganic arsenic is extensively methylated in the human body and primarily excreted in urine (5,6).

Arsenic can have immediate effects in children and can also manifest in chronic illness later in life. Acute exposure to arsenic can cause numerous clinical symptoms including vomiting, abdominal pain and diarrhoea. These may be followed by numbness and tingling of the extremities, muscle cramping and, in extreme cases, death (1). Clinical symptoms following acute exposure to arsenic may depend on the exposure dose.

Chronic exposure to low levels of arsenic occurs primarily through the consumption of contaminated water. Chronic, prenatal exposure to arsenic can lead to spontaneous abortion, stillbirth, infant death and low birthweight as well as neurobehavioural impairment later in life (1,7,8). Chronic consumption has been reported to produce skin lesions, skin, lung and bladder cancers, vascular disease and effects on the nervous system (3). Skin problems, especially pigmentation, lesions and hard patches on the palms of the hands and soles of the feet, are usually the first clinical symptom of chronic arsenic exposure (1).

Early-life exposure, both prenatal and during childhood, to arsenic has been linked to increases in death, due to
cancers, lung disease, heart attack and kidney failure, and effects on cognitive development, intelligence and memory later in life (1).

Arsenic and its compounds have been declared carcinogenic to humans by the International Agency for Research on Cancer (IARC) (9).

The only available treatment for chronic arsenic poisoning is to remove the patient from the source of arsenic exposure and provide supportive care. The World Health Organization (WHO) drinking water guideline for arsenic is currently set at 10µg/L with consideration of available technologies, detection protocols and feasibility, but lower concentrations can be achieved if appropriate resources are available (6).

References:

Photos:
• © Nasrine Karim, NGO: Earth Identity Project, Bangladesh. Hands and feet "before" from an arsenicosis patient. Used with permission.
Fluoride occurs naturally in soils and water, and high concentrations are often associated with groundwaters. It can also be released through industrial activities, such as aluminium production and the manufacture and use of phosphate fertilizers (1).

Fluoride is a chemical that can be **helpful in small quantities** and **harmful in large quantities**. It is often added to drinking water to achieve a concentration of 0.5–1.0 milligram per litre (mg/L) and reduce the incidence of dental caries (1). Concentrations in surface water are usually relatively low (less than 0.5 mg/L) while deeper groundwater wells in areas high in fluoride minerals may have concentrations up to 10 mg/L (2). Estimates suggest that as many as 180 million people worldwide may be exposed to high levels of fluoride from drinking water sources (3). Certain areas of the world are more affected by high levels of naturally occurring fluoride in soil and water, including India, China, Central Africa and South America, but high concentrations can be encountered locally in most parts of the world (2).

Fluoride is absorbed quickly following ingestion, but not metabolized, and diffuses throughout the body. About 40% is excreted in urine within 9 hours, and 50% over 24 hours (4). Fluoride is also excreted via faeces and sweat (2).

Fluoride has an affinity for mineralizing tissues of the body. In children, fluoride affects both the bones and teeth, and in adults it affects the bones. As the excretion rate is greater in adults, mineralization is proportionally less than in children (4).

The most readily identifiable health effects of consuming water with elevated levels of fluoride are motting of the teeth, known as dental fluorosis, and sclerosis of the bones. Children are particularly affected by dental fluorosis, as teeth take up fluoride during their formation (5).

Fluoride has been shown to be effective in preventing dental caries, from the observed association of low incidence of dental caries with naturally occurring fluoride in drinking water (at about 1 mg/L) (1). As a result, many health authorities around the world, including the World Health Organization (WHO), recommend fluoridation of public water supplies as an important public health measure. **WHO’s drinking water guideline for fluoride is currently set at 1.5 mg/L.** At concentrations above this, fluoride may affect tooth mineralization in children and lead to teeth motting, which can be unsightly. Chronic consumption of water with fluoride concentrations 3–6 mg/L, however, can cause progressively increasing skeletal fluorosis (3).

**Note:** discuss the photos on the slide. Note the discoloured teeth of children with fluorosis. The discoloration seen here is the classical depiction of dental fluorosis in children. Discolouration appears as brown or black streaks (or
lines), these have a horizontal orientation rather than vertical, are away from the gums and the
discolouration is seen in the teeth in pairs and not on a single tooth.

References:

Photos:
• © A. K. Susheela of Fluorosis Research & Rural Development Foundation of India (used with permission).
While not the major source of lead poisoning, high levels of lead may be found in drinking water sources. This is commonly a result of human activities, particularly where lead piping is used, or the use of leaded solder in water supply fittings. Concentrations are affected by factors such as temperature, water acidity and mineral content, and duration of pipe contact with water (1). Some water treatment protocols can increase the release of lead into drinking water (2). The lead contamination of drinking water in Flint, Michigan is an example of this. The contamination of drinking water in Flint was a result of a change in the community’s water source without appropriate corrosion control procedures, resulting in an increase of leaching from corroding lead pipes, solder and plumbing fixtures (3).

Urban run-off, particularly where leaded fuels are common, is a source of lead contamination, particularly of surface waters (1,2).

Lead is a neurodevelopmental toxicant. It interferes with haem synthesis, and can damage the central and peripheral nervous systems, kidneys and reproductive system (4). Lead can be absorbed by the body through inhalation, ingestion or placental transfer. While adults may absorb up to 10% of an ingested dose of lead, children may absorb as much as 50% of ingested lead (5). After absorption, lead is distributed in soft tissues and organs such as the kidneys, liver and bone marrow, where it has a relatively short half-life. The majority of the body burden of lead is distributed to the bones. In children, as much as 73% of the body burden of lead is found in bone (4). Lead concentrations in bone can increase with age, suggesting a slow elimination process. Lead can remain in bone for as long as 20 years and can serve as a continuous source of lead in blood for many years after exposure has ended (2).

Lead is a cumulative poison and can severely affect the developing central nervous system. Infants and fetuses are the most susceptible. Lead can readily cross the placenta, exposing a fetus in utero (5). Many epidemiological studies have been carried out on the effects of lead exposure on children’s neurodevelopment and have documented impaired cognition and behavioural issues affecting a child across their lifetime, even at low levels. Other adverse effects associated with exposure to high amounts of lead include increased risk of cardiovascular disease, kidney damage and interference with the production of red blood cells and the metabolism of calcium needed for bone formation (5).

The World Health Organization’s (WHO) guidelines for lead in drinking water are set at 10 micrograms per litre (µg/L), which represents the most practically achievable level. No safe level of lead exposure has been identified (1,2).

Note: for more information on the effects of lead on children’s health please see the Lead module.
References:
Mercury is an example of a chemical that is toxic when ingested in organic form. It is not present in large quantities in drinking water, but bioaccumulates in fresh and saltwater fish.

Mercury is released into the atmosphere through burning of coal, artisanal and small-scale gold-mining, certain industrial processes, sewerage systems, agriculture, waste incineration and urban run-off. It either directly contaminates water sources or is transported through the air and is deposited via rain into surface waters (1,2). Mercury pollution can travel significant distances from its source. Once in water, mercury is methylated by benthic bacteria, and bioconcentrates up the food chain. Fish, particularly long-lived, predatory fish, can have high concentrations of methylmercury in their flesh. The developing fetus and young children are highly sensitive to the developmental neurotoxicity of mercury which can seriously disrupt the development of the brain and cause major lifelong sequelae (1,3).

Methylmercury compounds are almost completely absorbed from the gastrointestinal tract and can cross biological membranes, including the placenta, the brain, spinal cord and peripheral nerves (4). The main effects of methylmercury poisoning are severe, irreversible, neurological disorders and neurodevelopmental disability (2,3). In utero exposure leads to interference with neuronal migration, organization of brain nuclei and layering of the cortex. These experimental findings are consistent with severe cerebral palsy, seizure disorders, blindness, deafness and neurodevelopmental problems that have been documented in children whose mothers ate heavily contaminated fish during pregnancy. More subtle neurodevelopmental deficits have been observed in some children who were exposure to lower levels of methylmercury in utero (3). Methylmercury can also damage the brain after birth. Long-term exposures outside the developmentally vulnerable periods also cause damage to the central nervous system. Progressive signs include paraesthesia, ataxia, tremor and muscle spasticity, leading to coma and death (4).

Absorption of mercury from drinking-water may be 15% or less, depending on the compound (5). Inorganic mercury compounds have a long biological half-life, accumulating in the kidneys where the toxic effects may lead to kidney failure (2,5).

Fish advisories have been developed in many countries which guide women of childbearing age, pregnant women and young children toward safe fish choices with low methylmercury levels (6,7). Both fresh and saltwater fish can be contaminated, so consulting local authorities is critical to safe fish consumption during pregnancy.

The Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury. The Convention aims to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. Parties to the convention are encourage to reduce and
eliminate sources of mercury in the environment (8).

**Note:** the World Health Organization’s (WHO) guidelines for drinking water only maintain a value for inorganic mercury. This guideline value is set at 6 micrograms per litre (µg/L) (9).

**Note:** if there is a local fish advisory in your country or area, mention it here.

**Note:** for more information on the effects of mercury on children’s health please see the Mercury module.

**References:**

**Figure:**
Nitrate is an essential nutrient found in all plants at varying concentrations and is a natural part of the earth’s nitrogen cycle. Generally, human exposure to nitrate is through the consumption of vegetables, usually at low levels (1). In some circumstances, however, nitrate can contaminate drinking water sources at high concentrations. Consuming water from sources contaminated with a high level of nitrate is the most significant risk factor for adverse child health outcomes (2).

Nitrate contamination of drinking water is usually due to human activities, primarily (1,3):
• agricultural run-off from inorganic nitrogen fertilizers and/or animal manure;
• discharges from poorly managed septic systems;
• discharges from wastewater treatment facilities.

Nitrate pollution can contaminate both surface water and groundwater, however pollution of groundwater is more commonly a consequence of natural vegetation and levels tend to change very slowly. Nitrate contamination in surface water can rapidly change due to pollution from run-off, uptake of phytoplankton and denitrification by bacteria. Nitrate pollution of private well water is the most significant concern to child health. Shallow wells with permeable soils are at the highest risk of contamination (1,3).

The human body rapidly and nearly completely (more than 90%) absorbs nitrate from ingested water into the blood where it is distributed widely across the body. Final excretion is usually via urine (1,2). The primary child health outcome from exposure to nitrates in drinking water is methaemoglobinaemia. Methaemoglobinaemia is a condition in which haemoglobin has decreased ability to transport oxygen to tissues. Clinical symptoms of methaemoglobinaemia include cyanosis (skin discolouration), tachycardia and weakness (2). In extreme cases methaemoglobinaemia can lead to death.

Infants younger than 6 months of age who are bottle-fed formula from private wells are at highest risk of consuming nitrates. They are particularly sensitive to methaemoglobinaemia due to high intake of water in relation to body weight and limited development of repair enzymes. Additionally, methaemoglobinaemia can be influenced and complicated by the presence of microbial contamination and gastrointestinal infection, particularly diarrhoea (1).

The World Health Organization’s (WHO) guidelines for nitrates in drinking water are set at 50 milligrams per litre (mg/L). This level is set as the most protective of the health of the most sensitive subpopulation (bottle-fed infants) (1).
Note: the case study in this module gives an example of nitrate poisoning and discusses prevention and treatment options. A case study on nitrate and child health is also featured in *The paediatric environmental history* module.

References:
Pesticides are a cause of increasing concern due to their widespread and often indiscriminate use. In both urban and rural settings, pesticides may reach water supplies from agricultural run-off (1). Although they are not specifically removed by conventional water treatment processes, natural filtration and biodegradation prior to and during treatment means that these substances are rarely detected in treated drinking water. However, elevated levels are often found in rural areas where intensive agricultural practices can result in direct contamination of water sources (1).

Public health concerns regarding pesticides in water arise from their potential to accumulate in the body. Chemicals in pesticides can be absorbed orally (2). Health effects depend upon various factors including (3):

- timing of exposure
- the specific type of pesticide
- duration of exposure.

The World Health Organization’s (WHO) guidelines for drinking water maintains values for many different classes of pesticides, including organophosphates, organochlorides and herbicides such as glyphosate. Use the guidelines to insert the most relevant pesticides in your region or context, and their value from WHO’s drinking water guidelines.

**Note:** for more information on the effects of pesticides and other persistent organic chemicals on children’s health please see the *Pesticides* and *Persistent organic pollutants* modules.

**References:**

The disinfection of drinking water using chemical substances, such as chlorine, has been applied for more than a century and has saved countless lives around the world. Disinfection by-products occur when chemicals, which are usually added to water sources to control microbial contamination, combine with organic materials. The benefits of disinfecting drinking water far exceed the risk of the small amounts of disinfection by-products generated in the process (1,2).

Four disinfection by-products, evaluated by the World Health Organization (WHO) and other regulatory agencies such as the United States of America’s Environmental Protection Agency (EPA) are listed in the table on this slide (1,3). The table shows their WHO guideline value for drinking water and carcinogenicity classifications from the International Agency for Research on Cancer (IARC) (1,4). There are few data available on the health effects of low doses of disinfection by-products on humans, particularly infants and children.

References:
Another emerging problem in water sources is the accumulation of pharmaceutical and chemical products, originally intended for human or animal use. (1).

Pharmaceuticals and chemicals used in personal care products, and their metabolites, are found in both surface and groundwaters (2). The use of pharmaceuticals by humans and in livestock is of increasing concern to human health and ecosystem integrity. Industrial discharge from pharmaceutical manufacturing plants is a major source of water contamination. Pharmaceuticals and their metabolites can end up in drinking water in much the same way as pesticides can through run-off. They can also contaminate drinking water sources through human wastewater systems, either via human excretion in urine and feces, or by inappropriate disposal of pharmaceutical products directly into the sewerage system. Thousands of different pharmaceutical products are produced and consumed every year. Annually in Austria, Germany and the United Kingdom of Great Britain and Northern Ireland alone, more than hundreds of tonnes of pharmaceutical compounds are used in human- and veterinary-related health problems (3).

These drugs may not be removed during standard drinking water treatment (1–4). Pharmaceuticals are designed to affect human systems, much like pesticides are designed to harm the biological systems of pests. Their presence in low dose, variable concentrations in drinking water is of special concern for children whose bodies are actively developing. The myriad potential effects on human health, animal health and ecosystems are areas of active research. This is a particular problem for low- and middle-income countries (LMICs) where pharmaceuticals are increasing in accessibility, but where wastewater and waste management infrastructure and water purification technologies may be inadequate to detect and remove them if they reach potential harmful concentrations (5). A similar problem exists with personal care products, such as cosmetics, creams, lotions, soaps and sunscreens, which can contaminate drinking water sources through routine washing and recreational use of waters (2).

Antimicrobials, including antibiotics, are a special case of pharmaceutical contamination in water. These are used therapeutically in humans and animals, prophylactically and as growth enhancers in intensive animal husbandry, and in cleaning products and other consumer products. It is well established that over-use of antimicrobials accelerates the development of antimicrobial resistance, which in turn threatens human health (6,7). It is also well established that antimicrobials are found in abundance in water sources (5,8). Children with immature immune and metabolic systems are often at greater risk for adverse outcomes when infected with resistant organisms either because the infection itself is more serious in children, or because children have fewer safe or well-studied options for antimicrobial treatment when they are required (9).

References:

Figure:
Radionuclides occur naturally in the environment from deposits of radioactive minerals, and from the disposal and storage of radioactive materials. Concentrations in surface waters are likely to be extremely low, and groundwater concentrations vary according to the type of aquifer minerals and dissolved anions. Radioactive materials cause changes in cell DNA, with an increased risk of cancer being the most serious outcome (1,2).

Residential radon is the second most common cause of lung cancer incidence worldwide, after smoking (1). Water can also be contaminated with radon, and exposure can occur through both ingesting water directly and inhaling water droplets during showering and other washing activities. Inhalation is an important pathway of exposure to radon in water and research has concluded that 90% of the dose attributable to radon in drinking water comes from inhalation rather than ingestion (2).

Studies have strongly linked chronic exposure to high levels of radon in the air to increased risk of lung cancer. Consuming drinking water containing radon may also increase the risk of stomach cancer, however a definite link is yet to be established (2). Concern for nuclear contamination of water bodies due to accidents at nuclear power plants and other facilities has mounted over the past few decades and remains an ongoing risk (3).

The World Health Organization’s (WHO) guidelines for drinking water recommend that screening levels for radon in drinking-water be set based on the national reference level for radon in air. In circumstances where high radon concentrations might be expected in drinking water, it is prudent to measure radon concentrations (2).

Note: for more information on the effects of radiation on children’s health please see the Children and radiation module.

References:

Photo:
• © WHO/ Yoshi Shimizu. Children playing while taking a bath in the rain, Philippines.
The next section of this training module discusses the role of health care professionals in reducing children’s exposure to contaminants in water or dangerous water-related situations.

Photo:

• © WHO/ SEARO/ Joao Soares Gusman. A boy and a girl play at a water source, Timor-Leste.
Health and environment professionals have a critical role to play in maintaining and stimulating change that will ensure children's access to safe water to protect their health.

**Everyone can do something:**

- at the one-to-one patient level, health care workers can include environmental etiologies in differential diagnoses and in preventive advice: is the disease linked to the quality or availability of water? It is important to limit the number of diagnoses given as “idiopathic” and to look hard for environmental, water-related causes of disease and disability;
- health care providers should be alert and detect “sentinel” cases. These cases are essential for developing, proposing and supporting community-based interventions. Publication of case studies and research enables knowledge sharing and experience that will benefit other communities and countries. Popularly, the birth of public health is often referred to when John Snow removed the pump handle from a contaminated well in 19th century London, illustrating that contaminated water was central to the spread of cholera;
- it is important that health care workers are informed, and can inform and educate patients, families, colleagues and students on the importance of water-related diseases of local relevance and how to avoid them;
- finally, health care workers must all become vigorous advocates for the protection of water sources from pollution, the appropriate treatment and storage of water, respect for drinking-water quality standards, and water conservation. These and other measures are crucial for protecting the environmental health of children and future generations. It is not enough to be an informed citizen, health care workers can write letters, testify at hearings, convince decision-makers, approach elected officials with information, education and clear messages based on scientific evidence;
- health care workers must recognize that as professionals with an understanding of both health and the environment, they powerful role models. Choices and opinions with respect to water and other environmental factors will be noticed: they should be thoughtful and sustainable.

**Photo:**

- © WHO/ Fernando G. Revilla. A local doctor conducting a physical examination on a baby, Bolivia (plurinational state of).
The most powerful tool at the patient care level is the paediatric environmental history. Within the paediatric environmental history, there are many opportunities to ask questions about water availability and quality, and children’s exposure to water (1–3).

As with any question in the medical history, water questions may need to be repeated multiple times, by multiple providers and in multiple settings.

This slide lists some examples of opportunities for prevention, diagnosis and treatment. Discussing water-related issues can be part of diagnostic questions, as well as part of anticipatory guidance, at well child visits.

**Note:** for more information on how to take a paediatric environmental history please view the module *The paediatric environmental history*.

**References:**

**Photo:**
- © WHO/ Esther Ruth Mbabzi. Sister Recho, a midwife in the Nutrition Department of Soroti Regional Referral Hospital speaks to mothers about nutrition, Uganda.
Examples of key questions

- Do you use well water or a community water supply?
- Is your water treated?
  - How? By whom?
- Do you have running water, or do you store water?
- If you store water, what is the storage container?
  - Is it covered? Does it have a tap? Does it have a narrow neck?
  - Has it ever been used for other purpose?
  - How far do you go to collect water? Can you collect enough?
- If you use well water, is the well head protected?
  - Has it been tested for bacteria? Chemicals?
  - How often is it tested?

Here are a few examples of questions about household water that can be used as a starting point to ensure that families are managing drinking water safely and efficiently (1,2):

- Do you use well water or a community water supply?
- Is your water treated?
  - How?
  - By whom?
- Do you have running water, or do you store water?
- If you store your water, what container do you use?
  - Is it covered? Does it have a tap? Does it have a narrow neck?
  - Has the container ever been used for any other purpose?
  - How far do you have to go to collect water? Can you collect enough?
- If you use well water, is the well head (at the top of the well) protected?
  - Has it been tested for bacteria? Chemicals?
  - How often is it tested?

**Note:** adapt this slide to correlate with community norms, conditions and needs in your area. Use reference (2) to explore the World Health Organization’s (WHO) publications on water quality and safety, and to identify water-related issues and relevant questions for health care workers in your context.

**Reference:**
Community water programs are generally centralized treatment and distribution systems following specific drinking water standards.

The World Health Organization (WHO) updated its *Guidelines for drinking-water quality* in 2022 (1), however local authorities may have different or more stringent regulations based on local water sources, pollutants and conditions. All systems should be driven by health-based drinking water standards which can be monitored, maintained and enforced.

The components of a community drinking water program involve, at a minimum, the following (1):

1. **health-based water quality standards** that are set according to a critical evaluation of local health concerns;
2. **system assessment** to determine whether the water-supply chain as a whole (from source through to treatment and the point of consumption) can deliver water of a quality that meets the above targets;
3. **operational monitoring** of the control measures in the supply chain, which are particularly important in ensuring drinking-water safety;
4. **management plans** documenting the system assessment and monitoring protocols and describing actions to be taken during normal operation and following incidents, including upgrades and improvement of documentation and communication;
5. **a system of independent surveillance** verifying that the above are all operating properly.

**Reference:**
When treated, high-quality drinking-water is not available, there are home treatment options. See below three low-cost options for home treatment:

1. **Bring water to a rolling boil then remove from heat and cool**: microbial contamination can be eliminated by bringing water to a rolling boil. It does not need to be boiled any longer. Over-boiling can result in concentration of chemical contaminants that may be present and does not improve microbial safety (1).

2. **Home treatment**: home filtration and chlorination are also viable options (known as “point-of-use” treatment systems). This method depends on the source and condition of the water collected. Local authorities should be consulted for treatment recommendations tailored to the community and its water sources (2–4).

3. **Collection and storage**: proper storage is critical to prevent recontamination. Ideally the water is stored in a covered container with a tap for drawing water. This avoids dipping into the water and recontamination after home treatment (2,3).

**Note**: discuss relevant home treatment methods available in your local community, area or country.

**References**:


**Image**:

- © WHO.
Every chemical contaminant that may be present in water cannot be removed by using a single technology.

This slide shows several kinds of filtration and purification systems with examples of which chemical contaminants they do and do not remove. Before choosing a system, the chemical contaminants to be removed must be accurately identified. Some of these systems can be expensive and difficult to maintain. Proper maintenance is critical, otherwise home treatment systems can be both ineffective and dangerous. Quality control is also important. Local authorities, government bodies and nongovernmental organizations may be able to assist with appropriate identification, acquisition and maintenance of these systems (1,2).

References:

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Cation exchange</th>
<th>Anion exchange</th>
<th>Activated carbon</th>
<th>Reverse osmosis</th>
<th>Distillation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Fluoride</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lead</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Organic Hg</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Nitrate</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VOCs</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Radium</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Coliforms</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Hg, mercury; VOCs, volatile organic compounds.
Health professionals understand the concept of primary prevention – stopping a problem before it can cause harm. Protecting water sources is the most efficient method to ensure clean and safe drinking water and is a method of primary prevention in medical practice (1). Health care professionals are powerful voices in any discussion about children’s public health and safety.

Both surface water and groundwater must be protected, although surface water is more immediately vulnerable to contamination. Contamination from human and animal waste causes microbial pollution and increases the risk and spread of waterborne and water-washed infectious diseases. Industrial discharges from legal and illegal industry, contamination from mining operations, and run-off from farms and urban centres all contribute to water contamination. Riparian buffer zones and storm-water management in cities are necessary to control non-point sources. Point-source pollution from sewage treatment plants and industrial discharges can be controlled by appropriate technology, monitoring and enforcement of laws and regulations on drinking water quality (2).

The images on the slide show a well maintained and protected well head (top photo) and a poorly maintained well head (bottom photo). Even the cleanest well water can become contaminated at the point of withdrawal if the well head is not protected and well maintained.

**Note:** discuss the most significant risks to drinking water safety in your community, region or country. Discuss relevant primary prevention methods that have been successfully used or could be useful in your context.

**References:**

**Photos:**
- Top: © WHO/ Payden. Two girls collect water, Nepal.
- Bottom: © WHO. Water pump, Ukraine.
Health care professionals can be voices of support for global water safety and equity movements and actions. The United Nations (UN) Sustainable Development Goals (SDGs) have a significant emphasis on health (SDG 3), water and sanitation (SDG 6). SDG 6 specifically focuses on achieving access to adequate and equitable clean water and sanitation for all and explicitly references improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials (1).

There are many other international actions and programs that aim to accelerate access to clean drinking water, including:

- **World Water Day**: an annual UN Day of Observance, held on 22 March. It aims to celebrate and raise awareness of those who do not have access to clean water. Each year a different water-related theme is chosen. In 2023, the theme of World Water Day is accelerating change to solve the water and sanitation crisis (2).

- **Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS)**: is UN-Water initiative implemented by the World Health Organization (WHO). It aims to provide policy-makers at all levels with reliable, easily accessible and comprehensive analysis of water, sanitation and hygiene (WASH) systems to make informed decisions. GLASS also evaluates financial aspects of water, sanitation and hygiene programs and services, including how well funds are absorbed, who funds services, the amount and sufficiency of funding and the types of services funded (3).

- **World Health Assembly (WHA) Resolution 64.24 on drinking water, sanitation and health**: called on WHO to continue to highlight the importance of drinking water and sanitation to human health and the prevention of diseases. The Resolution requires member states to develop and strengthen, with all stakeholders, national public health strategies, so that they highlight the importance of safe drinking water, sanitation and hygiene as the basis for primary prevention (4).

- **WHA Resolution 72.7 on water, sanitation and hygiene in health care facilities**: requires member states to integrate WASH into key national health programs and policies, include WASH in health care budgets, and establish and implement national minimum standards. The Resolution aims to ensure that all members states have health care facilities that can provide quality essential health services for everyone (5).

References:


Figure:
- © WHO.
As the global population rises and climate change affects the global water cycle, the prospect of increasing numbers of people living in areas of water scarcity looms large. Children and women are at particularly high risk and often bear the burden of water collection and management.

United Nations (UN) agencies, such as UN-Water, United Nations Children’s Fund (UNICEF) and the World Health Organization (WHO), maintain estimates on the proportion of the global population that is living in extreme water scarcity. Estimates have found that:

- In 2020:
  - 2.3 billion people globally lived in areas of high or extremely high water vulnerability
  - 450 million children globally lived in water-vulnerable areas

- By 2030:
  - 24–700 million people globally could be displaced due to water scarcity

- By 2050:
  - 4.8–5.7 billion people globally could be living in areas of extreme water scarcity at least one month per year

Protecting and conserving fresh water now is critical to the health and survival of future generations. As discussed at the beginning of this training module, water is a finite resource and freshwater is crucial to healthy and stable societies.

References:

Photo:
WHO/ Billy Miaron. Elama (centre) tries to help manage the water fetching process at Hula Hula Springs in Marsabit County, Kenya. With ongoing drought in Marsabit, the spring is the only available water source for the whole community.
The final section of this module discusses a recognized issue of chemical water pollution and the special vulnerability of children.

**Note:** if you have case studies that detail local, regional or national water interventions targeting the improvement of public health, they can be used here.

**Photo:**
A 3-month-old white infant presents with:

- central cyanosis
- tachypnea
- diarrhoea
- vomiting
- drowsiness.

The baby is bottle-fed powdered formula using reconstituted water at home. Feedings consist of 4 ounces of diluted formula every 2 hours and the baby has previously displayed below average weight gain. A physical examination of the baby shows:

- Lethargic, afebrile, slate-grey colour
- Normal cardiac and pulmonary exam, normal blood pressure
- Slightly elevated high rate (160) and pulse rate (60)
- No improvement with 100% oxygen

The baby is admitted to hospital and the following tests are done.

**Diagnostic tests:**

- Bedside examination of 1–2 drops of dried blood on filter paper shows chocolate brown colour which does not change with time exposed to the air (in comparison to deoxygenated blood which appears red/violet and then becomes brighter red when exposed to the atmosphere);
- Complete blood count (and appropriate anaemia work if present) and arterial blood gases with co-oximetry to determine the oxygen saturation gap from which methaemoglobin levels can be inferred and calculated. Arterial blood gases alone will miss the diagnosis.

The baby is diagnosed with methaemoglobinaemia. Treatment with methylene blue acts as a co-factor for the NADH-dependent haemoglobin reductase and should reduce methaemoglobinaemia levels within about an hour. If the baby fails to respond to methylene blue (look for G6PD deficiency, or hemoglobinopathies), additional treatment includes exchange transfusion and hyperbaric oxygen (1).

**Reference:**

**Case study: nitrates in water**

**Blue baby syndrome**

Infants at highest risk:

- Drink more
- High gut pH promotes reduction of nitrate to nitrite
- Fetal haemoglobin more readily forms methaemoglobin
- Cyanosis may take longer to appear clinically
- Reduced NADH-dependent methaemoglobin reductase

- Diarrhoea and dehydration
- Independent risk factors and more common in infants

**Infants are at the highest risk to nitrates in drinking water.** This is due to a range of physiological factors (1,2):

- they drink more water per unit body weight than any other age group. If powered feeding formula is used (as in this case study), and the water used is contaminated, this can result in very high exposure doses. In this case study, the family used drinking water from a private well;
- infants have high gut pH, which supports bacteria that promotes reduction of nitrate to nitrite;
- fetal haemoglobin more readily forms methaemoglobin compared to adult haemoglobin;
- infants with a higher proportion of fetal haemoglobin (fetal haemoglobin typically remains high until about 4 months of age) may have severely reduced oxygenation before cyanosis appears clinically;
- reduced NADH-dependent methaemoglobin reductase, at birth only 50% of adult levels and infants do not reach adult levels until at least 4 months of age;
- gastroenteritis, diarrhoea and dehydration are independent risk factors for methaemoglobinemia regardless of nitrate ingestion. Water that could be contaminated with bacteria, as well as chemicals, represents a double threat:
  - promotes endogenous production of nitrates and nitrites via inflammation;
  - increased absorption in the large intestine;
  - acidosis from dehydration reduces up to 50% effectiveness of NADH-dependent methaemoglobin reductase;
  - sepsis can produce nitric oxide endogenously that is then converted to nitrate.

People with G6PD deficiency, most common in people of African, Asian or Mediterranean descent, are particularly vulnerable to nitrate toxicity, as are pregnant women and fetuses (1).

The photo shown on this slide shows a family with cyanotic features, with comparisons between a normal individual and a patient. Note the differences in colour between the hand on the far left and the other three hands. Additionally, in the section below see the chocolate brown colour of arterial blood samples from patients with cyanosis compared to a normal sample (far left).

**References:**


Photo:

- Kim DS, Baek HJ, Kim BR, Yoon BA, Lee JH, Kook H. “Lifelong cyanosis and skin color and arterial blood color in the patient’s family.”
  
  [https://commons.wikimedia.org/wiki/File:Lifelong_cyanosis_and_skin_color_and_arterial_blood_color_in_the_patient%27s_family_(cropped_BC).jpg](https://commons.wikimedia.org/wiki/File:Lifelong_cyanosis_and_skin_color_and_arterial_blood_color_in_the_patient%27s_family_(cropped_BC).jpg). This file is licensed under the Creative Commons Attribution-Share Alike 4.0 International license (CC BY-SA 4.0; [https://creativecommons.org/licenses/by-sa/4.0/deed.en](https://creativecommons.org/licenses/by-sa/4.0/deed.en)).
Nitrate is an example of an inorganic chemical that can contaminate drinking water. Some additional details are listed below (1,2):

- Nitrate and nitrite are water soluble
- They migrate easily from soil into groundwater
- Readily absorbed in the human body following ingestion

**Sources:**
- Natural microbial action on plant and animal wastes
  - Septic systems and livestock
- Shallow, rural, domestic wells most at risk

**WHO drinking water guidelines:**
- Nitrate = 50 mg/L
- Nitrite = 3 mg/L

Primary sources of nitrates in water include (2):

- Natural microbial action on plant and animal waste due to:
  - Septic systems
  - Livestock
  - Nitrogen-containing fertilizers
- Shallow, rural, domestic wells, which are at highest risk of nitrate contamination and pose the most significant threat to human health (1).

The World Health Organization’s (WHO) guidelines on drinking water quality identified values that are **most protective of the health of the most sensitive subpopulation (bottle-fed infants)** (2):

- Nitrate = 50 milligrams per litre (mg/L)
- Nitrite = 3 mg/L

**References:**


Curious and informed health care providers can make all the difference. Preventing nitrate exposure is key and can be accomplished by (1–3):

- early identification of any drinking water-related problems;
- staying informed about drinking water sources in your community;
- asking patients about their sources of drinking water at prenatal and infant visits;
- discussing water testing with patients (where appropriate);
- discussing maintenance and protection of well head (where appropriate);
- promoting and encouraging breastfeeding. The World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF) recommend exclusively breastfeeding for the first 6 months of life with continued breastfeeding along with complementary foods while continuing to breastfeed for up to two years and beyond (4).

Early identification of methaemoglobinaemia, through physical exam and bedside diagnostics with appropriate follow-up, can save lives and ensure healthy growth and development at critical early life-stages.

In low- and middle-income countries (LMICs), the availability of appropriate testing and treatment technologies for nitrates in water may be unavailable or inaccessible. If nitrate contamination is suspected in drinking water sources the following actions may be useful (3):

- prevent the source of nitrates. Depending on the context this may include management of agricultural practices or sanitation practices;
- ensure children do not consume water that may be contaminated with nitrates, especially children under 1 year of age;
- if possible, use an alterative source of water for bottle-fed children, such as bottled water;
- do not overboil water (see Slide 38 for more detail);
- ensure protection of the well head;
- develop educational programs for expecting parents, especially mothers, to discuss water safety;
- if methaemoglobinaemia is suspected in a child, seek the primary source of drinking water and eliminate it as soon as possible.

References:


Health professionals have the opportunity and the obligation to deliver the best care we can to support children’s health and wellness. Yet, globally in 2019 (1):

- a quarter of health care facilities, servicing 1.8 billion people, lacked basic water services;
- 10% of health care facilities had no sanitation services;
- one in three health care facilities lacked hand hygiene facilities at the point of care;
- one third of health care facilities did not have systems to safely segregate waste.

Many schools around the world also lack basic hand-washing and sanitation services and facilities for students (2). The World Health Organization (WHO) has developed a primer for health professionals which gives links to further documents and research about water availability. It is a gateway to further information and is available on WHO’s website (3).

Water is life and children are the future. It is vital to ensure children’s health, wellbeing and futures through access to safe and clean water.

References:

Photo:
- © WHO/ Mubeen Ansari. Children whose home was damaged by the flooding play in a stream in Madyan in Pakistan’s Swat valley.
For more information on water and child health see the World Health Organization (WHO) training package on children’s health and the environment for the health care sector (1). The following modules may be of particular interest:

- **Children and chemicals**
- **Global climate change and child health**
- **Lead**
- **Mercury**
- **Pesticides**
- **Sanitation and hygiene**

To read more on water and child health see the below references:

- **Guidelines for drinking-water quality** (2)
- **Guidelines on sanitation and health** (3)
- **Boil water: technical brief** (4)
- **Progress on household drinking water, sanitation and hygiene 2000–2020: five years into the SDGs** (5)
- **Environmental health criteria 237: principles for evaluating health risks in children associated with exposure to chemicals** (6) and its accompanying summary (7).

**References:**

Acknowledgements for second version

Initial edits by Katherine M. Shea (USA).

Working group for second edition: Marie-Noël Bruné Drisse (WHO), Gloria Chen (USA), Julia F. Gorman (WHO consultant), Amalia Laborde (Uruguay), Katherine M. Shea (USA).

Reviewers: Maria Brown (UNICEF), Jennifer de France (WHO) and Paul Jagals (Australia).

Final review, technical and copy-editing: Julia F. Gorman (WHO consultant).

WHO CEH training project coordinator: Marie-Noël Bruné Drisse (WHO).

This publication was made possible with financial support from the Swedish International Development Cooperation Agency (SIDA), Sweden.

Update: December 2022.

Design by L’IV Com Sàrl, Villars-sous-Yens, Switzerland.
Acknowledgements from previous edition

WHO is grateful to the US EPA Office of Children's Health Protection for financial support that made this project possible and for some of the data, graphics and text used in preparing these materials for a broad audience. Further support was kindly provided by the UK Department of Health and the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Germany.

First draft prepared by Katherine M. Shea (USA).

With the advice of the Working Group Members on the Training Package for the Health Sector: Cristina Alonso (Uruguay); Yona Amitai (Israel); Stephan Boese-O'Reilly (Germany); Irena Buka (Canada); Lilian Corra (Argentina); Ruth A. Etzel (USA); Ligia Fruchtengarten (Brazil); Amalia Laborde (Uruguay); Leda Nemer (WHO/EURO); R. Romizzi (Italy); S. Borgo (Italy).

Reviewers: Y. Amitai (Israel), Maulik Baxi (Canada), Lesley Brennan (Canada), Alexander Doroshenko (Canada), Ruth A. Etzel (USA), F. van Hoof (Belgium), Alvaro R. Osornio-Vargas (Canada), Donald Spady (Canada), F. Were (Kenya).

Previous update: August 2008.

WHO CEH Training Project coordination: Marie-Noël Brune Drisse (WHO), Jenny Pronczuk (WHO).
Disclaimer

© World Health Organization 2023. Some rights reserved. This work is available under the Creative Commons Attribution Non-Commercial ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; https://creativecommons.org/licenses/by-nc-sa/3.0/igo).

Third-party materials, if any, used or re-used from this work that is attributed to a third party, such as tables, figures or images, is your responsibility to determine whether permission is needed for that reuse and to obtain permission from the copyright holder. The risk of claims arising from any reuse of any third-party material included in this work rests solely with the user.

This training module was developed by the World Health Organization (WHO) and is intended to be used for training purposes only. The opinions, conclusions, and data expressed or implied by the training module do not necessarily represent the official position of the World Health Organization (WHO). The contents of this training module are based upon references available in the published literature as of the last stated update date. Users are encouraged to search standard medical databases for updates in the science for issues of particular interest or sensitivity in their regions and areas of specific concern.

All reasonable precautions have been taken by WHO to verify the information contained in this training module. However, the training module is being distributed without warranty of any kind, either express or implied. The responsibility for the interpretation and use of the training lies with the reader. In no event shall WHO be liable for damages arising from its use.

The designations employed and the presentation of the material in this training module do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its borders or boundaries. Defined lines on maps represent approximate border lines for which there may not be precise legal agreement.

The mention of specific companies or of certain manufacturers’ products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted; the names of proprietary products are distinguished by initial capital letters.

The authors alone are responsible for the views expressed in this training package and they do not necessarily represent the decisions, policy or views of the World Health Organization.