Springer Water

Anja du Plessis

Water as an Inescapable Risk

Current Global Water Availability, Quality and Risks with a Specific Focus on South Africa

Springer

Springer Water

The book series Springer Water comprises a broad portfolio of multi- and interdisciplinary scientific books, aiming at researchers, students, and everyone interested in water-related science. The series includes peer-reviewed monographs, edited volumes, textbooks, and conference proceedings. Its volumes combine all kinds of water-related research areas, such as: the movement, distribution and quality of freshwater; water resources; the quality and pollution of water and its influence on health; the water industry including drinking water, wastewater, and desalination services and technologies; water history; as well as water management and the governmental, political, developmental, and ethical aspects of water.

More information about this series at http://www.springer.com/series/13419

Anja du Plessis

Water as an Inescapable Risk

Current Global Water Availability, Quality and Risks with a Specific Focus on South Africa

Springer

Anja du Plessis
Department of Geography, School of
Ecological and Human Sustainability
University of South Africa
Johannesburg, South Africa

ISSN 2364-6934 ISSN 2364-8198 (electronic)
Springer Water
ISBN 978-3-030-03185-5 ISBN 978-3-030-03186-2 (eBook)
https://doi.org/10.1007/978-3-030-03186-2

Library of Congress Control Number: 2018960470

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Water has been and continues to be recognised as a vital resource for all aspects of human and environmental health and life. The wide reality is, even though it has been described as a fundamental human right and international goals have been developed around achieving improved access and sustainability of it, water is still continuously being degraded and misused by all water use sectors around the world.

The combination of a constant increase in the world's human population, continued desire for economic growth as well as continued water pollution will lead to intensified competition between the different water usage sectors and place more pressure on the world's water resources as these sectors attempt to satisfy demands. Additionally, the increasing threat of climate variability, water scarcity and stress around the world, specifically in South Africa, will also put added pressure on water availability and consequently create increased competition between water sectors as each demand more with the continued increase in population and economic growth. A "Business as Usual" mentality is, therefore, unsustainable and new "business unusual" strategies need to be developed.

Water is recognised as an inescapable risk for all spheres due to unsustainable water use, continued water degradation and the evident threat of climate variability around the world and more specifically in South Africa. The book is consequently divided into two parts, namely "Water as a Global Risk" and "Water as a Regional and National Risk" in the context of Southern and South Africa to exemplify the various risks that water problems currently pose now and in the future to all spheres, i.e. the environment, society and economy.

Focus is placed on current and future water availability and scarcity with the use of case studies to obtain a better understanding of the state of the world's water resources and emphasise the increasing challenges that water scarcity and stress pose around the globe. The influences of climate variability on water availability is also recognised through illustrating current observations, impacts, vulnerabilities and future risks. Case studies are used to highlight that the effects of climate variability are already a reality in various countries around the world and affect the environment, human settlements, health and livelihoods as well as the economy.

This book further emphasises that the degradation of water quality should be recognised as a major threat and risk around the world. Poor water quality directly translates into decreasing the availability of the world's water resources and attributes to water scarcity. Water scarcity caused by increased poor water quality has been exacerbated by increased pollution mainly caused by the disposal of large quantities of insufficiently treated, or untreated, wastewater. Chapter 5 of the book consequently illustrates this by focussing on the primary water quality challenges, main contaminants and the dirtiest places around the world to ultimately highlight the dire situation which some regions currently face.

Part II of the book focusses on evaluating South Africa's water resources as a whole in terms of its fresh surface water resources' quality. A brief background of Southern Africa's water resources (surface and groundwater) is provided followed by the establishment of current water quality risk areas for the nine Water Management Areas of South Africa. The establishment of water quality as well as its overall risk for the whole of South Africa is of prime importance as it attempts to create and contribute to informed knowledge and awareness for current and future water uses. These established results should be used to improve current water management practices and decision-making processes.

South Africa's National Water Resource Strategy of 2014 acknowledged that the resource is not receiving the attention and status it deserves and wastage, pollution and degradation is widespread. The sustainability of South Africa's freshwater resources has reached a critical point. Real opportunities exist where South Africa can emerge as a leader in Africa by transitioning into water smart economies. This can be achieved through investment into new cost-effective technologies as well as enterprise innovations, which all aim to contribute to ensured water security. Decisive steps, however, need to be taken now as the country cannot afford to wait.

The book, therefore, contributes to and emphasises the general international consensus that water quality issues worldwide, specifically in South Africa, will have progressive and significant impacts or constraints on environmental and human health as well as economic development. This book ultimately achieves its main purpose by emphasising the fact that water is and will become an inescapable risk with the use of various case studies on a global scale as well as on a national South African scale with the establishment of water quality risk areas. The book finally calls for coordinated and decisive investment and action into addressing the highlighted water quality challenges.

Multiple opportunities exist in the water sector. Water, however, needs to be placed at the forefront of the global and South African agenda for these opportunities to be recognised, invested in and to ultimately ensure future sustainability to which the world should strive for.

Johannesburg, South Africa Anja du Plessis

Acknowledgements

The author would like to thank the Department of Water and Sanitation's Resource Quality Information Services Department for water quality data for the selected physical, chemical and microbiological water quality parameters over the relevant time period as well as relevant GIS data. The author would also like to thank South African National Botanical Institute for the 2013/2014 land cover dataset.

Contents

Abbreviations

AMD	Acid Mine Drainage
CMA	Catchment Management Agency
DWS	Department of Water and Sanitation
GDP	Gross Domestic Product
GHGs	Greenhouse Gasses
IPCC	Intergovernmental Panel on Climate Change
MDG	Millennium Development Goals
NRW	Non-Revenue Water
PCB	Polychlorinated Biphenyls
POP	Persistent Organic Pollutant
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
UN	United Nations
USA	United States of America
WC/WDM	Water Conservation/Water Demand Management
WDM	Water Demand Management
WMA	Water Management Area
WWTWs	WasteWater Treatment Works

List of Figures

Part I
Water as a Global Risk

Chapter 1
Current and Future Water Availability

Water has been widely recognised as a resource of vital importance due to the pivotal role it plays in human health, development and overall well-being. It is a fundamental human right and international goals have consequently been developed to achieve improved access and sustainability of water resources across the globe. The newly adopted Sustainable Development Goals aims to encourage countries around the world to achieve these set global goals by 2030.

Even though water is one of the most widely distributed substances, it is not always suitable for human consumption. Accessible and useable freshwater sources for human consumption is limited and unevenly distributed. The human populations do not always coincide with water-rich regions. It may be widely distributed and available, however, it is not always available when and where human populations need it. Different water uses affect water availability in regions. Main water use sectors use available for specific activities and may consequently negatively affect water sources through over-withdrawal or pollution through depositing wastes.

The combination of a constant increase in the world's human population as well as continued desire for economic growth will lead to intensified competition between the different water-usage sectors and place more pressure on the world's water resources as these sectors attempt to satisfy demands. A "Business as Usual" mentality is therefore becoming unsustainable and new "business unusual" strategies need to be developed.

1.1 Realisation of Water as an Important Resource

The effective and efficient management of water on a global and national scale has been deemed to be of vital importance due to it being crucial for various aspects of human health, development and well-being as well as a fundamental human right internationally.

A. du Plessis, *Water as an Inescapable Risk*, Springer Water,
https://doi.org/10.1007/978-3-030-03186-2_1

The importance of this resource has once again been recognised in the newly adopted Sustainable Development Goals (SDGs). The SDGs or otherwise known as the Global Goals, were adopted by countries in 2015 as part of the new sustainable development agenda which will target the next 15 years. A total of 17 goals have been developed which focusses mainly on ending poverty, protecting the planet and ultimately ensuring prosperity for all. These 17 goals build on the Millennium Development Goals and include new areas such as climate change, economic inequality, innovation, sustainable consumption as well as peace and justice. These goals have been designed to be interconnected, meaning that a success on one goal will involve addressing issues more commonly associated with another. Clear guidelines and targets have been set for countries to adopt in accord with their own unique priorities and the environmental challenges across the globe (UNDP 2017; WHO 2018).

The world's water has been recognised as a priority and subsequently, a goal has been developed which focusses on ensuring access to water and sanitation for all. The clean water and sanitation goal distinguishes water as an essential part of the world we want to live in and recognises that sufficient freshwater is needed to achieve this. This goal tries to address the degradation of freshwater resources through unsustainable economics and poor infrastructure, to name but a few, which have led to millions of people, mostly children, die from water-related diseases accompanied with inadequate water supply, sanitation and hygiene. The following targets have been set to be achieved by 2030:

- Universal and equitable access to safe and affordable drinking water for all;
- Access to adequate and equitable sanitation and hygiene for all. Put an end to open defecation by paying special attention to the needs of women and girls and those in vulnerable situations;
- Improve water quality through the reduction of pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally;
- Increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity;
- Implement integrated water resources management at all levels, including through transboundary cooperation where appropriate;
- Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes;
- Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies; and
- Lastly, support and strengthen the participation of local communities in improving water and sanitation management (UNDP 2017).

The goal, therefore, emphasises that water scarcity, poor water quality as well as inadequate sanitation have a significant negative impact especially on food security, livelihood choices and educational opportunities for poor families around the world.

Consequently, other proposed goals have also been included related to water and sanitation targets and includes the following interconnected goals for 2030:

- *Goal 3.3*: End the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases as well as combat hepatitis, waterborne diseases and other communicable diseases;
- *Goal 3.9*: Substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination;
- *Goal 11.5*: Significantly reduce the number of deaths and the number of affected people and decrease economic losses relative to Gross Domestic Product (GDP) caused by disasters, including water-related disasters, with the focus on protecting the poor and people in vulnerable situations;
- *Goal 12.4*: Achieve environmentally sound management of chemicals and all wastes throughout their life cycle in accordance with agreed international frameworks and significantly reduce their release to air, water and soil to minimize their adverse impacts on human health and the environment;
- *Goal 15.1*: Ensure conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements; and
- *Goal 15.8*: Introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems, and control or eradicate the priority species (UNDP 2017).

It is estimated that by 2050, at least one in four people is likely to live in a country which is affected by chronic or recurring shortages of freshwater. Water is, therefore, becoming an ever-increasing inescapable risk to all spheres of the world as the resource is continually being degraded and overused, causing widespread environmental degradation, water-related human health issues and increasing economic risk in terms of investment and future growth.

Part 1 of the book will, therefore, focus upon current water availability, distribution and use of freshwater resources, possible influences of climate change, water scarcity and stress as well as water-related problems, a possible source of conflict and as a global risk.

1.2 Current Water Availability

Water is one of the most widely distributed substances to be found in the natural environment and constitutes the earth's oceans, seas, lakes, rivers and underground water sources. However, not all of these widely distributed resources are suitable or available for human consumption.

Even though approximately 75% of the earth's surface is covered with water, only 3% of this is freshwater—the rest is seawater and undrinkable. However, this is just an estimate as the dynamic nature and permanent motion of water makes it difficult to reliably assess the total water stock/store of the earth. Current estimates are that the earth's hydrosphere contains approximately 1,386 million km^3 of water but not all of these resources are potentially available to humans since freshwater is required by the agricultural sector, industries and domestic and recreational users (Kibona et al. 2009; Cassardo and Jones 2011; Lui et al. 2011).

Of the 3% of total available freshwater, only 0.5% is available—the other 2.5% is frozen, locked up in glaciers, ice caps and permanent snow cover in the polar regions. The available 0.5% of freshwater occurs in different forms namely aquifers, rainfall, natural lakes, reservoirs and rivers. Underground aquifers or groundwater accounts for the most freshwater with 10 million km^3 stored in this form. Since the 1950s, there has been a rapid expansion of groundwater exploitation resulting in supplying 50% of drinking water, 40% industrial water and 20% of irrigation water globally. Rainfall falling on land accounts for 119,000 km^3, after accounting for evaporation, and natural lakes a total of 91,000 km^3 of the world's freshwater resources. Furthermore, man-made storage facilities or reservoirs have increased the global storage capacity of the world since 1950s sevenfold and account for over 5,000 km^3. Lastly, it is estimated that 2,120 km^3 is found in rivers which are constantly replaced from rainfall and melting of snow and ice (WBCSD 2006).

Freshwater is also not evenly distributed across the globe. Less than 10 countries hold approximately 60% of the world's total available freshwater supply. These countries include Brazil, Russia, China, Canada, Indonesia, United States of America (USA), India, Colombia and the Democratic Republic of the Congo. It should be noted that local variations within these countries also exist and can be highly significant.

It is important to note that both the human population and water resources are unevenly distributed across the earth's surface resulting in some areas that are densely populated by human populations not necessarily coinciding with regions that are rich in water supplies.

The minimum basic water requirement for human health is 50 L per capita per day and the minimum amount of water required per capita for food is approximately 400,000 L per year, as estimated by the World Business Council for Sustainable Development. Regions such as the USA consume more than eight times that amount for human consumption and four times that amount per year for food production confirming that water resources are unevenly distributed across the world (Kibona et al. 2009; Pimentel et al. 2010; Cassardo and Jones 2011).

The minimum requirements set for basic water requirement for human health indicates that the total amount of water available on Earth is sufficient to provide for the whole population. However, most of the total freshwater is concentrated in specific regions, while other regions such as the Middle East and North Africa face a water deficit (Cassardo and Jones 2011). Therefore, one might say that the world might have enough water but it is not always available when and where the human population needs it. Other factors such as climate, normal seasonal variations,

droughts, floods may all contribute to local extreme conditions which may lead to increased water scarcity and stress. We need to take the different water uses into account as well, as this further directly affects water availability within a region.

1.3 Global Water Use

The main water use sectors around the world can be grouped as agriculture, industrial and domestic water use and includes the following main water uses:

- *Agricultural water use*: irrigation, for livestock, for fisheries and for aquaculture,
- *Industrial water use*: economic entities such as mines, oil refineries, manufacturing plants, as well as energy installations using water for the cooling of power plants; and
- *Domestic water use*: drinking water, bathing, cooking, sanitation and gardening activities.

The competition for water resources between these water sectors are steadily increasing mainly due to the continued growth of the human population and aspirations of economic growth. On a global scale, agriculture accounts for 70% of water usage, followed by industrial use (22%) and domestic use (8%). Importantly, water usage is not uniform across regions and differs quite significantly between high-income and low-middle income countries. High-income countries are characterized by industrial usage being the most dominant water use sector, using 59%, followed by agricultural use (30%) and domestic water use (11%). Low- and middle income countries are dominated by agricultural water use accounting for 82%, followed by industrial use (10%) and domestic use (8%) (WBCSD 2006).

1.3.1 Agricultural Water Use

The agricultural water use sector dominates water use within developing nations where irrigation accounts for over 90% of water withdrawals. In comparison, regions where rain is abundant such as the case of England, agricultural water use only accounts for 1% whereas agricultural water usage exceeds 70% of total usage in Portugal and Greece which are located on the same continent. Agricultural water use, therefore, varies significantly according to the region/ country's characteristics.

The Green Revolution has been characterized by irrigation as the key component, which enabled many developing countries to produce sufficient food for their growing human populations. The sector will demand more water to produce more food for the increasing human population; however, this will increase the competition for water between water use sectors as well as inefficient irrigation practices which could constrain future production.

It is estimated that 15–35% of irrigation withdrawals are unsustainable globally which is a major concern for future food production and more regions are moving towards a high to moderate overdraft of irrigation withdrawals in an attempt to produce more food.

1.3.2 Industrial Water Use

Industrial water use is the second largest user of water globally and varies significantly from one type of industry to another. Water is used for energy in terms of hydro projects, cooling water for thermal power generation, process water, water for products and in some cases for waste disposal to name but a few. In this sector, business is largely dependent on water meaning that no water means no business.

The increase of competition between water sectors have caused some industries to look at alternative processes to reduce water used. Some examples include the following:

- A paper mill in Finland decreased the water used per unit by over 90% over the past 20 years through changing from chemical to thermo-mechanical pulp as well as the installation of biological wastewater treatment facility that enables the recycling of water;
- An Indian textile firm reduced its water use by over 80% by replacing zinc with aluminium in its synthetic fibre production. The firm reduced the trace metals in wastewater and consequently enabled reuse and the use of treated water for irrigation by local farmers; and
- A sugar production plant in Mexico decreased its consumption by over 90% through improving housekeeping and segregation sewage from process wastewater.

The largest single use of water is for the cooling in thermal power generation. In terms of process water, the industry uses water to produce steam for direct drive power and for use in various production processes and chemical reactions. Other industries which use water for products include businesses like beverage and pharmaceutical sectors, consume water by using it as an ingredient in finished products for human consumption (products delivered in liquid form). The term "virtual water" is consequently used to describe the water that is embedded in both agricultural and manufactured products as well as the water used in the growing or manufacturing process (WBCSD 2006).

Water is also used as a disposal site for wastewater or cleaning water into natural freshwater systems. Rivers and other water bodies can handle small quantities of waste broken down by nature, however, these limits are often exceeded and cause water quality to decline downstream causing it to be no longer useable without expensive treatment.

Industrial water usage is directly proportional to the average income level of its people. Industrial water withdrawals constitute 5% in low-income countries as

opposed to the above 40% in some high-income countries. Furthermore, a number of countries in Asia are now also developing their economies around industrial development so that water usage in this sector will increase over subsequent years (Kibona et al. 2009; Lui et al. 2011). Industrial water use will, therefore, increase further across the globe, which may be accompanied with an increase of water-related risks such as increased competition for the resource as well as increased pollution if wastewater is continually disposed of into surrounding water bodies.

1.3.3 Domestic Water Use

Clean water and sanitation is an international human right which needs to be adhered to in all countries. Individuals, therefore, must have clean water for drinking and freshwater for cooking, washing and sanitation. The water use per capita for domestic use varies significantly across the globe. More than one billion people, mostly located in Asia, are still without improved drinking water and approximately 3,900 children die annually due to polluted water and poor hygiene. Approximately, 2.6 billion people are still without improved sanitation and the human population numbers are still increasing. The global coverage is mostly good in most regions across the globe.

The WHO/UNICEF Joint Monitoring Programme reported in 2004 that the world is on track to meet the drinking water target, however, the sub-Saharan Africa region is still lagging behind and the progress towards the sanitation target was too slow to meet the goal.

The access to water issue is directly related to distribution issues. A good example of this is that people living in urban slums are often close to water resources but infrastructure is not in place to supply them with clean drinking water and sanitation.

1.4 Future Water Availability and Conclusions

Water use sectors are facing increased rivalry between themselves in terms of water rights and withdrawals. Industrial water usage increases with the country's income and may consequently create increased difficulties in the allocation of water between the major water use sectors with increased economic growth. This may consequently become a significant business risk for industries as their increased need for water may not be able to be accommodated with the other water use sectors also demanding more.

The continuous growth in the human population is demanding an increase of agricultural outputs, which requires an increase of both water and energy consumption around the world. The primary challenge for this sector is to make 70% more food available in the next 40 years for the world's human population, which will increase the sector's water demand. Other water use sectors are facing the same predicament. It is predicted that global energy consumption will increase by 49%

from 2007 to 2035 which will consequently place more pressure on water resources in an attempt to increase production. In terms of the domestic water use sector, the basic household water requirement is 50 L per person per day which excludes gardens (Gleick 2006; Kibona et al. 2009). This estimate is, however, exceeded in most countries. Overconsumption as well as the goal of improving access to clean water and sanitation will also place further immense pressure on the world's resources as the demand increases. Another water use sector which also needs to be considered is recreational water use which includes the type of water use associated with reservoirs and activities such as boating, angling, water skiing, as well as swimming, to name a few. Even though this water sector has a low-water consumption of only 1% of the world's water resources, the sector is slowly increasing and may have further consequences for other water use sectors such as agriculture by reducing the availability of water for users at specific times. A good example of this is in the event of water being retained in a reservoir to allow for boating in late winter. The storage of water in the specific reservoir may cause this water to be unavailable to farmers during the spring planting season (Kibona et al. 2009; Lui et al. 2011).

Lastly, environmental water usage uses the least water of the main water usage categories and benefits ecosystems rather than human beings. Notwithstanding this, the total water usage is increasing as a result of artificial wetlands and lakes that are intended for creating habitats for various wildlife species. As in the case of recreational water usage, environmental water usage is non-consumptive but may reduce the total volume of water that can be made available to other users at specific times and locations. With an increase in the adoption of ecocentric and biocentric value systems, we can expect more water to be directed in the future to ecosystems and nature reserves than to human needs (Kibona et al. 2009; Lui et al. 2011; UN 2012).

The combination of a constant increase in the world's human population as well as continued desire for economic growth will consequently lead to intensified competition between the different water-usage sectors and place more pressure on the world's water resources as these water use sectors attempt to satisfy demands. Physical evidence already suggests that human activities have already reached or even exceeded the renewable water limits in numerous regions across the globe. A clear indicator of unsustainable water usage is the now common practice of chronic over-extraction of groundwater in numerous important food-producing regions and in large urban areas. Much of China's North Plain, the USA's Great Plains and California's Central Valley, parts of the Middle East and North Africa, the valley of Mexico and parts of Southeast Asia are exceeding their groundwater recharge levels. Another example would be the lower reach of the Yellow River located in China which ran dry every year the past decade during all or part of the dry season when irrigation farming is at its most prolific—pointing to excessive water usage (Kibona et al. 2009).

A "Business as Usual" mentality is, therefore, not an option and new "business unusual" strategies need to be developed. These strategies need to be financially viable, socially acceptable and ecologically sustainable. To decrease or mitigate water-related risks for industries as well as ensure sustainable water usage, trade-offs will have to be made and water management strategies and technologies should

be developed or improved upon on all scales, i.e. global, regional and national/ local. The increasing threat of water scarcity and stress around the world also needs to be taken into account as this will put added pressure on water availability as well as create increased competition between water sectors as each demand more with the continued increase in population and economic growth.

References

Cassardo C, Jones JAA (2011) Managing water in a changing world. Water 3:618–628

Gleick P (2006) The world's water: the biennial report on freshwater resources. Island Press, Washington

Kibona D, Kidulile G, Rwabukambara F (2009) Environment, climate warming and water management. Transit Stud Rev 16:484–500

Lui J, Dorjderem A, Fu J, Lei X, Lui H, Macer D, Qiao Q, Sun A, Tachiyama K, Yu L, Zheng Y (2011) Water ethics and water resource management. Ethics and climate change in Asia and the Pacific (ECCAP) project, working group 14 report. UNESCO, Bangkok

Pimentel D, Whitecraft M, Scott ZR, Zhao L, Satkiewicz P, Scott TJ, Phillips J, Szimak D, Singh G, Gonzalez DO, Moe TL (2010) Will limited land, water, and energy control human population numbers in the future? Hum Ecol 38:599–611

UN (United Nations) (2012) The United Nations world water development report 4, vol 1–3. UN

UNDP (United Nations Development Programme) (2017) Sustainable development goals. Available via http://www.undp.org/content/undp/en/home/sustainable-development-goals/background.html. Accessed 25 Feb 2018

WBCSD (World Business Council for Sustainable Development) (2006) Facts and trends: water. WBCSD, Earthprint Limited

WHO (World Health Organisation) (2018) Millennium development goals (MDGs). Available via http://www.who.int/topics/millennium_development_goals/about/en/ Accessed 25 Feb 2018