Chapter

Unlocking Water Issues Towards Food Security in Africa

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Abstract

Water plays an important role in food security and provides the basis for healthy ecosystems and human well-being. The relationship between water and food production is key to creating resilient and sustainable food systems. This chapter will discuss the effects of water quality and scarcity with respect to food security in Africa. The effects of water availability and its usage in the African landscape and how this has impacted food security will be highlighted. Lastly, issues concerning water pollution and food safety will be tackled to identify knowledge gaps that impede food security in Africa in its efforts toward attaining the United Nations Sustainable Development Goals.

Keywords: agriculture, availability, contaminants, ecosystems, food security, health, pollution, safety, sanitation, scarcity, water quality, water

1. Introduction

Water is an important resource that supports life on earth. Its availability plays key roles for attaining socio-economic developments globally [1]. It is also a priority toward meeting the United Nations Sustainable Development Goal (SDG) 6 that seeks to ensure access to water and sanitation for all [2]. This requires an adequate enabling environment and strong systems at country level. The United Nations General Assembly has called for country-led, coordinated efforts to provide financial resources and build capacity and technology transfer to help countries yield stronger and sustainable services [3]. Water is thus an essential resource for balancing the well-being of humans and healthy ecosystems.

The survival of humans and continuing social-economic developments depend on the supply of appropriate water quality and quantity. The relationship between humans and ecosystems is core as people strive to improve their well-being. Ecosystem services are beneficial to all living creatures including humans in a number of ways [4]. Water, for instance, contributes to ecological functions through the provisioning of habitat for aquatic life, including fish that is food for humans.

Water also provides ecosystem services that include freshwater supply, regulatory functions such as dilution and water purification, and fulfilling cultural necessities (e.g., water for traditional, esthetic, or medicinal and spiritual purposes). The benefits derived from ecosystem services are available to humans, regardless of where they live or where the services are generated. For example, urban dwellers enjoy river ecosystem service benefits including fishing for food or growing trees

along the river banks, which can be used as timber to build houses or as firewood for cooking.

Ensuring sustainable management of aquatic ecosystems for improved food security is therefore important [5]. This is especially true in urban areas where human activities may pollute distant ecosystems through effluent discharges caused by industrial and domestic or mining activities [6]. Human activities can pollute water bodies and impact socio-economic developments negatively. Any changes in water quality can affect short- or long-term food security goals if aquatic resources are not properly managed.

This chapter discusses the effects of water quality and scarcity with respect to food security on the African continent. A comprehensive synthetic evaluation of various published and technical reports was conducted in order to draw the relationship between the potential of water and food security in the African region. The use, distribution, and requirement for food systems that promote water conservation to create sustainable food production are explored. Lastly, issues concerning water pollution and food safety are discussed to identify knowledge gaps that impede food security in Africa toward the attainment of the United Nations Sustainable Development Goals.

2. Water and human survival

This section seeks to highlight the basic human need for water and track the global water distribution and its importance in food security. Water is a basic unit of life and an essential nutrient that is required in amounts that exceed the body's ability to produce it [7]. Like all nutrients, water performs different functions in the body [8]. Water is an essential component of cells, tissues, and organs required for digestion, absorption, and dissolution and as a carrier for nutrients, eliminating waste products; temperature regulation; and as a lubricant and shock absorber [9–11].

To achieve all these functions, total body water must be approximately 60% of body weight in males and 50% of body weight in females [12]. The water distribution is up to 60% intracellular (this amount is lower in females due to larger amounts of subcutaneous tissue and smaller muscle mass) and 20% in extracellular space [13]. The extracellular fluid compartment comprises fluid in blood, interstitial fluid, bone, connective tissue, and transcellular fluid. Variation in water intake depends on human health, weight, and human physical performance.

Human survival can be achieved with minimum water requirement where water lost through normal activities gets replenished [14]. The average adult body naturally loses almost 2–3 L of water daily which must be replenished to function on a day-to-day basis. This loss occurs mainly via urine, perspiration, feces, and exhaled air.

The amount of body water that gets lost depends on individual and environmental factors. These factors are affected by the climate a person lives in, his or her age, physical activity level, and kidney function [8]. To regulate the body's water levels, the water input must balance water output through metabolic processes (0.3 L/day), fluid intake triggered by thirst (1.5 L/day), and solid foods triggered by appetite (approximates 0.7 L/day). Too little or too much water in the body can lead to less-than-optimal body function.

Early stages of decreased water intake in the form of dehydration can lead to difficulty in concentrating, headache, and sleepiness. Decreased water intake has also been associated with bladder and lower urinary tract cancer and increased risk of colorectal cancer as well as kidney stone formation [15]. Taking too much water

can also put an unnecessary burden on the cardiovascular system and the kidneys and can cause a drop in the concentration of electrolytes in cells causing harm in the long run.

While water may be a renewable resource, it is unfortunate that there is only a finite amount and there are no substitutes. Without clean and safe water, human survival cannot be achieved. This has a great impact on the global burden of disease, health, education, and economic productivity of populations.

2.1 Water challenges affecting human survival

Water is an important component in a number of human functions, hygiene, and the overall maintenance of health. At the most basic level, water service must meet consumption and hygiene needs and sustain good health at household level [16]. Millions of the world's poorest people, however, die each year from preventable diseases due to poor hygiene, lack of clean drinking water, and lack of proper sanitation facilities [17].

The reality is that water and sanitation are weakly integrated into countries' poverty reduction strategies. Many national governments are failing to put in place the policies and finances needed to accelerate progress toward achieving clean water and adequate sanitation.

In many rural communities, lakes, dams, and stream that are the main sources of water run dry for long periods, forcing people to use unsafe water sources [18]. For the 2.1 billion people who lack access to clean water, they can only afford to get a measly 5 L a day and fail to meet the recommended basic minimum of 20 L a day required for human health, economic, and social development [19]. This is a far cry from the 200 L a day per person that people from rich countries consume on average in a day.

A report on global distribution of the global drinking water services in 2015 found that 71% of the global population (5.2 billion people) had access to a safely managed drinking water service [19]. The report further found that sub-Saharan Africa was the region with the lowest number of people with access to safe drinking water located on their premises. Only Australia and New Zealand had 100% access, where all of the population had basic services (including basic drinking water, sanitation, and hygiene) in their households.

The same report estimated that two-third of the total global population was living in water-stressed areas that experience water scarcity for at least 1 month in a year in 2015 [2]. Of the two-third, 844 million people lacked basic drinking water service and 263 million people were reported to be spending over 30 minutes per round trip to collect water from an improved water source [19].

Still, 159 million people were reported to collect drinking water directly from surface water sources and over half of these people were living in sub-Saharan Africa. These people share their domestic water sources with animals. A large fraction of the people that live in extremely vulnerable situations of water scarcity all year-round are found in Libya, Somalia, Pakistan, Morocco, Niger, and Jordan where 50–90% of the country's population lives under those circumstances [20].

3. Global distribution of water

An estimated three fifth of the earth's surface is covered by water, which makes up a total volume of almost 35 million km^3 [2]. Of the available amount, only 200,000 km^3 (1%) of this is fresh water that is usable by humans. This is the water that is expected to fulfill the demands of the increasing global population, meet

the food production needs using the limited amount of arable land, and sustain industrialization.

Historically, people looked for location to set up their livelihoods near water supplies such as river bases that could provide drinking water and carry off waste. Over time, areas close to water sources became populated by industries and agricultural holdings which use water for irrigation and also to power industries [21].

Distribution of piped water is realized as a sign of progress toward achieving the SDGs. Industrialized countries (20%) have managed to achieve piped water coverage in 85% of their entire household. The poor countries, however, have only managed limited piped water coverage with only 25% of all their households having access [19]. Industrialized countries have been better able to achieve water security compared to poor countries and this is evident from the average water usage data of 200 L per person per day in rich countries compared to the 5 L per person per day in poor countries [18].

Factors that contribute to high water scarcity levels include areas with a high population density, areas with irrigated agriculture, and areas with very low natural water availability [20]. Geographically, water scarcity can be found in in the world's arid areas with low water availability like the Sahara, Taklamakan, Gobi, and central Australian deserts.

Water scarcity has also been found to be intense in areas with high population density and irrigation intensity. Globally, these areas are found near river basins and include the Ganges basin in India, the Limpopo basin in Southern Africa, and the Murray-Darling basin in Australia [20].

Distribution by sectors shows that water use is spread between domestic, agriculture, and industry sectors. Agriculture accounts for over 70% of freshwater use [16, 22] and industry water use accounts for 20% globally. In spite of this, it is believed that there is enough water in the world for domestic, agriculture, and industry purposes; the only problem is how this water is distributed especially to the poor who are systematically excluded from the distribution.

Water use varies significantly by sector across the world. How do these three sectors use fresh water?

3.1 Agriculture

As discussed above, water use varies considerably across the world especially between the poor and rich. Agriculture is the biggest user of fresh water with Africa and Asia, accounting for the largest users under this sector with an estimated 85–90% of all freshwater [23]. Future demands for water for agriculture are threatened by climate change, technological development, and urbanization. The challenge is to produce more food to meet the growing population demands using less water and other resource inputs in an environmentally friendly manner [24]. Low-income countries' average agriculture usage is estimated at 90%; 79% for middle income and only 41% in high incomes countries [22].

3.2 Industry

Industrial water use includes all the water used for manufacturing, energy generation, and other industrial activities such as dilution, steam generation, washing, and cooling of manufacturing equipment [25]. Globally, an estimated 20% of total available fresh water is used for industrial purposes. Within the industrial sector, hydropower and nuclear power generation uses 57–69% and the thermal power generation uses 0.5–3% [23]. Industries also pose a threat to fresh water because of the amount of wastewater it produces, its mobility, and loading of industrial pollutants

and their potential impacts on water resources, human health, and the environment. High-income countries tend to use the largest portion of water on industries (17%), with low-income countries using the least with an average 2% [26].

3.3 Domestic

Domestic water is the most visible form of water and it shows the problem that exists in the distribution of fresh water between the rich and the poor. People in developed countries consume almost up to 10 times more water daily than those in developing countries. In developed countries, where large cities have centralized water supply and an efficient canal system, domestic consumption averages 200 L per person per day [23].

In developing countries within Asia, Africa, and Latin America regions, consumption in cities and towns is between 50 and 100 L per person per day, and in the water scarce areas within these regions, the amounts can be as low as 5 L per person per day [23]. Countries with the largest population, China followed by India, have the highest water use globally [26].

The change in water distribution will have a serious implication on people's health and well-being, especially for people living in high population density areas, areas with irrigated agriculture, and areas with very low natural water availability. These are the estimated 1.8–2.9 billion people who experience severe water scarcity for at least 4–6 months per year and the 500 million people face severe water scarcity all year round [20].

The distribution of water between sectors is expected to change over the coming years as a result of population growth, increased water scarcity, and drought due to climate change. Water use for irrigation and other water using sectors of the economy are expected to experience extreme competition which will place more burden on food security.

4. Water in food security

Water forms an essential part in national food security. To attain food security, there must be an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production [27, 28]. Any sustainable attainment of food safety and security for a fast-growing population requires thoughtful decisions to develop and manage water resources.

Food security and safety are key development agenda items in most developing regions (Global Panel on Agriculture and Food Systems for Nutrition, 2016). Global research and funding have been prioritized and channeled toward fighting against food insecurity. Although substantial progress globally is evident [29], the same cannot be said for some of the African regions. Sub-Saharan Africa continues to have less access to sufficient quantity and quality food for proper health and growth. The report also classified the sub-Saharan countries as food insecure, with limited access to safe food within their population.

Despite the global food security achievements realized in recent years, food security and limited access to food safety still remain as challenges in Africa. Water scarcity and irregular rainfall distribution are proving to be an impediment to Africa's efforts to ensure food security. Agriculture production systems, which are the backbone of food security, are also adjusting to tightening water availability by reducing freshwater use especially in the African region. This has resulted in the emergence of new diets that are sensitive to the significant influences of water and land use [30].

As the water challenge for agricultural production in Africa increases, it is expected that the share of irrigated agriculture in global water use could rise by over 30% by 2030 [30]. Total global water demand could double by 2050. The increased competition for scarce water and land resources increases concerns about where the additional food will come from. The challenges are further exacerbated by climatic changes that cause irregularities in water availability across the African landscape [31].

Water requirements in agriculture vary significantly not only in terms of quantity, but also in terms of quality and timing depending on food type. This is very significant especially when it comes to staple foods such as maize, rice, and wheat that are critical in food security of many countries in Africa. Some of these countries have increased awareness toward conserving their national water supply by opting for virtual water trade—importing food from outside the country in the effort to conserve water resources and maintain food security [32]. Other countries have shifted food production within the agriculture sector focusing more on planting water-efficient crops.

Apart from water being important in production, it also plays a huge role in food processing, transformation, and preparation adding to the competition against industrial and domestic water use [33]. Even though food processing uses much less water than primary production, this part of the food system requires water that is of high-quality standards and that does not pose any health and safety risks on both human and ecosystem health.

There is also a drive toward introducing water-use efficiency, reducing pollution impacts from processing industries [34]. Poor quality water used in food processing can lead to food-borne disease such as diarrhea and other diseases that contribute to malnutrition. The unsafe food creates a vicious circle of diseases affecting particularly the more vulnerable populations that include children, the elderly, and the sick [33].

Priority must be given to encouraging greater efficiency of water use and the development of integrated water management plans [30]. The shortage of food production due to water scarcity calls the need to manage every water drop to attain food security and food safety in Africa. This raises awareness that water for agricultural production is a pressing issue.

It has been noted that agricultural developments require a consistent and sustainable provision of large quantities of good quality water for food security [35]. The present situation is a clear sign that previous potential solutions to solving Africa's food insecurity have not received the most needed attention when defining development goals on the continent. Societies depend on water availability to meet a wide range of needs including water for irrigation, domestic, and industrial use.

Poverty and water are inextricably intertwined. Food security cannot be achieved without tackling water issues since lack of safe water underpins food insecurity. Countries continue to invest in the protection and management of water resources to continue deriving benefits for improved living standards. Undoubtedly, major water investments in agriculture are necessary toward meeting food production needs [35]. Crucial role players are needed to put together efforts to conserve water for a food secure world.

4.1 Water scarcity impacts on food security

Many Africans depend on aquatic and riparian plants and animals as an important source of food for both humans and livestock. These include fish, shellfish, bait, edible plants, and grazing. In addition, some areas such as wetlands and floodplains across Africa may be used for the cultivation of food crops. In this way, these riparian areas contribute to food security and livelihoods. These services are of particular importance to poor communities [36].

Nonetheless, the provision of reliable sources of water whether for small-scale water for food processing or large-scale water for irrigation is necessary to move beyond subsistence farming toward a more food secure continent [37]. The availability of water allows farmers to continue growing crops of high value such as vegetables, which are highly sensitive to water stress periods [38].

Although quality of water is crucial for peoples' nutrition and water availability for food security in developing countries [39], water investments have been rapidly declining. While irrigation has a high potential for environmental damages or disturbances, it has contributed positively to poverty eradication [39]. Irrigated agriculture has benefited both rural and urban poor by lowering food prices [39]. The availability of water for irrigation means less people fall below the poverty line, and that poor communities, women in particular, also benefit greatly from irrigation as a major source of water for most of their domestic uses, fishing, small and/or informal businesses [39].

Nonetheless, small-scale water availability can impact on food security positively. The availability of water for small-scale harvesting has a huge effect on incomes and food security in developing and poorest communities. Major water investments will have more drastic and positive impacts on the poorest communities, where the majority of people live on less than US$1 on a daily basis [39].

Existing challenges between water availability, quality, and sustainable agriculture linkages must be explored and be made explicit in planning potential agriculture-based strategies for improving food security. The need for fresh clean water is, however, threatened by the changing quantity and quality of the freshwater resources on which people depend for survival. The need for clean water is also linked to adequate sanitation and improved health [14]. Proper sanitation helps to protect water sources from bacterial, viral, and protozoal agents that cause water-related diseases. The concern for many is how can water quality be attained?

5. Water quality management

As much as water is an essential component of life, it is a hotbed for carriers of many diseases caused by consuming unclean water. Access to safe drinking-water, sanitation, and hygiene (WASH) services is an important element of food security and has a positive impact on nutrition [40]. A number of approaches are used to assess water pollution effects on the ecosystems which have a direct contribution to food security and nutrition.

A common approach is to use chemical indicators to measure the concentration of chemicals or toxicants within a water body using either water samples or direct in-stream measurement of the water source using water samples as (chemical indicators). If the chemicals within the water are in exceedance with acceptable limits, that water system is regarded as polluted and not fit for human consumption. Biomonitoring can also be used to assess water quality by examining the presence or absence of certain species or organisms in a water body [41].

Another approach that is used to assess water pollution is ecotoxicology. An investigation is conducted to examine responses of insects, fish, and other invertebrates to a chemical or stressor as biological indicators of water quality [42]. Thus, polluted aquatic systems may not adequately support the provision of fish and insects as food for humans. Similarly, necessary microbes that support plant growth in soils may not thrive in polluted environments, thereby affecting food security.

Without good quality water, the lives of millions of people especially young children are at risk of dying from preventable diseases caused by poor water, and a lack of sanitation and hygiene. There is a growing interest to better understand and measure

the effect of programs and approaches not only directed toward improving water management in agriculture and food production but also to include integrated approach to implementing safe water and adequate sanitation [40]. Approaches and practices for ongoing efforts to better link WASH and nutrition programs integrating WASH into food security and nutrition programs are discussed in the following section.

5.1 Water, sanitation, and hygiene (WASH) programs and food security

The World Health Organization [43] report defines drinking water as water with acceptable quality in terms of its chemical, bacteriological, and physical parameters for safe human consumption. Estimates indicate that about 80% of all sicknesses and diseases on a global scale are linked to consumption of unclean and unsafe water and poor sanitation.

However, the quality of any water is influenced by both natural and human factors [44]. Without human influences, water quality would be determined by natural factors and/or processes such as bedrock minerals, deposition of dust, natural leaching of soil minerals and organic matter, and biological processes, among others. Water quality is determined by using water quality guidelines or standards to make a comparison between the physical and chemical characteristics of water samples. The guidelines and standards are developed to ensure the safe consumption of water and protection of ecosystems.

Africa with its soaring human population continues to experience a decline in water quality [43, 44]. Adequate water, sanitation, and hygiene are essential components for reducing poverty, illness, and death and bring about an improved socio-economic development. Poor WASH programs expose people to water-borne diseases, resulting in death and disabilities in certain cases [44]. The United Nations International Children's Emergency Fund (UNICEF) report revealed that the absence of toilets results in the contamination of water resources, while a lack of clean water impedes on basic hygiene [45]. However, increasing WASH programs have led to increased access to adequate drinking water sources and improved sanitation globally since 1990 [43].

To explore how WASH programs could improve the water and sanitation conditions for poor and developing countries across Africa, it is important to define hygiene and sanitation. Peal et al. [46] defined "sanitation" as the treatment and management of human excreta from coming into contact with humans, while "hygiene" is a required action to avoid the transmission of diseases within and between different communities. WASH programs are vital for helping people avoid contaminating water sources, which in turn improves their access and the overall food safety and security.

WASH programs also help to improve water quality for adequate food production due to their design nature, whereby communities work together to disseminate WASH information for a more collaborative program and implementation [46]. Here, practitioners work together with communities and local authorities to deliver the components of the WASH program on-site. This is complemented by practitioners revisiting the communities or distributing surveys for monitoring and evaluation purpose. Therefore, WASH program approaches have the potential to improve food security within the poor and developing African countries.

6. Effects of water pollution on food security

Water pollution is the building up of one or more substances in water to an extent that they cause water-related problems for people and animals [47]. It is a complex problem that is underpinned by many causes, which makes it difficult to

solve. Increasing human population continues to exert immense pressure on the world's water resources [29]. Both urbanization and industrial revolutions have exacerbated water pollution through effluent and untreated wastewater discharges.

Irrigated agriculture has resulted in increased salinity of freshwater bodies as salts are flushed out from soils [48]. When farmers fertilize their fields or control insects using herbicides, the chemicals used get washed away as salts through surface run-off into nearby water systems. Toxic chemicals released into the atmosphere by industries can also enter into water systems as acid rain [49].

An increase in water salinity negatively impacts on the survival of aquatic macroinvertebrates, while some crops become intolerant to high soil salinities if thresholds are exceeded [50]. As a consequence, soil productivity is affected and can lead to low crop production and food insecurity. It is therefore clear that low crop production is not only an issue in semi-arid regions but also areas that receive plenteous rainfall.

Thompson and Darwish [49] argued that the poor quality of water has a direct impact on food security, with metals detected in some edible food in China, posing a high health-related risk to consumers. If pollution effects are properly monitored using the approaches outlined above, Africa can produce quality food for its citizens. However, the UNICEF [45] report outlines the importance of educating people on water quality issues as another approach to solving water pollution.

Further, strict environmental laws are necessary to minimize water pollution. For example, environmental reports indicate that the "polluter pays" principle is effective in tackling pollution [49]. The polluter principle makes it less expensive for humans to behave in an environmental cautious and/or responsible manner. It is sad, to note, however, that some countries considered to have the best water laws in Africa and beyond, such as South Africa [51], are still struggling to deal with historical water quality issues that subsequently impact on their food security. Further, unstable countries due to political reasons such as Libya would greatly be affected by food insecurities considering their dry nature. The water quality of both countries is discussed in the following sections.

6.1 South Africa: a country with poor water quality

South Africa has sufficient water to meet all the needs of the country until the year 2025 and beyond [37]. However, the country is faced with challenges related to water quality, which impedes on food production to meet people's demand for food. Poor water quality renders water unusable. Changes in agricultural practices and the expansion of urban settlements have a serious effect on the quality of water [37]. Furthermore, acid mine drainage (AMD), pesticides from agricultural practices, unmonitored sewerage systems, domestic water usage like washing clothes on the river and dumping waste in water sources in some areas of the country, and salinization from the weathering of minerals all pollute water [42, 52, 53]. Once water is polluted, it may be difficult and extremely expensive to redress, particularly in the case of underground water, which may affect agricultural production in terms of excessive salts on the soil and usable water for food production. It is thus important to note that good water quality would be suitable for food production to ensure food security.

6.2 Libya: a country in a political crisis

Libya has a rapid growing demand for freshwater availability while the water supply is limited [54]. The issue of severe water deficits as a result of nonending water demands in Libya has become more problematic for the increasing population

under low rainfall, which is a result of climate change. Furthermore, the country has been experiencing high rates of pollution and depletion due to water resource unavailability. This has had major impacts on Libya's economy and social and environmental resistance capacity.

Considering that Libya is one of the driest countries on a global scale with high temperatures, meeting and maintaining acceptable living standards for the future is extremely difficult, especially in relation to food security. Food sufficiency remains uncertain in Libya due to its political instability coupled with poor water quality and soaring human population [54]. The country is likely to experience severe and most devastating situations and high risks of food insecurity and malnutrition with current political instabilities.

7. Water and food safety

This section discusses the relationship between water and food safety. Water is seen as an essential component in the food chain, starting from production, processing, and eventually consumption. In addition, water pollution has historically impacted on food safety, which constitutes an important threat to human health, food, and nutritional security. In most sub-Sahara African countries, food safety problems vary in nature, severity, and extent. These challenges are often exacerbated by the effect of climate change and natural disasters such as floods and hurricanes, whereby food may become contaminated by surface water that has itself been contaminated by sewage and wastewaters. It is well documented that flood waters often pick up large quantities of wastes and pathogenic bacteria from farms, sewer systems, latrines, and septic tanks. Overcrowding of the survivors after disasters may aggravate the situation, particularly if sanitary conditions are poor.

Any breakdown in vital services, such as water supply or electricity, also adversely affects the quality of food. In the absence of electricity, cold storage may be more difficult, if not impossible, and foods may be subject to bacterial growth. This may be obtained at any stage of the food chain, from production to consumption. Lack of safe drinking water and sanitation hampers the hygienic preparation of food and increases the risk of food contamination.

Food safety has become a constant global concern apart from affecting human health; factors such as international trade and food security are also influenced. Consequently, most research institutions, healthcare institutions, and governments of several African countries have conducted comprehensive studies on the effect of water on food safety in various production chains. According to a recent study, the main water issues that affect food safety in low income countries include bacterial pathogens, followed by pesticide residues and healthy diet [40]. Although the reported evidence of food-borne disease is still limited, the known incidences of food borne disease in low income countries such as sub-Saharan African largely emanate from three major sources, namely biological hazards and chemical and physical contamination.

7.1 Biological water contaminants

Water and food contaminated by microorganisms are major contributing factors for the emerging diarrheal diseases in the developing countries, and over 1 billion children under the age of 5 years are affected worldwide [26]. The high prevalence of deaths related to food and water contamination in developing countries could be attributed to several factors. For example, in many African

countries, milk and dairy production constitute an important source of livelihoods for most peasant and smallholder farmers. Furthermore, animal production has become part of agricultural diversification strategy for most African countries in an attempt to ensure food security. The intensification of animal production has also generated a considerable impact on the environment considering the fact that milk provides suitable condition for the growth of different kinds of microorganisms, and microbial hazards are the most important concern within the dairy industry.

Biological agents associated with water contamination that have an impact on food safety include enteric pathogens such as bacteria, viruses, and protozoa. A study conducted in North-West Province of South Africa reported that multi-drug resistant *Staphylococcus aureus* strains were detected in samples of raw, bulk, and pasteurized milk [43]. Other common biological contaminants are *Escherichia coli*. The *E. coli* bacteria belong to the intestinal microbiota of humans and animals and are generally not harmful. Certain *E. coli* strains, however, harbor virulence factors and can cause intestinal and extra-intestinal diseases. For example, Shiga toxin-producing *Escherichia coli* zoonotic bacteria have globally been associated with various foods of animal origin, especially beef and sheep meat [40].

Apart from animal product contamination, biological contaminants may also occur in crop products. Foodborne outbreaks from fruit and vegetable produce have caused economic loss, food wastage and loss confidence regarding the safety of fresh produce from most African countries. Studies on the safety of fresh produce have identified water as one of the key risk factors that contribute to contamination of the farm produce. Indeed, studies have shown that most foodborne diseases are caused by consumption of fresh, perishable foods sold in informal markets [44].

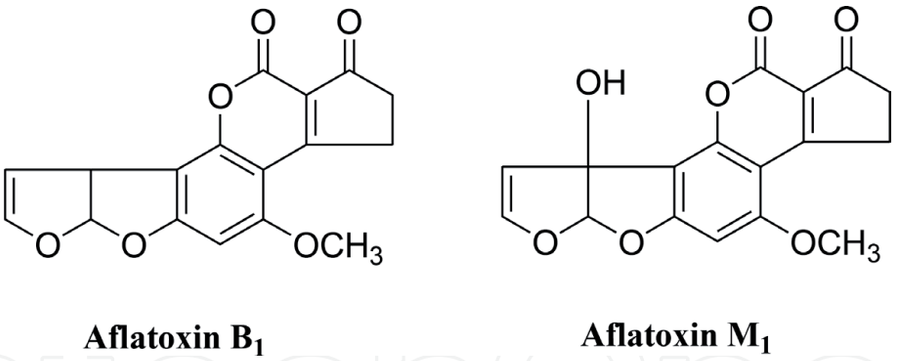
7.2 Chemical hazards

Generally, mycotoxins, heavy metals, and over-application of fertilizers and pesticides are considered to be the most important chemical factors impacting on food safety in most developing countries including the African region [45]. In nature, thousands of mycotoxins occur but only a few of them present significant food safety challenges.

Mycotoxins are secondary metabolites mainly produced by fungal species from the *Aspergillus, Penicillium, and Fusarium genera*. They often develop during production, harvest, and storage of grains and nuts in the presence of water [45]. In the food production process, mycotoxins are among the most potent mutagenic and carcinogenic substances known. Ingestion of mycotoxins poses chronic health risks such as hepatotoxicity, genotoxicity, suppression of immunity, estrogenicity, nephrotoxicity, teratogenicity, and carcinogenic effects [44].

The adverse health effects of mycotoxins are compounded by the fact that they are not completely eliminated during food processing operations and can contaminate finished processed food products [55]. The presence of mycotoxins, particularly the aflatoxins, has generated a lot of interest in the food products from African countries. The work by Maxwell (1998) evaluated the presence of aflatoxins in human body fluids and tissues in relation to child health in the tropics. The findings showed that in Ghana, Kenya, Nigeria, and Sierra Leone, 25% of cord blood samples contained aflatoxins, ranging from 7 ng/L to 65 μg/L. The major classes of aflatoxins that were identified in the African countries include B1 and M1. **Figure 1** shows the chemical structures of the most prevalent aflatoxins in African countries.

Heavy metals have also contributed negatively to the food safety status in most African countries. As such, human exposure to heavy metals in Africa has become



Aflatoxin B_1 **Aflatoxin M_1**

Figure 1.
Chemical structures of aflatoxins prevalent in African countries.

a major health risk and has received the attention of national and international environmentalists [47]. Rapid population growth, increasing urbanization, and the increasing appearance of slums and townships as a consequence of poor planning coupled with increasing industrial activities are some of the major factors that have contributed to the accumulation of heavy metals in food products. Africa has large deposits of mineral resources, and mining activities have increased with poor environmental regulations and compliance. Thus, heavy metals have constituted agents of toxic pollution of water, air, soil, and food products.

An environmental assessment report by the United Nations Environment Programme (UNEP) released in 2011, showed that drinking water, air, and agricultural soil in 10 communities from southeastern Nigeria contained over 900 times permissible levels of hydrocarbon and heavy metals [47]. The report further indicated that heavy metal pollution is a continental public health challenge in the sub-Saharan African region. Another study conducted in the Democratic Republic of Congo showed a 43-fold increase in the urinary concentration of cadmium, cobalt, lead, and uranium in human subjects including children living in mining areas compared to controls [56]. The increase in the levels of the heavy metals was largely attributed to ingestion of contaminated food products and water with toxic chemical compounds. The increasing negative effects on food safety from water and soil pollution have, therefore, potentially put more people at risk of carcinogenic diseases, particularly in food producing areas.

8. Conclusion

Water is the most vital natural resource on the planet that many life forms depend on for survival. This chapter has shown how population growth, competition for water across sectors, and the exposure to infectious agents or toxic chemicals pose a serious threat to water security, food security, and human existence. There is increased pressure on all sectors to minimize water use by considering more efficient use of water and alternative sources of water. This is only possible if the normative criteria of the human right to safe drinking water which are accessibility, availability, and quality are enforced to ensure that all current and foreseeable water demands highlighted under SDG 6 are met. Little promising progress has been achieved, but much work still has to be done to make water sustainability a reality before the SDG target date of 2030. The present status of water potential in Africa suggests that synergies that adopt sharing of expertise, experiences, knowledge, analytical capabilities, and optimizing mechanisms for greater food safety assurance and awareness by looking at both chemical and microbial hazards in foods should be promoted in the continent.

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