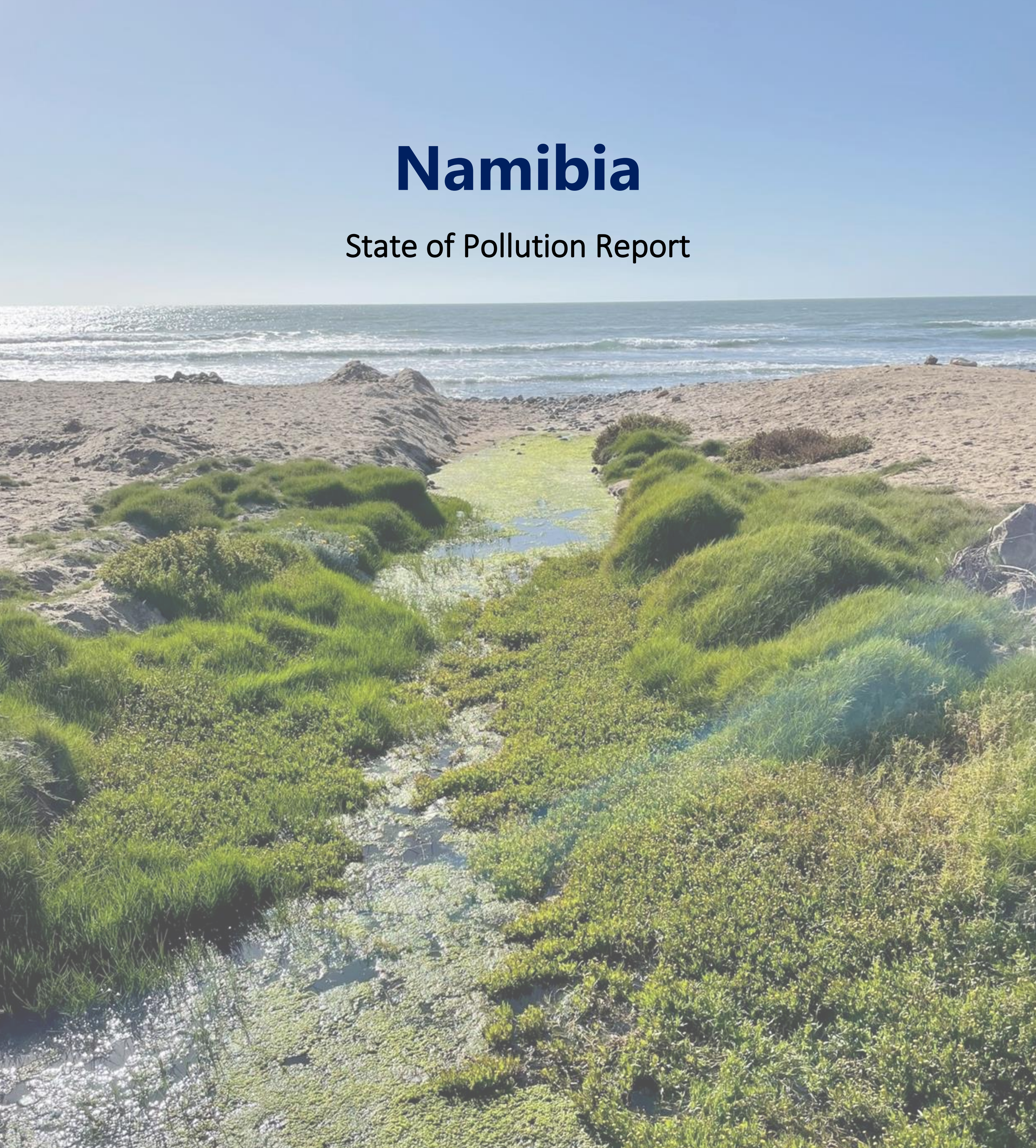
Namibia

State of Pollution Report



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4. Report Prepared by:

Mirja Stoldt (Namibia Nature Foundation)

5. Review:

Angus Middleton (NNF) & Silke van der Merwe (Mosaic Consulting)

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Title: Namibia State of Pollution

Author: Mirja Stoldt (Namibia Nature Foundation)

Reviewed by: Angus Middleton (NNF) & Silke van der Merwe (Mosaic Consulting)

Producers: Namibia Nature Foundation (NNF, Namibia)

Contact: info@nnf.org.na

Supporting partners: Department for Environment, Food and Rural Affairs (Defra, UK) and Joint Nature Conservation Committee (JNCC).

Contact: Reducing.Pollution@jncc.gov.uk

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List of Abbreviations

Abbreviation/acronym	Description
ALRI	Acute Lower Respiratory Infections
APZ	Aquifer Protection Zone
CCAC	Climate and Clean Air Coalition
CDC	Centres for Disease Control
CFCs	Chlorofluorocarbons
CO	Carbon monoxide
CO_2	Carbon dioxide
COPD	Chronic Obstructive Pulmonary Disease
CORB	Cubango and Okavango River Basin
CoW	City of Windhoek
DALYs	Disability-adjusted life years
DDT	Dichlorodiphenyltrichloroethane
DEFRA	Department of Environment, Food & Rural Affairs
EC	European Commission
E. coli	Escherichia coli
EDS	Early Dry Season
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EU	European Union
FAO	Forest & Agriculture Organisation
FSC	Forest Stewardship Council
GHG	Greenhouse Gases
GDP	Gross Domestic Product
HCFCs	Hydrochlorofluorocarbon
HCH	Hexachlorocyclohexane
HIV / AIDS	Human Immunodeficiency Virus / Acquired Immunodeficiency Syndrome
IHME	Institute for Health Metrics Evaluation
IRLUP	Integrated Regional Land Use Plans
JNCC	Joint Nature Conservation Committee
K	Potassium
LDS	Late Dry Season

Abbreviation/acronym	Description
Li	Lithium
LLRW	Low-Level Radioactive Waste
LRAT	Long Range Atmospheric Transport
MCL	Maximum Contaminant Level
MEFT	Ministry of Environment, Forestry and Tourism
Na	Sodium
NGOWP	National Geographic Okavango Wilderness Project
NNF	Namibia Nature Foundation
NO_2	Nitrogen dioxide
NO_3	Nitrate
NPC	National Planning Commission
NSA	National Statistics Agency
O_3	Ozone
PCB	Polychlorinated biphenyl
PM	Particulate Matter
POP	Persistent Organic Pollutants
ppb	Parts per billion
SADC	Southern African Development Community
SEA	Strategic Environmental Assessment
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
U-POPs	Unintentional Persistent Organic Pollutants
US OSHA	US Occupational Safety and Health
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation

1. Background

1.1 Pollution: A Global Challenge

> *"Pollution is the introduction of harmful materials into the environment. These harmful materials are called pollutants. Pollutants can be natural, such as volcanic ash. They can also be created by human activity, such as trash or runoff produced by factories. Pollutants damage the quality of air, water, and land."*
>
> - *National Geographic Society Encyclopaedia*

Human expansion and activity have shaped the environment we live in today. The quest for natural resources for development in almost every part of the world has had negative impacts on habitats, natural resources, and ecosystems. Air pollution has changed the composition of the atmosphere which has manifested in human health impacts and climate change challenges. Soil pollution has impacted on the productive capacity of land and water pollution has had negative consequences for freshwater and marine ecosystems (Margoluis et al. no date.). All of these impacts degrade the natural systems upon which we rely and undermine human development and wellbeing.

Biodiversity is vital for a functioning and stable ecosystem. It is closely connected to ecosystem services such as primary production, nutrient cycling, soil formation, water provision, food or feed production, and thus sustainable development (Backhaus et al. 2012). Biodiversity provides raw materials for pharmaceutical production, nutrition and regulates the climate (Margoluis et al. no date.). There is therefore a general consensus that human health is inextricably linked to the health of the environment (Margoluis et al. no date.).

In recent years, the COVID-19 pandemic has driven the public health debate and strengthened the links between human wellbeing and environmental issues, including pollution. Economic shutdowns improved air quality in many places of the world (Health Effects Institute 2020), while at the same time pictures of face masks circulated in water bodies, the environment and on wildlife.

In our interconnected world, pollution can be found everywhere and can spread to the most remote places. Traces of agro- (mainly pesticides) and other chemicals have been found in the Antarctic ice sheet and the Great Pacific Garbage Patch collects plastic from all over. Pollution can be carried by air and water currents. For example, wind can carry radioactive materials accidently emitted from a nuclear reactor around the world. Ocean currents and migrating fish carry marine pollutants and smoke from industrial processes can travel to neighbouring countries (National Geographic no date.).

1.2 The Link Between Environment and Human Health

The Blacksmith Institute estimated that the health of about 125 million people is threatened by pollution at a global level. While pollution threats are closely monitored in developed countries, the negative impacts of hazardous pollutants on health are often not considered in developing countries (Blacksmith Institute 2012). Pollution driven by urbanisation, industrialisation, inadequate waste management, agriculture, and natural causes such as fires, and dust create environmental health risks. Air pollution, exposure to heavy metals or hazardous waste can lead to illnesses, poor living conditions, and destroy ecosystems, which can exacerbate poverty and stunt economic growth. Similar to climate change, the poorest countries and communities in the world cannot afford to protect themselves and are disproportionally affected by pollution (World Bank no date.).

Pollution of our land, air and water resources has caused more than 9 million premature deaths and has become the largest environmental cause accounting for 16% of deaths worldwide. The economic costs of global air pollution alone create an estimated USD 5.7 trillion in economic damages, which is equivalent to 4.8% of global GDP (World Bank no date.). The World Health Organisation estimates that 80% of people living in urban areas are exposed to emission levels above WHO standards, which is likely to increase with urbanisation and estimates that 50% of the global population will be living in urban areas by 2030 (Aseel et al. 2019).

In 2016, the worst global pollution problems based on Disability-Adjusted Life Years (DALYs) -in order of severity- included lead acid battery recycling, mining and ore processing, lead smelters, tanneries, artisanal small-scale gold mining, industrial dumpsites, industrial estates, chemical manufacturing, product manufacturing and the dye industry. Collectively, these industries endangered over 32 million people accounting for 7 to 17 million Disability-Adjusted Life Years (DALYs) in low- and middle-income countries (Pure Earth & Green Cross 2016).

1.3 Understanding Pollution in Low- to-Middle Income Countries

Although pollution is well researched, synthesised and presented for public consumption and policy development in many parts of the world. In Namibia and in African Sates in general, there is however limited information and data on pollution and, as a result, little public discourse, and policy development in these countries. Understanding linkages between human health, biodiversity and the environment are vital to protect natural resources and ecosystems and improve or maintain human wellbeing and quality of life (Margoluis et al. no date.).

Namibia faces significant environmental threats such as land degradation, biodiversity loss, declining marine resources, pollution of scarce water resources and climate change. Due to Namibia's vast landscapes and low population density, issues of pollution have long been overlooked. However, increasing economic activity and fast urban growth pose major threats to the environment and are increasingly bringing the impacts of pollution into focus.

Uncontrolled pollution can negatively impact public health, ecosystems, biodiversity, and can accelerate climate change. To enhance the ability of Official Development Assistance (ODA) Countries to manage chemicals and to reduce air, chemical, and waste pollution, the UK's Joint Nature Conservation Committee ("JNCC") funded by the UK Department of Environment, Food and Rural Affairs (DEFRA) has launched a global programme to reduce air, chemical, and waste pollution, with the aim of reversing biodiversity loss, build ecological resilience and improve human health.

The "Reducing Pollution Through Partnership" project uniquely addresses the problem of pollution within the context of the twin challenges of biodiversity loss and climate change and their socio-economic impacts – especially on health and safety. The project aims to scope and support the design of a wider pollution programme to enhance the ability of low- to middle- income countries to manage chemicals and to reduce air, chemical, and waste pollution.

This report will provide a higher-level overview of the state of pollution in Namibia to provide a basis for further initiatives and projects in the future.

2. Methodology

The main objective of the State of Pollution report was to create a higher-level overview of pollution in Namibia including the main pollutants, polluters, drivers of pollution and impacts.

The report is based on the analysis of existing literature and data including Environmental Impact Assessment (EIA) and Environmental Management Plans (EMP) required under Namibia's Environmental Management Act of 2007. EIAs assess the ecological and socio-economic impacts of various different activities. This includes potential pollution threats.

The results section presents the impacts of pollution on air, water, land, and biota in line with the Global Environmental Outlook methodology of the Nations Environment Programme (UNEP). Indicators include:

- **Air:** Includes emissions as well as potential pollution and dust.
- **Water:** Assesses impacts on different components of the hydrological cycle and the water holding capacity of the soil and landscape.
- **Land:** Looks at the primary productivity of the land, nutrient cycling, impacts on soil properties and conditions, erosion, surface temperature of the soil as well as the aesthetic appeal of the landscape.
- **Biota:** Considers impacts on the habitat, biological diversity and species composition of flora and fauna, alien invasive species as well as food and feed availability.

To get a better overview of pollution research in Namibia, the state of research was mapped. Publish or Perish (Copyright © 2021 Anne-Wil Harzing), a software which retrieves and analyses academic citations, was used to search for all academic research on "pollution AND Namibia" available on Google Scholar. This allowed for the analysis of a large sample from a wide range of journals from different disciplines. The Publish and Perish search found n=998 papers with both "pollution" and "Namibia" between 1971 and 2022. The search results were exported to Excel and verified: Of the 998 articles, 16 were excluded because they were a duplication of individual papers. 296 were excluded, because they did not present pollution data or information for Namibia. In many cases, one of the references was from Namibia, but the main text was not. 408 were excluded because they did not specifically address pollution. For the final sample of 278 articles additional columns on the pollutants, pollution sources and impact areas assessed in the study as well as the study area, latitude, and longitude for further mapping of the results were added. The results were mainly analysed for frequency using MS Excel. QGIS 3.14 was used to show the distribution of the studies throughout Namibia.

The literature review was complemented by exploratory stakeholder interviews, a stakeholder workshop, and a survey, to get a more comprehensive understanding of pollution in Namibia based on the experiences of different stakeholders and sectors. It also helped to verify and frame the findings from the literature review.

2.1 Stakeholder Interviews

The stakeholder interviews were conducted at the beginning of the project to get a better understanding of the pollution challenge and what is currently being done by different stakeholders. The interviews were semi-structured covering the following areas: (1) To what extent interview partners deal with pollution issues, (2) the main pollution challenges Namibia is facing today, (3) what is currently being done against pollution, and (4) organisations and stakeholders involved in pollution issues. The semi-structured nature allowed for comparison of responses and was flexible enough to adapt to the conversation and expertise of interview partners. Most interviews lasted for 60 to 90 minutes.

In total, 11 interviews were conducted. Interview partners were chosen based on their experience in the field of pollution (judgemental / purposive sampling). Six of the 11 interview partners were female, five were male. Of the 11 interviews, 4 were with civil society organisations, 2 with private sector, 4 with national and local government officials and 1 with a donor / development organisation working on waste management.

2.2 Stakeholder Workshop

The purpose of the pollution workshop was to engage local expertise to verify JNCC's global analysis results and gather information on the main pollutants, pollution sources, impacts and ongoing initiatives in Namibia.

The workshop was hosted online to allow for the participation of stakeholders outside Namibia and JNCC, and mainly consisted of two parts: (1) the presentation of the JNCC results and subsequent discussion, and (2) an interactive and exploratory breakout session on the main pollutants, sources, impacts and ongoing initiatives.

The workshop was attended by 20 external experts and 7 NNF and JNCC representatives from various organisations and sectors.

2.3 Survey

The main findings and information from the stakeholder interviews and local sense check workshop were used to design a survey to collect some concrete quantitative information on perceptions around pollution.

The survey consists of four main sections:

1) Demographic Information
2) Extent and Types of Pollution in Namibia
3) Impact and Drivers of Pollution
4) Pollution Governance & Interventions

The survey was sent to all workshop participants engaged in the stakeholder workshops and interviews and all members of the Namibia Chamber of Environment. The survey was completed by 21 people (10 male and 10 female, 1 no response). 35% of respondents were between 25 and 34 years old, 20% between 18 and 24, 20% between 45 and 54 and 15% between 35 and 44. The remainder (n=2) were above 55. Survey respondents had a broad range of different backgrounds and represented different sectors (Fig. 1). Most respondents were from Windhoek (14) and more than 50% were from the public sector, followed by private sector (over 30%) and civil society (>15%).

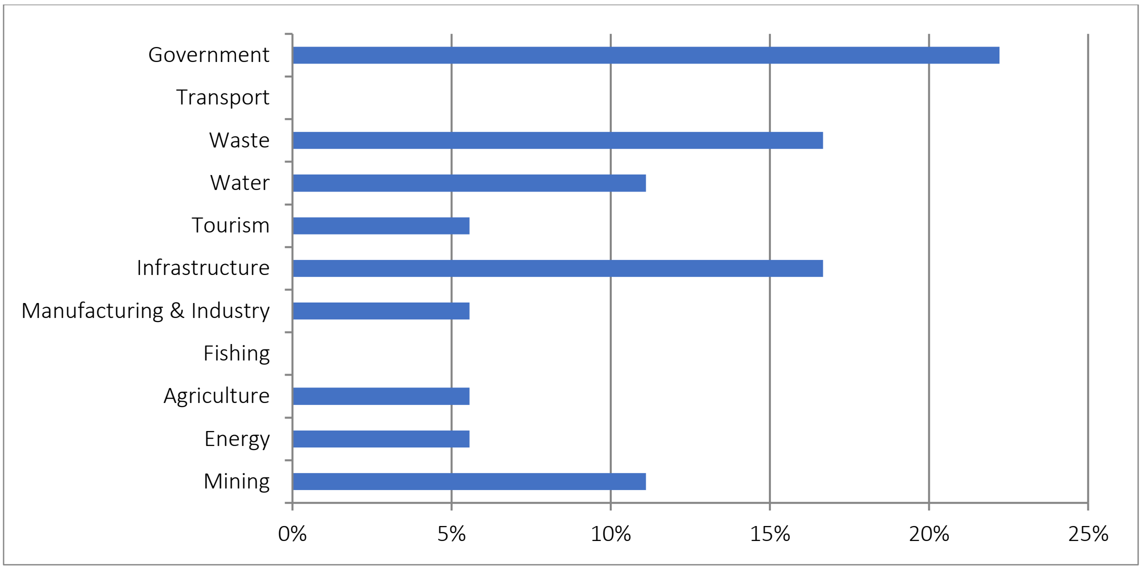


Figure 1. Background of survey respondents.

One of the major challenges is the limited data and information on pollution in Namibia. Current efforts are limited and scattered. This report provides a first comprehensive overview of pollution in Namibia and will have to be complemented by more targeted studies in the future to improve the geographic coverage and quantitative information. Quantitative data on pollution in Namibia is limited. Local organisations often do not have the laboratory facilities and human capacity to sample and analyse soils and water. Some parameters can only be tested in South Africa, which can be expensive. Many government institutions do not have databases or data collection methodologies and/or were unwilling to information. Namibia also has not submitted their most recent inventories under the Stockholm Convention and UNFCCC.

3. Pollution in Namibia

3.1 Namibia at a Glance

Namibia Fast Facts

- Area: 824,292 km^2
- Location: SW Africa. Borders Angola and Zambia in the north, South Africa in the south and Botswana in the east.
- Population: > 2.3 million
- Capital City: Windhoek
- Official Name: Republic of Namibia
- Date of Independence: 21 March 1990
- System of Government: Multi-party Democracy
- Head of State: President Dr Hage Geingob since 2015.

Namibia is a large country with a small population of around 2.5 million people bordering Angola, Zambia, Botswana, and South Africa. Namibia is the driest country in Sub-Saharan Africa (World Bank 2022). Political stability and good economic management have allowed Namibia to reduce poverty and become a middle-income country. However, Namibia remains one of the most unequal countries in the world with a GINI index of 63.3 in 2003, 61.0 in 2009, and 59.1 in 2015 (World Bank 2022). In 2016, 47.9% of the Namibian population lived in urban areas with 52.1% living in rural areas (NSA 2017). The average population density (2.4 inhabitants per km^2) is among the lowest in the world, but unequally distributed (European Commission 2007).

The maintenance of ecosystems and biological biodiversity is enshrined in the Namibian Constitution. Around 42% of the country is under some form of conservation -mainly national parks, as well as communal and private conservancies. Before the COVID-19 pandemic, tourism was among the fastest growing industries in Namibia with high employment potential and considerable contribution to GDP (Schneider 2012). Other major economic sectors in Namibia are meat production, fisheries, beverages, agricultural and horticultural products, and mining. Namibia has rich deposits of diamonds, gold, silver, uranium, copper, lead, tin, lithium, and thorium -amongst others (CIA 2021).

Major environmental concerns in Namibia include:

1) **High Vulnerability to Climate Change:** Namibia belongs to the most severely affected countries in the world in terms of climate change (EC 2007). Over the past 40 years, maximum temperatures, and the frequency of number of days exceeding 35^{o}C have increased (MET, 2013). Namibia has experienced three major drought events in 2013, 2015 and 2019 (Kahiurika et al. 2019). The year 2019 was the driest in 90 years. Namibia's temperature is projected to increase between 1^{o}C to 4^{o}C in winter and between 1^{o}C and 3.5^{o}C in summer in the period 2046 to 2065, with a substantial increase in hot days throughout the year. According to New (2018), it is projected that with 1.5^{o}C of global warming, Namibia could experience 50 more days of heatwave exposure. Many key sectors such as human health, water resources, agriculture (crop and livestock production), food security, biodiversity, ecotourism, coastal zone management, and human settlements as well as trade and industry have been identified as vulnerable to climate change (MET, 2013; MET, 2019).

2) **Water Scarcity:** Increased aridity is putting further pressure on water availability in Namibia, an already limited, unreliable and scarce resource. Groundwater is the country's main source of water supply and over 100,000 boreholes are drilled country-wide to provide access to drinking water for people, livestock and game, crop production and to supply mines (Christelis & Struckmeier, 2011). About 60% of Namibia's population depends on groundwater, which is considerably threatened by pollution -especially from agrochemicals (Mapani & Ellemies 2011). There is limited surface water, as most rivers are ephemeral (except for the Zambezi, Kunene, and Kavango Rivers), and evaporation rates are high (Mapani 2005).

3) **Land Degradation:** Some key issues are bush encroachment, vegetation degradation and desertification, soil erosion and decreasing soil fertility. This is driven by inappropriate land management practices (including overgrazing, the expansion of crop cultivation, soil mining, and uncontrolled biomass harvesting -amongst others) and climate change (EC 2007; Darkoh 2009).

4) **Biodiversity Loss:** Namibia has considerable biodiversity, a high level of endemism (EC 2007) and is considered environmentally fragile (CIA 2021) due to human induced and natural pressures. Major pressures on biodiversity include climate change, pollution, poaching and illegal wildlife trade, and alien and invasive species (Darkoh 2009). Soil, air, and water pollution can considerably impact the diversity, composition and structure of plant and animal communities (Mapaure et al. 2011).

5) **Pollution:** Promotion of industrial development increases risks of industrial pollution (EC 2007). Modern lifestyles have also led to more solid waste, most of which is dumped on land (Darkoh 2009).

3.2 Health in Namibia

In a 2019 World Bank report, Namibia's health progress scored low compared to other countries, especially among low-income communities. Life expectancy is considerably lower than in countries with a similar health sector spending and maternal mortality remains high (World Bank 2019). Based on the Institute of Health Metrics and Evaluation (IHME) major causes of premature death (Fig. 2) include HIV/AIDS, stroke, respiratory infections, heart diseases, neonatal disorders, tuberculosis, diabetes, diarrheal diseases, road injuries and chronic obstructive pulmonary disease (COPD) (IHME 2019, World Bank 2019).

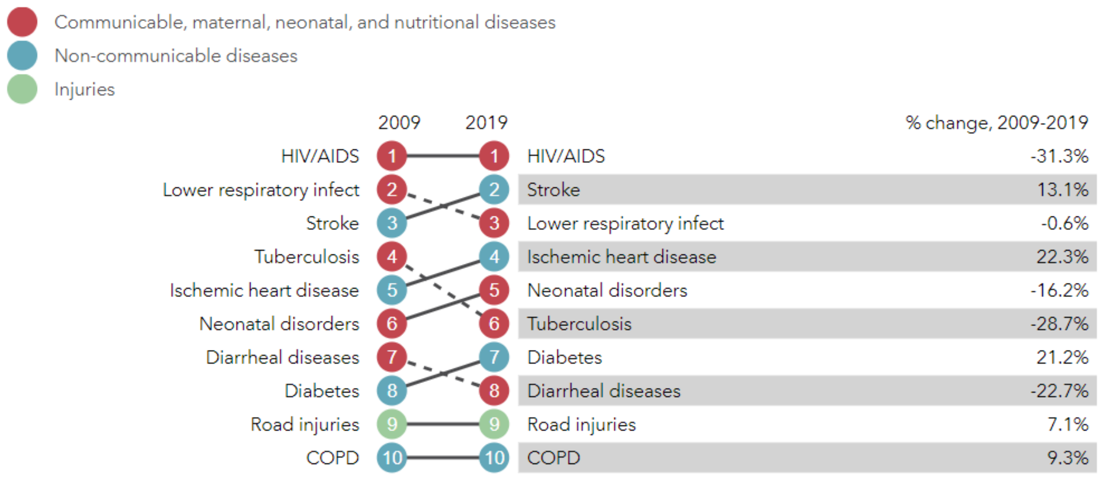


Figure 2. Causes of premature deaths in Namibia (IHME 2019).

These major causes of premature death and disability are driven by risk factors including unsafe sex, malnutrition, air pollution, high blood pressure, WASH, and dietary risks – amongst others outlined in Figure 3. The risk tends to be higher for the poor (World Bank 2019, IHME 2019).

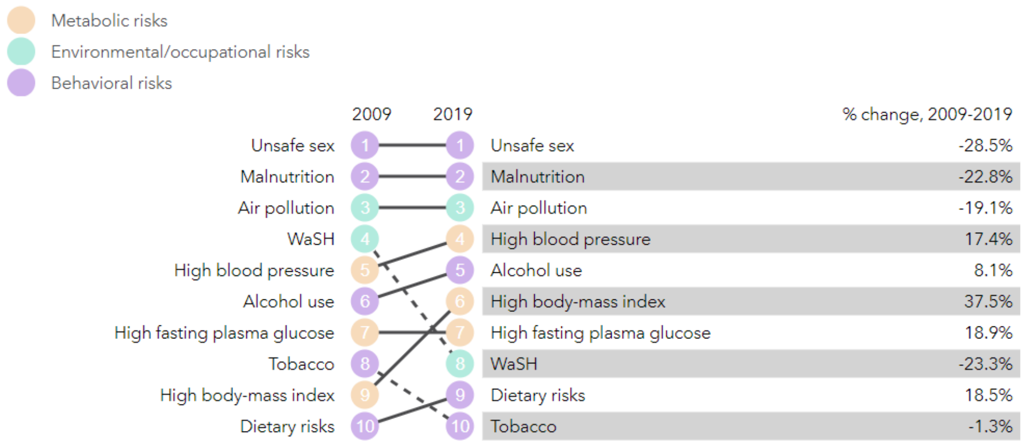
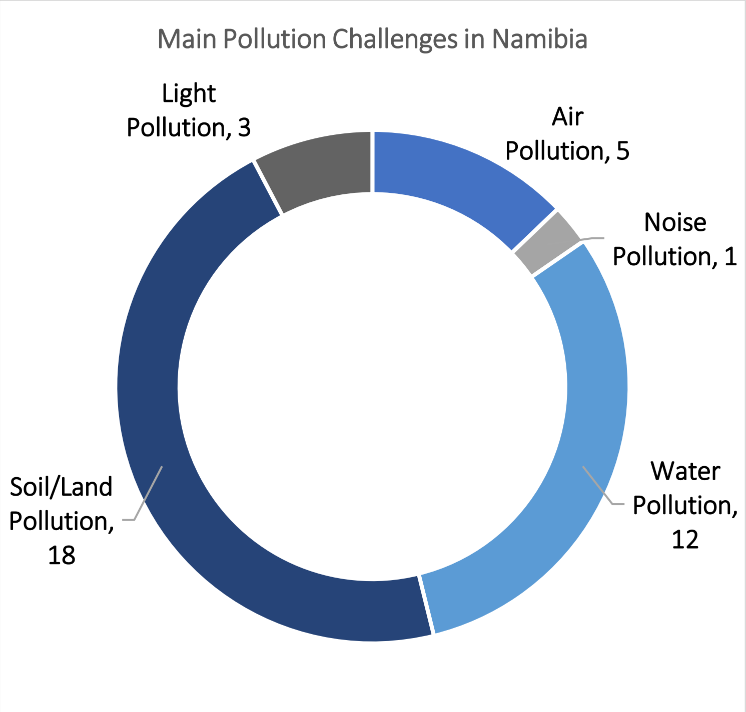


Figure 3. Risk factors driving disability and deaths in Namibia (IHME 2019).

Air pollution and WASH related illnesses are among the top risk factors for disability and deaths in Namibia (IHME 2019). Namibia faces a double burden: Firstly, there is an epidemiological transition from communicable to non-communicable diseases (e.g. cardiovascular diseases, cancer, respiratory diseases, and diabetes). In addition, climate change and droughts contribute to respiratory and gastrointestinal diseases, which spread easily when water is scarce (World Bank 2019). Climate change, increasing variability and changing rainfall patterns have also contributed to the spread and persistence of Malaria in many parts of Southern Africa. This can weaken the adaptive capacity of people (Darkoh 2009).

3.3 Pollution in Namibia



Over 95% of survey respondents considered pollution to be a problem in Namibia and the majority stated that the impact of pollution on biodiversity has significantly increased (42.9%) or slightly increased (28.6%) over the past 10 years. Most survey respondents considered land or soil pollution to be the biggest challenge (Fig. 4) closely followed by water pollution. Other pollution issues such as air, noise or light pollution were less significant. The top 3 pollution problems include (1) plastic (n=13), (2) wastewater (n=6) and (3) industrial emissions, sewage, and open defaecation (all n=5).

Figure 4. The main pollution types in Namibia according to survey respondents.

Major drivers of pollution according to survey respondents were urbanisation (n=14), population growth (n=12), limited monitoring and enforcement (n=10) and lack of a dedicated regulatory framework (n=8). Most respondents were extremely concerned about the resilience of communities against climate change (Fig. 5) and concerned about groundwater and drinking water supplies, aquatic ecosystems, biodiversity, degradation of the environment, health impacts and land productivity. Air quality seemed to be of less concern.

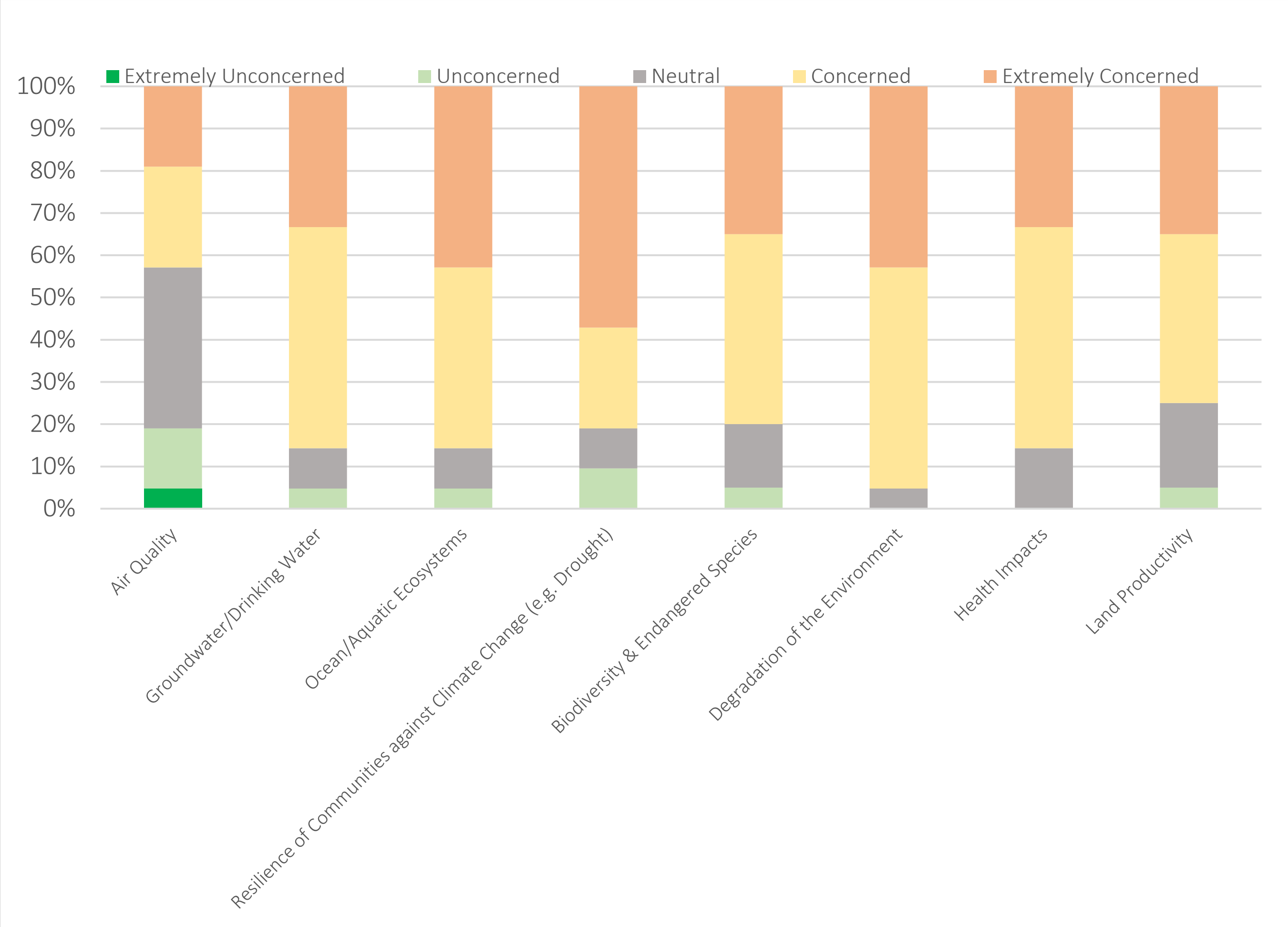


Figure 5. Concern of survey respondents of the impact of pollution on different environmental parameters.

Some of the main sectors that are considered as contributing to pollution in Namibia included agriculture; mining and oil extraction; industry; fisheries; transport; solid waste management; water treatment; tourism; sanitation; and manufacturing especially the production of plastics and glass for Namibia's breweries.

Most respondents indicated that little effort (n=9) is put into mitigating pollution, while others were neutral (n=5) or suggested that there is some effort (n=5). More than 60% were aware of current policies and regulations around pollution.

Some of the key priority areas that were identified for future pollution-related work included:

- Green energy
- Capacity building on the impacts of pollution on the environment
- Capacity building on reducing, reusing, and recycling waste (circular economy)
- Improved waste infrastructure
- Improved sewage and wastewater treatment
- Pesticides and herbicides
- Developing an air quality strategy and a clean air technology centre
- Improved legislation and enforcement of regulations

Key stakeholders that should be involved in pollution control efforts include citizen champions and youth, government, private sector Ministry of Health and Social Services, Ministry of Environment, Forestry and Tourism, Ministry of Education, civil society, development organisations, regional and local authorities.

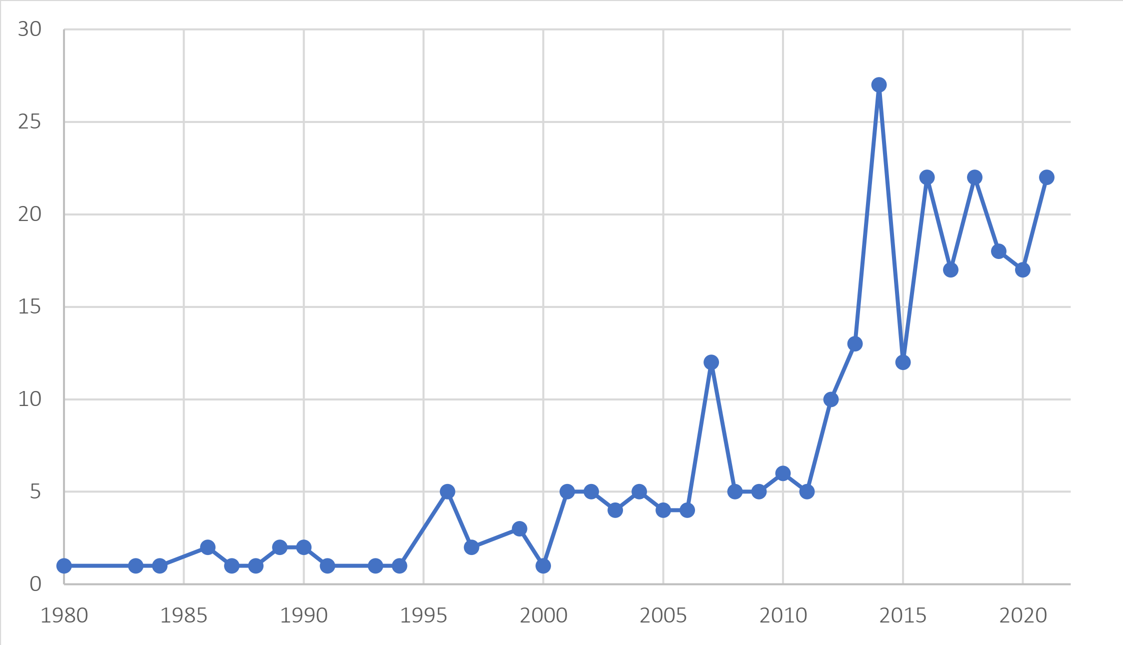


Figure 6. The trend in pollution research between 1980 and 2021.

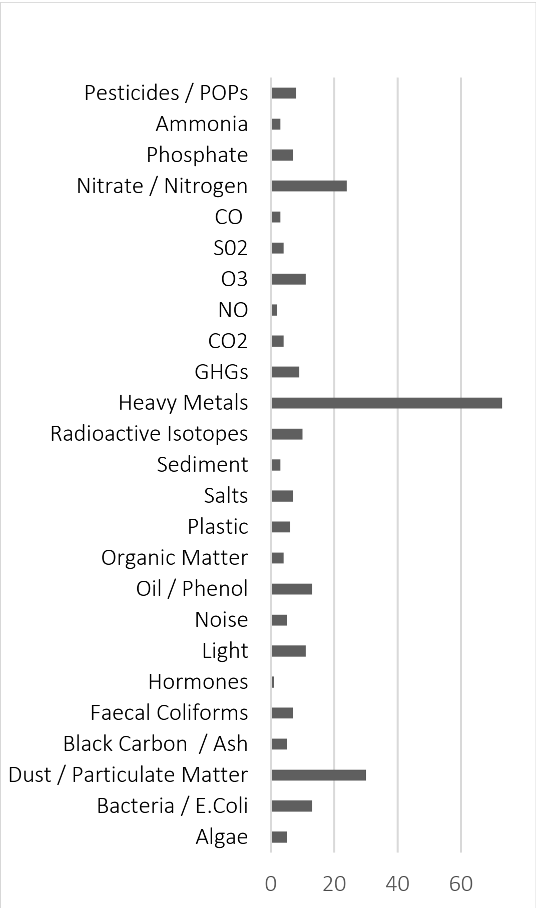


Figure 7. The main pollutants researched in Namibia between 1980 and 2021.

Pollution research in Namibia has increased over time peaking in 2014 with 27 studies. By far the majority of research in Namibia is on heavy metals mainly lead (42 studies), copper (41 studies) and arsenic (33 studies) – especially around the Tsumeb copper smelter. This is followed by nitrate or nitrogen pollution as well as dust and particulate matter. The main pollutants are closely aligned to the main pollution sources of sectors studied, which includes mining, agriculture, and waste / landfills. Most research looked at the impacts on health, air, biodiversity, and surface water. Although research studies are relatively well distributed throughout the country, there appear to be hotspots in the main mining areas along the central cost.

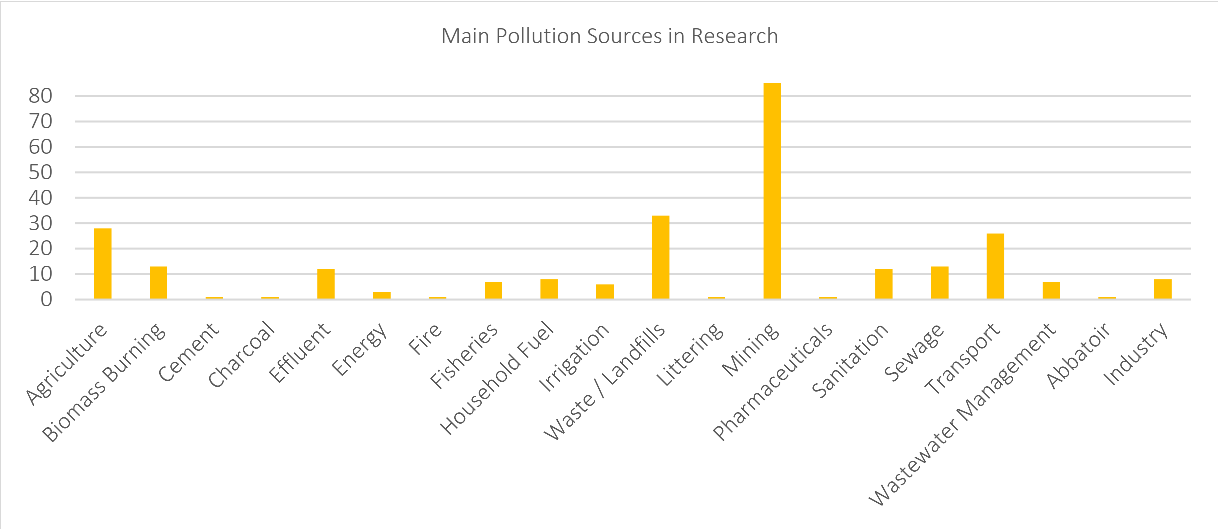


Figure 8. The main sources of pollution researched.

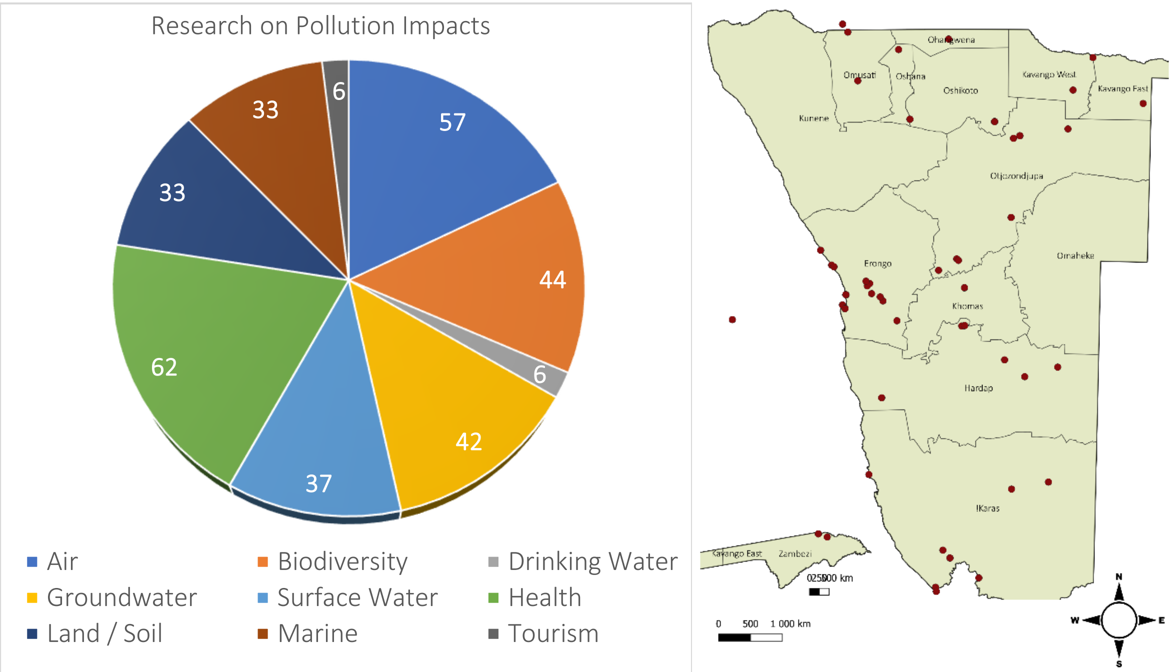


Figure 9. Main pollution impacts (left) and the distribution of research (right).

3.4 Governance Framework

Legislation and regulations on pollution in Namibia can be disaggregated based on the local, national, regional, and international level.

Most pollution related governance in Namibia falls under several **international conventions**. Namibia has signed onto:

- The **Basel Convention**, the **Rotterdam Convention** and the **Bamako Convention** on the Ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa all focusing on hazardous waste.

- The **Stockholm Convention on Persistent Organic Pollutants** (2001), which classifies POPs into Annex A, B, C and D pollutants with different regulations and requirements on the production, use, import and export of the chemicals, as well as the environmentally sound disposal and appropriate measures to handle, collect, transport, and store these pollutants in an environmentally sound manner.
- The **Minamata Convention on Mercury** (2013) to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.
- The **Kyoto Protocol** and the **Paris Agreement** of the United Nations Framework Convention on Climate Change (UNFCCC), which aim to limit or reduce the emissions of greenhouse gases.
- The **Vienna Convention for the Protection of the Ozone Layer** (1985) and the **Montreal Protocol on Substances that Deplete the Ozone Layer (**1987) which control the production and consumption of specific chemicals including CFCs, halons, fully halogenated CFCs (HCFCs), methyl bromide, and similar chemicals.
- As well as multiple international agreements on oil pollution damage and prevention of pollution from ships, such as the **International Convention on Civil Liability for Oil Pollution Damage** (1969), the **International Convention for the Prevention of Pollution from Ships** (1973), modified by the MARPOL Protocol, **the International Convention on Oil Pollution Preparedness, Response and Co-operation** (OPRC) and the **International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties** (1969).

In addition, Namibia has signed onto two main **regional** documents by the Southern African Development Community (SADC) including:

- The **SADC Protocol on Shared Watercourse Systems**, which makes provision of the prevention, reduction, and control of pollution.
- Article 23 of the **SADC Protocol on Health**, which requires parties to *"collaborate, co-operate and assist each other in a cross-sectoral approach in addressing regional environmental health issues and other concerns, including toxic waste, waste management, port health services, pollution of air, land and water, and the degradation of natural resources".*

At a **national** level, pollution related issues are mainly governed by:

- The **Environmental Management Act 7** of 2007 presenting principles of environmental management assessments, which must be undertaken for activities with potential significant effects on the environment and natural resources.
- The **Atmospheric Pollution Prevention Ordinance** (Act 9 of 2009) providing guidelines on smoke control and fuel burning, dust control and the prevention of dust pollution of the atmosphere.
- The **Public and Environmental Health Act** of 2015 to prevent the occurrence of health nuisances; unhygienic conditions; offensive conditions; or other conditions harmful or dangerous to human health. The Act provides guidelines on integrated waste management, the prevention of water to not endanger human health, drainage of land or premises, the disposal of offensive liquids and the removal and disposal of rubbish, refuse, manure, and waste matters; and provides standards of purity for an effluent liquid containing waste, sewage or other offensive matters that may be used for domestic, agricultural, industrial, or other purposes and endanger public health.
- The **Soil Conservation Act** 1969, which makes provision for the prevention and control of soil erosion and the protection, improvement and conservation of soil, vegetation, and water supply sources.

- The **Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act** 1947 regulating chemical products used in Namibia.
- The **Hazardous Substances Ordinance 14** of 1974, which controls substances that may cause injury or ill-health to or death of human beings due to their toxic, corrosive, irritant, strongly sensitising or flammable nature.
- The **Atomic Energy and Radiation Protection Act** which ensures adequate protection of the environment and of people against the harmful effects of radiation.
- The **Minerals Prospecting and Mining Act 33** of 1992 regulating the mining industry and ensuring "the safety, welfare and health of persons employed in such claim area, and to prevent or minimise any pollution of the environment".
- The **Water Resources Management Act 11** of 2013 to "ensure that water resources in Namibia are managed, developed, used, conserved and protected", which provides detailed guidelines on water pollution control.
- The **Prevention and Combatting of Pollution at Sea by Oil Act 6** of 1981.
- The **National Solid Waste Management Strategy** which aims to reduce risks to the environment and public health from current waste disposal sites and illegal dumping by strengthening the institutional, organisational, and legal framework for solid waste management.

In some cases, pollution control is part of **local** strategic documents and plans. For example:

- The **Zambezi Integrated Regional Land-Use Plans** (IRLUP) focuses on the protection of water resources and the prevention of water pollution and wastage.
- The Strategic Environmental Assessment (SEA) of the **Karas IRLUP** deals with pollution threats from mining (e.g. soil contamination and heavy metal pollution of groundwater) and oil pollution from marine industrial operations.
- The **Kavango East IRLUP** considers the placement of sewage ponds and landfill sites to avoid pollution of underground water resources and the Okavango River in their urban services. It outlines the potential negative impacts of pollution from sewage works and sand mining on riverbanks.
- The **Kavango West IRLUP** notes that increasing pollution threatens the quality of diminishing water supplies from mining, irrigation schemes, sand mining, sewage ponds and landfill sites.
- The **Hardap IRLUP** and SEA considerably focus on the pollution of water resources by irrigation schemes threatening the Fish River with eutrophication. In addition, cattle, and human faeces (due to poor sanitation services) threaten aquifers, and solid waste management systems are required for the Sossusvlei area, one of Namibia's main tourism attractions.
- Towns and municipalities are generally responsible for the management of solid waste. The City of Windhoek has a Solid Waste Management Policy based on the Waste Management Section in the Local Authorities Act of 1992.

4. State of Pollution in Namibia

The State of Pollution outlined in the section below summarises the results of a detailed literature review, as well as stakeholder interviews, a survey, and a stakeholder / local sense check workshop. The main pollutants, polluters and drivers of pollution are grouped under the main components of the environment they impact.

4.1 Land

In the integrated and complex world in which we live, land pollution can have a considerable impact on the environment, humans, and biodiversity. Land pollution can lead to the contamination of water bodies and groundwater, as well as nutrient enrichment, loss of topsoil, shift habitats and threaten biodiversity, increase the risk of wildfires by exacerbating dry conditions, and impact human health (Krainlew 2018, FAO & UNEP 2021).

Especially the contamination of soil can have far reaching consequences. People in rural areas often heavily depend on natural resources for their livelihoods and live in extreme poverty (FAO & UNEP 2021). In Namibia, around 70% of the population depend on natural resources for their survival and main livelihood strategy. Soil pollution can have a considerable negative impact on the yields and quality of crops and the food produced reducing the income of farmers. Decreases in the productivity of agricultural land, as well as food quality and quantity can further reduce the income of communities facing severe poverty. Impacts on human health tend to disproportionally affect poorer communities, and jointly this can undermine the capacity of these communities to improve their economic situation (FAO & UNEP 2021).

Soil pollution can also negatively impact soil organic carbon and the soil structure reducing the resilience of the land and ecosystem to climate change. Soil and water pollution are often closely linked. Water pollution can cause soil pollution, for example by wastewater discharge or irrigating with polluted water, and soil pollution can cause water pollution, for example through leaching, soil erosion and runoff (FAO & UNEP 2021).

The contamination of soils can also contribute to disease outbreaks and can have long-term impacts on human health. Contaminants can reach humans directly through the soil, through dust, food, and water and has a disproportionate impact on the health of vulnerable groups, such as children, pregnant women, babies and the poorest. Low- to middle-income countries tend to have a higher mortality and disease burden due to limited access to clean technologies, pollution remediation technologies as well as environmental safeguards and food safety regulations. In addition, the lack of sanitation and open defecation can increase soil pollution and lead to a higher transmission of soil-borne diseases (FAO & UNEP 2021).

4.1.1 Main Pollutants

Some of the main pollutants that can contaminate land and soils in Namibia include:

Heavy Metals

High concentrations of **Thallium** in the topsoil (10-fold of the concentrations found in the lower soil layers) were found in the vicinity of the Rosh Pinah site, indicating a substantial input of Thallium through human activities (Grösslová et al. 2018). Various studies have assessed negative impacts of historical mining operations of the Kombat copper mine and found significantly high concentrations of **copper** and **lead** in tailings, especially in the dry season (up to 9086 mg/kg and 5589 mg/kg). Due to erosion, arable soil in the surroundings of the tailings dam had high Cu and Pb concentrations (up to 150 mg/kg and 164 mg/kg), which is higher than the Canadian guideline values for agricultural land (63 mg/kg and 70 mg/kg) used in the study (Mileusnić et al. 2014). Studies assessing pollution around the Tsumeb Smelter Complex, which processed poly-metallic ores for more than 100 years, indicate critical soil contamination from historic emissions and windborne dust from the tailings dam and dumps. The study found high concentrations of heavy metals in the topsoil and none of the investigated soils was deemed suitable for agricultural use. Some soils showed very high values for **arsenic, cadmium, lead, copper, and zinc** (Mapani et al. 2014).

Health risks from critical concentrations of some of these heavy metals and trace elements can be considerable and include skin damage, cancer (skin, lung, bladder, and kidney), infant mortality and neurological problems from arsenic; poisoning of the liver, kidneys, spleen, heart, lungs, stomach, intestines, nails, and hair from cadmium; acute abdominal pain, diarrhoea, vomiting and tachycardia from copper; brain damage, seizure, coma or death from lead poisoning, which is much more efficiently absorbed by children (Mapani et al. 2010).

Nitrogen

The excessive use of nitrogen fertilisers can change biological cycles and is emitted into the atmosphere as nitrogen oxide. In 2018, the application of 109 million tonnes of synthetic nitrogen fertiliser worldwide has caused emissions of 700,000 CO_2 equivalents (FAO & UNEP 2021). A study from 2019 shows that Namibia uses substantial amounts of fertiliser. Irrigated farms around the Okavango River Basin mainly produce maize and wheat. Around 400 kg of fertiliser per hectare are applied every year, which is about 1.5 times the average application volume recommended in South Africa (Vushe 2019).

Pesticides

Pesticides and chemical fertilisers are used in crop production. However, they can change the composition of the topsoil and make them more susceptible to other harmful species (e.g. fungi) and erode the soil over time (Krainlew 2018).

Persistent Organic Pollutants

DDT, a Persistent Organic Pollutant has been used for malaria control. In 2014, 69.8% of Namibia's population lived in areas with malaria risk. DDT is the most effective pesticide against mosquitoes and is used by the Ministry of Health and Social Services under strictly controlled conditions (Republic of Namibia 2014).

Soil Erosion

Some of the major challenges around land has been land cover change, the intensification of land use and land degradation (Bruinsma 2003). Another risk associated with agriculture is land clearing and soil erosion. Woodland is Namibia is being cleared for two main reasons: (1) bush control and (2) demand for firewood for cooking and heating in rural areas (Weber & Mendelsohn 2017). Clearing land and removing vegetation loosens the soil, which can lead to barren land and eroded soils over time (Krainlew 2018). Other sectors with a high soil erosion potential include construction, which often involves land clearing, and sand mining. Especially removing material supporting the riverbed can lead to erosion, instability, and degradation. (Botha et al. 2021) Over 80% of marine pollution is caused by land-based activities. Through soil erosion, about 35 million tonnes of soil are mobilised every year and discharged into water bodies and coastal areas (FAO & UNEP 2021).

Figure 10. Areas around the Waterberg in Namibia showing areas in which bush encroachment was cleared with bulldozers (USGS Earth Explorer).

4.1.2 Main Sources

Mining

Mining Fast Facts

- Mining contributes to **25%** of the country's income. It is the largest contributor to the Namibian economy
- Natural resources include diamonds, uranium, copper, gold, lead, tin, lithium, cadmium, zinc, salt, and vanadium.
- In 2015, the mining industry accounted for approximately **19,000 jobs** in Namibia.
- Five major companies account for 95% of the mining income.
- **Diamond** and **uranium** mining are by far the two most vital industries in Namibia.
- The mining sector has great potential to grow and continue to development in the country. The most recently discovery was Oil off the coast of Namibia.
- The regulations with regard to health and safety of mining have also become more formal and are enforced by the Ministry of Mines and Energy. This helps to ensure that staff and people in surrounding areas are not harmed by the effects of mining including radiation and pollution.

(BDO no date.).

One of the key sectors in Namibia contributing to land and soil pollution is the mining sector. Mining activities produce waste, which often contains pollutants such as heavy metals, which may contaminate water resources, soils and air and thus have a negative impact on biodiversity, ecosystem resilience and human health (Mapaure et al. 2011). Pollution from mining activities in Namibia is relatively well researched. The erosion of tailing dams – through wind and water – can lead to high concentrations of trace elements such as Zinc, Arsenic, Copper, Cadmium Lead and Mercury in wastes and surrounding soils. Many of these have a high bioavailability, are toxic and can end up in the food chain. This negative impact on the surrounding environment can last for years after the closure of the mine (Mapaure et al. 2011, Mileusnić et al. 2014, Mapani et al. 2010).

A study by Mapani et al. (2010) assessed the health risks associated with pollution from the slag dumps, tailings, and ore roasting facilities of a historic ore mine near Berg Aukas, which is transported offsite by wind. They suggest the contamination of agricultural soils used to grow food crops is a considerable problem. The regular consumption of these crops can have considerable impacts on human health (Mapani et al. 2010).

Studies assessing pollution around the Tsumeb Smelter Complex, which processed poly-metallic ores for more than 100 years, indicate critical soil contamination from historic emissions and windborne dust from the tailings dam and dumps. Heavy metals negatively impact soil bacteria and thus soil health. The study found high concentrations of heavy metals in the topsoil and none of the investigated soils was deemed suitable for agricultural use. Some soils showed very high values for **arsenic, cadmium, lead, copper, and zinc**. Food crop samples indicated lead concentrations above EU and WHO guidelines. In parsley and carrots these exceeded WHO guidelines by almost 20 times and remained at 7 times after diligent cleaning with distilled water. The flesh of cleaned marula samples exceeded WHO thresholds by 50% to 200%. High concentrations of cadmium were found in chilli, pumpkins and carrots exceeding EU thresholds by 4 to 6 times. Washed parsley, carrots and pumpkins also had high arsenic concentrations exceeding WHO thresholds by 2 to 4 times. The concentration of heavy metals tends to be higher at the root and less is translocated to other parts of the plants (Mapani et al. 2014).

In Uranium mining, hazardous material can be transported offsite through dust, radon gas or leaching liquid. Contact with water and air can lead to continuous bacterially induced production of sulphuric acid and can result in the leaching of uranium or other contaminants for centuries. Likely pollution parameters are TDS, TSS and heavy metals. Solid waste from mining and tilling is one of the biggest components of nuclear waste. This Low-Level Radioactive Waste (LLRW) originates from rock processing, tailings, liquid waste from processing and radon gas. There is also a risk of air pollution through the radon gas, CO_2 emissions, dust, and particulate matter. In addition, mining processes often considerably alter the landscape creating large open spaces above and/or beneath the surface of the earth. This can lead to erosion and compromise the integrity of the land (Krainlew 2018).

Agriculture

Another sector with considerable impacts on land is agriculture. Although the contribution of the agricultural sector to GDP is small, it is an important livelihoods strategy for the majority of Namibia’s rural population. More than 70% of Namibia’s population depends on agriculture. With the development of the agricultural sector, the use of agrochemicals increased (Republic of Namibia 2014). Unsustainable agricultural practices are a major cause of soil pollution and soil erosion worldwide with considerable climate change impacts (Krainlew 2018). The intensive use of fertiliser can lead to the acidification of the soil. Nitrogen fertilisers and ammonia can lead to emissions that can infiltrate the soil through acid rain (Bruinsma 2003).

Waste Management

Poor waste management and transport are two major causes of soil pollution in urban areas (FAO & UNEP 2021). Changes in consumption and production patterns with a fast turnover of products has caused the excessive production of waste. Globally, about 2 billion tonnes of solid waste are produced per year. A large proportion of this solid waste is not properly managed or recycled and ends up in the environment. Poor waste management is one of the main sources of soil pollution in the Global South (FAO & UNEP 2021).

Waste management and landfills considerably contribute to land pollution in Namibia. Per capita household waste generation in Namibia is 0.56kg in high-income areas, 0.19kg in middle-income groups and 0.33kg in low-income groups. The main types of waste generated are organic food (19%), garden refuse (15%), glass (12%), paper (9%), carton (7.4%), plastic bags (9%) and plastic containers (7%) (City of Windhoek 2013).

Currently, proper waste management is only conducted in larger towns and municipalities often by private contractors. Very little recyclable materials are collected and most end up in general dumpsites (Mughal 2014).

The COVID-19 pandemic is driving plastic waste pollution in most African countries by considerably increasing the number of single-use plastics, clearly showing urbanisation trends and limitations in plastic waste management systems (Benson et al. 2021).

Industry

Industrial operations in general have a considerable potential for pollution if the risk is not mitigated. Industrial activities - especially through poorly manged stockpiles - can lead to the diffusion of chemicals into soils and can be transported via water and air to contaminate the environment (FAO & UNEP 2021).

Most larger vehicles and equipment can leak hydrocarbons. Especially the storage of liquified petroleum gas and fuels often beneath fuel stations can cause considerable damage to soils, biodiversity, and water resources if they leak (Botha et al. 2021, Bosman et al. 2021).

4.1.3 Drivers

Key drivers of land pollution include:

- **Legislation:** There is no national approach to waste management in Namibia, and a lack of appropriate by-laws address the issue (Mughal 2014). In addition, there is a lack of strategy and a coordinated approach between stakeholders (Republic of Namibia n.d.)
- **Monitoring & Enforcement:** A lack of legislation and by-laws limits the ability to fine or punish wrongdoing (Mughal 2014).
  - **Costs:** Solid Waste Management can be expensive in both capital and operating costs. These costs must be better planned for in the budgets of local authorities. The long transport distances considerably increase the costs of recycling waste in Namibia (Republic of Namibia n.d.)
  - **Limited Awareness & Understanding**: There is a lack of understanding of the impact of pollution on the environment and health of people. There is also a limited understanding of the importance of minimising waste, which requires a shift in attitudes and culture (Republic of Namibia n.d.).
  - **Urbanisation & Population Growth**: Rapid population growth and urbanisation considerably increase pollution risk. These two factors are expected to increase global solid waste production from 2 billion tonnes per year in 2021 to 3,4 billion tonnes by 2050 (FAO & UNEP 2021)
  - **Lack of Information**: There is limited data on total waste quantities and different pollutants, which makes planning, monitoring, and mitigation very difficult (Republic of Namibia n.d.).

Main Threats / Impacts

- Negative health impacts from contaminated food / fodder and POPs for malaria / tse tse fly control.
- Changes in biological processes.
- Soil erosion and acidification.
- Decreasing soil fertility.

Main Pollutants

- Heavy Metals
- Nitrogen
- Pesticides
- POPs
- Soil Erosion

Main Sources

- Mining
- Agriculture
- Waste Management
- Industry

Drivers

- Gaps in Legislation
- Monitoring & Enforcement
- High Costs
- Limited Awareness & Understanding
- Urbanisation & Population Growth

4.2 Biota

Terrestrial pollution often leads to a chain reaction with considerable negative impacts on biodiversity. For example, soil pollution impacts the plants growing in the soil, causing contamination along the food chain and entire ecosystem until it reaches humans. The contamination of soil can change the composition of soil organisms. Even low levels of contamination can cause changes in physiology and feeding behaviours. Changes in the activity of soil organisms changes biogeochemical cycles. In addition, contaminants from polluted soils can be transported off-site triggering a chain of degradation in terrestrial and aquatic ecosystems with considerable damage to ecosystem services (FAO & UNEP 2021).

Namibia has diverse and unique ecosystems and biodiversity, which support key economic sectors such as agriculture and tourism. Although Namibia is committed to the conservation of biodiversity and has developed a considerable legislative and regulatory framework, land degradation and erosion of the resource base threaten these efforts (Forsynthe et al. 2018).

The JNCC Global Analysis identified herbicides and pesticides, solid waste, oil spills and sewage as the main pollution threats to biodiversity in Namibia. 28 terrestrial and freshwater species in Namibia are threatened by pollution according to the IUCN Red List. 17 species are threatened by both climate change and pollution. Most species are threatened by agriculture and forestry effluents (25), followed by industrial and military effluents (18) and domestic and urban wastewater (12). In the analysis birds are the most threatened followed by bony fish and mammals (JNCC 2021). During the stakeholder workshop it was confirmed that this is subject to taxonomic bias with birds being over-researched (e.g. a Namibian Red List for birds is available).

4.2.1 Main Pollutants

Some key pollutants with negative impacts on biodiversity and ecosystem services include:

Persistent Organic Pollutants (POPs)

Pesticides based on chlorinated hydrocarbons -such as HCH, DDT, chlordane, and toxaphene- have been extensively used worldwide and polychlorinated biphenyls (PCBs) are commonly used in industrial production and are part of electrical transformers, capacitors, and voltage regulators. These organochloride compounds are resistant to biological degradation, insoluble in water and highly persistent. They enter the food chain and accumulate in high concentrations in adipose tissue at higher trophic levels (Vetter et al 1999). POP residues have been detected in almost all ecosystems across the world. Through Long Range Atmospheric Transport (LRAT) they are often affect areas far away from their source. As a result, they can have an adverse impact on humans and wildlife decades after the source has been removed. DDT, for example, has been widely used in the 1940s and caused the decline of many raptor populations. Despite the ban of DDT in the 1970s, residues and adverse impacts are still documented in Africa, North America, and Europe today. PCBs, also banned since at the end of the 20th century, still contaminate the environment in Africa mainly caused by leakage or the inadequate disposal of electric transformers, electric waste, shipwrecks, and biomass burning (Harcia-Heras et al. 2017). Namibia has not submitted an updated POP inventory to the Stockholm Convention and was busy compiling an updated intervention while this report was prepared. Between 2006 and 2009, 65 000 kg DDT were imported annually for malaria campaigns by the Ministry of

Health and Social Services. This increased to 175 000 kg annually between 2010 and 2013 (Republic of Namibia 2014).

Pesticides

Pesticides are one of the three main pillars of the Green Revolution, next to new seed varieties and fertilisers. Pesticides (including insecticides, fungicides, herbicides etc.) are *"designed to kill something somewhere"* and thus impact species diversity in the areas in which they are applied depending on the degree of selectivity. Major impacts of pesticides on biodiversity include habitat loss and population decline of non-target species (McLaughlin & Mineau 1995). Major groups threatened by pesticides include scavenging diurnal birds of prey, vultures, some eagles, falcons, etc.; nocturnal birds of prey, both rodent and insect-eating owl species; non-target mammals such as aardwolf, hedgehog, pangolins; insect-eating garden birds; cranes, gamebirds, and waterbirds; useful insects such as honeybees, dung beetles, praying mantis, ladybirds; as well as amphibians and fish (NARREC 2006). The use of pesticides and fertilisers can also have a negative impact on water quality. Through trophic hierarchies, pesticides targeted at a specific organism can affect non-target species and have consequences for the entire ecosystem (SLR 2019).

Pesticides and Poachers

All over the world, poison has been used to kill wildlife for a decades. Synthetic pesticides have increasingly replaced traditional poisons because they are relatively cheap, easy to obtain and effective. In Namibia, the use of poison or agrochemicals to kill wildlife is illegal, but due to limited enforcement and the difficulty of preventing the abuse of pesticides they are still commonly used for two main purposes (Ogada 2014): **Intentional poisoning of predators by farmers:** During colonial times, lethal control of predators such as lions, wild dogs, hyenas, and cheetahs was common. Caracals and especially jackals are targeted by farmers to protect livestock. Vultures are also often deliberately targeted due to strong beliefs that they can kill lambs and carry off children (Ogada 2014). **Poisoning of carcasses by poachers:** Increasing elephant poaching has considerably increased poisoning of vultures. Poachers poison carcasses to avoid vultures giving away the location of the carcass and thus poaching activities (Ogada 2014).

Wildlife poisoning can have considerable impacts on non-target species. A study conducted in Namibia, suggests that 100 non-target species are killed for every targeted predator and mainly include birds such as tawny eagles, vultures, owls and bataleurs and some mammalian carnivores such as aardwolves or bat-eared foxes. The most abused pesticides in Namibia, according Ogada (2014) are strychnine (normally used for rats), aldicarb (insecticide) and carbofuran (insecticide) (Ogada 2014).

Nutrients

Fertilisers are another key pillar of the Green Revolution, that can have a considerable impact on biodiversity, mainly due to the risk of water pollution (McLaughlin & Mineau 1995). Animals and humans generally have similar drinking water quality requirements. In many cases, the safe limits for animals are only slightly higher than for humans. A study analysing the water quality of water holes in the Khaudom National Park indicated considerable hydrochemical changes compared to the abstracted groundwater. Faecal input from runoff and evaporation have caused increasing concentrations of potassium (K), lithium (Li), sodium (Na), nitrate (NO_3) and nitrogen dioxide (NO_2). The runoff can also cause bacteriological contamination and parasites e.g. anthrax (Wanke & Wanke 2007). Nitrates in water are often a result of agricultural activity (especially manure and fertilisers for example from feedlots), wastewater treatment especially septic systems (WHO 2011) and the incorrect disposal of animal and human waste, industrial waste, and food processing waste (CDC 2015). Excessive nitrate concentrations are associated with thyroid disease, colorectal cancer, central nervous system birth defects and adverse reproductive outcomes -amongst others (Ward et al. 2018). High nutrient loads can also contribute to the creation of "dead zones": High nutrient contents can lead to the excessive growth of algae depleting oxygen levels and creation "biological deserts" (Biswas & Tortajada 2019). In addition, there is a strong relationship between inorganic fertiliser and pesticide use. Increased use of fertilisers can also increase the risk of crop diseases (McLaughlin & Mineau 1995). Figure 11 shows a phytoplankton bloom off the coast of Namibia, which occur regularly. On the NASA Visual Earth platform similar satellite images are available for 2003, 2004 and 2007.

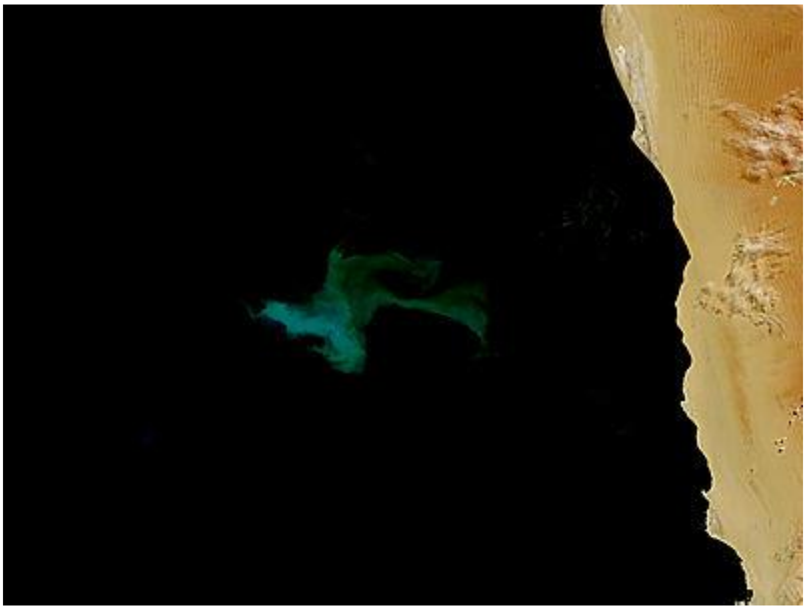


Figure 11. Phytoplankton plume in the Atlantic Ocean off the coast of Namibia in 2014 (NASA Visible Earth).

Noise pollution

can have considerable negative impacts on biodiversity. Noise is often created by machinery, transportation systems, vehicles, and aircrafts (Onjefu et al. 2019). Around the City of Windhoek - especially the northern industrial areas- noise pollution levels well above WHO limits and are mainly caused by traffic noise. Residents of the Windhoek area reported wildlife migrating out of a specific area due to the construction of a new road to the airport (Hauptfleisch et al., 2020).

Lead

Lead is a very toxic heavy metal, which can accumulate over time and affect all body systems. Lead poisoning of raptors and birds of prey is one of the main causes of mortality of these species at a global scale. The lead is easily consumed by predators by feeding on prey shot with lead bullets. Modern high velocity weapons often cause the bullets to fragment along the wound (Krüger & Amar 2018).

Microplastics

Plastic waste dumped in the environment fragments into smaller pieces over time and are called microplastics. These can be ingested by animals and cause death. Wildlife – and especially marine life- can get entangled in old fishing nets, ropes, and plastic bags (Sadan & De Kock 2021).

4.2.2 Main Sources

Key sectors in Namibia that contribute to potential adverse impacts of pollution on biodiversity are outlined below.

Agriculture

There are four main impact areas of agriculture on biodiversity and ecosystems:

1) Habitat loss due to agricultural expansion (Bruinsma 2003).
2) Declines in species richness and genetic diversity by introducing domestic livestock and crop species (Bruinsma 2003).
3) Population declines in wild species and micro-organisms that support the sustenance of food and agricultural production by cycling nutrients, controlling pests, and pollinating crops. Soil microbial populations can be changed by the intensive use of mineral fertilisers. The use of pesticides can impact insect-eating birds controlling pests, or bees and other insects providing pollination services (Bruinsma 2003).
4) Declines in wild species that maintain agricultural landscapes (Bruinsma 2003). For example, in Namibia declines in wild browser populations supported the proliferation of bush (Archer et al. 2017).

The Namibian government used pesticides at a relatively large scale to control locust or Army worm outbreaks, which threaten livelihoods in communal areas, and keeps emergency stocks of relevant pesticides (Republic of Namibia 2014).

Mining

Pollution from the mining sector can have a considerable impact on biodiversity. A study assessing the impact of heavy metals on biodiversity surrounding a former copper mine in northern Namibia showed considerably reduced woody plant densities, diversity and species richness, and the complete disappearance of pollution-sensitive species. Close to the mine dump, species composition and vegetation structure were significantly different when compared to a control site (Mapaure et al. 2011). The seepage of concentrated brine and bittern discharger from salt mining can also have a negative impact on flora and fauna.

The Namib Desert is rich in endemics and biotic communities due to its age, extreme and unfavourable climatic conditions. Especially the central area of the Namib is known for its diversity of endemic invertebrates with very restricted ranges. The southern part of the Namib is one of the 25 global biodiversity hotspots with a large number of endemic plants. The northern parts also contain mammal, invertebrate and reptile endemics, that are not found elsewhere in the Namib. The Namib Desert is protected, hosts several protected areas and is the second largest tourism attraction in Namibia. At the same time, it hosts vast mineral reserves including diamonds, copper, zinc, and uranium. Since 2010, there has been an increase in uranium mining driven by increasing oil prices and a move away from fossil fuels (Wassernaar et al. 2013). Figure 12 below shows Namibia’s protected areas including communal conservancies, conservancy forests and private reserves. There are a considerable number of active mines, active mining licenses as well as prospecting licences and license applications in protected areas.

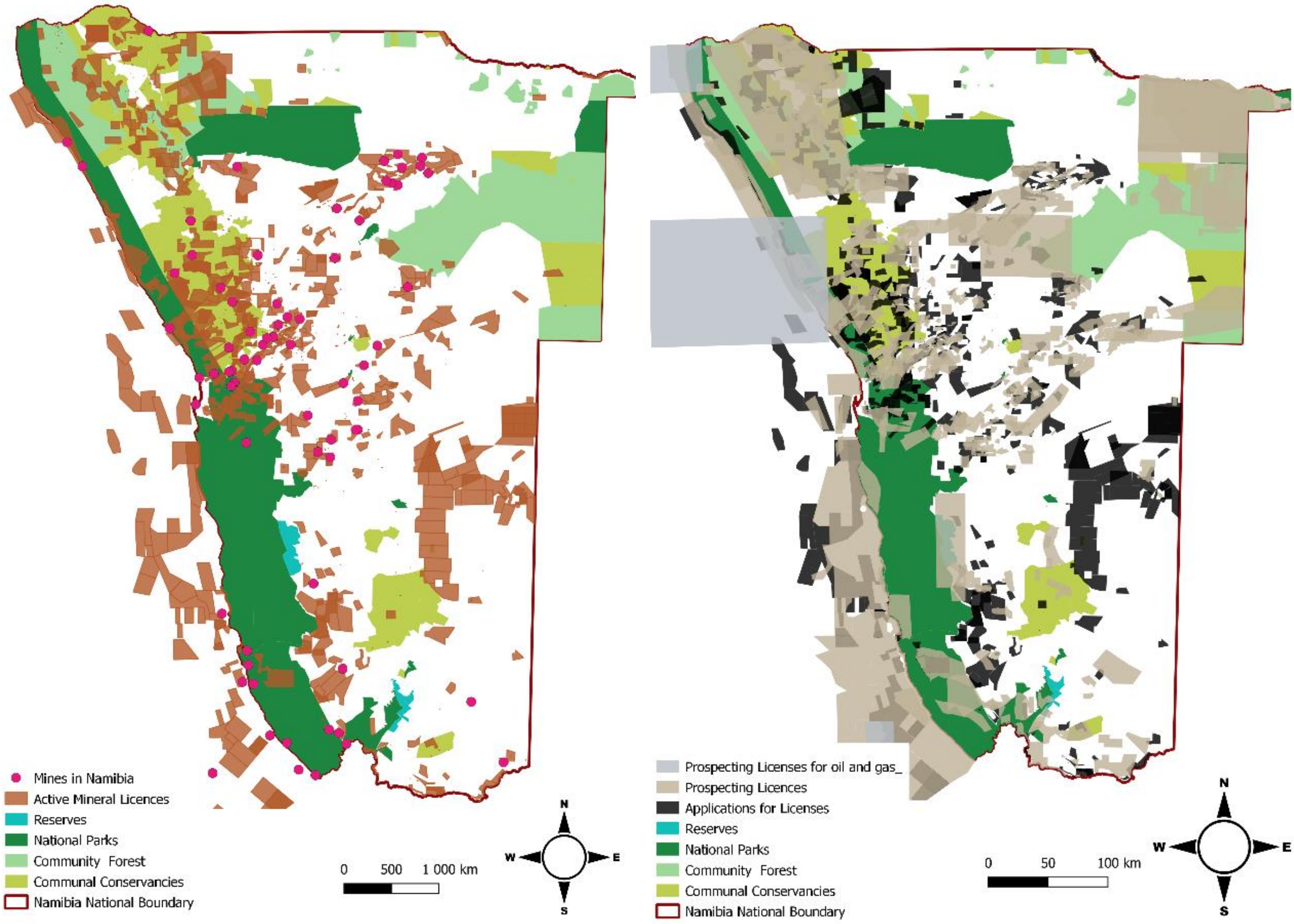


Figure 12. Current active mines (left) and mining licences and protected areas in Namibia (right) (Source: NSA Digital Namibia).

Mining can have a considerable impact on biodiversity by clearing land for infrastructure and roads in both the prospecting and mining phases. It can also impact the stability of arid ecosystems and their services by disrupting ecological processes, for example nutrient cycles and the movement of wildlife. Groundwater extraction and drainage from the mines may impact plant growth and survival, and water availability for wildlife and people downstream (Wassernaar et al. 2013).

Dust deposition, for example from limestone, can have a negative impact on flora. Dust transported by wind is common for arid environments and is a considerable source of fine particulate matter. The dust can settle on plants, and in the absence of rain for extended periods, and can have various physical and chemical impacts on the plants. Limestone dust for example can impact the energy balance of leaves, abrade their surface, block stomata and impact photosynthesis, lead to chlorophyll degradation and stimulate the absorption of phytotoxic air pollutants. A study on desert plants conducted close to a limestone quarry at the Scorpion Zinc mine in Rosh Pinah (Namibia) found decreases in plant performance due to decreasing chlorophyll content, reduced CO_2 assimilation, decreasing electron transport and changes in the oxygen-evolving complex. Plants quickly recovered when limestone quarrying was stopped, especially if assisted by rainfall (Van Heerden et al. 2007).

Waste Management

Poor waste management can also have a considerable impact on biodiversity. Waste can be transported from landfill sites by wind and water, which can transmit diseases. Any construction or industrial activity can lead to soil contamination, erosion, dust, solid waste, noise, and excessive lighting at night, which may have a negative impact on biodiversity. Waste disposal is a major problem in Namibia. There are only two registered hazardous waste disposal sites (in Windhoek and Walvis Bay) in the entire country and illegal dumping is common. Many towns or villages do not have formal waste collection systems (Republic of Namibia n.d.).

Plastic pollution is a considerable problem. Changing lifestyles and consumptive patterns have driven plastic pollution over the years. The way plastic is produced and managed after use is highly unsustainable. Plastic waste dumped in the environment fragments into smaller pieces over time and are called microplastics (Sadan & De Kock 2021).

Tourism & Hunting

Tourism also tends to bring people into remote areas of the country to enjoy biodiversity. Tourism activities can contribute to solid waste, as well as sewage and wastewater problems. Noise pollution can also disrupt wildlife and local communities.

Hunting is carried out across Namibia to sustainably manage the appreciable levels of wildlife, whilst trophy hunting is an important component of Namibia's tourism industry and contributes to conservation by mobilising funding. However, the use of lead ammunition can have a negative impact on terrestrial and aquatic environments. Through the food chain, lead can also have an impact on humans. Especially children are vulnerable to the impacts of lead (UNEP 2010).

4.2.3 Main Drivers

Key drivers of pollution impacts on biodiversity include:

- **Agricultural Expansion** in Namibia is driving the use of agrochemicals, which also increases potential risks to ecosystems and biodiversity.
- **Limited Capacity and Awareness**, especially within the mining industry, the government and scientific community, on how to recover ecosystems and successfully rehabilitate mines (Wassernaar et al. 2013).
- **Limited Knowledge** on the response of arid ecosystems in Namibia to pollution and the most appropriate management techniques (Wassernaar et al. 2013).
- **Regulations and Legislation** is fragmented and does not explicitly refer to restoration e.g. after closing mines -although they refer to rehabilitation, which mainly consists of removing human-made structures (Wassernaar et al. 2013).

Main Threats / Impacts

- Changes in physiology and feeding behaviour.
- Degradation of terrestrial and aquatic ecosystems.
- Eutrophication and creation of dead zones in aquatic ecosystems.
- Bioaccumulation in animal tissue.
- Loss in species diversity and population decline of non-target species.
- Habitat loss and migration.
- Bacterial contamination, parasites, and diseases.

Main Pollutants

- POPs
- Pesticides
- Nutrients
- Noise
- Lead
- Microplastics

Main Sources

- Agriculture
- Mining
- Waste Management
- Tourism & Trophy Hunting

Drivers
- Agricultural Expansion
- Capacity & Awareness
- Limited Knowledge
- Gaps in Regulations / Legislation

4.3 Air

Air pollution can be caused by natural processes and anthropogenic activities and can have considerable environmental and human health impacts. Ambient and household air pollution are among the largest environmental risks to human health causing one in nine deaths every year (WHO 2016). In 2019, air pollution was the 4th leading cause of early death (6.67 million in total) after high blood pressure, tobacco use and a poor diet (Health Effects Institute 2020). Air quality in many developing countries is deteriorating fast due to economic growth, industrialisation, and urbanisation, which often leads to food insecurity, respiratory diseases, and degradation of the environments (Swanepoel et al. 2007).

4.3.1 Main Pollutants

Major air pollution issues in Namibia include the following:

Ozone: Tropospheric or ground-level ozone is a highly reactive pollutant with considerable adverse impacts on human health, crops, and vegetation. Ozone is formed through complex chemical reactions between nitrous oxides, volatile organic compounds, and sunlight. Nitrous oxides largely stem from burning fossil fuels. Volatile organic compounds are created by motorised vehicles, gas and oil extraction, and other industrial activities. Current ozone levels are around 30 – 70% higher than 100 years ago due to increasing emissions and temperatures, which accelerate ozone formation. Ozone is also a greenhouse gas that contributes to global warming. Ozone can travel long distances leading to high ozone levels far away from emission sources (Health Effects Institute 2020).
The anticyclonic climatic conditions, abundant sunshine and significant sources of nitrous oxide and volatile organic compounds in Southern Africa encourages the accumulation of airborne pollutants leading to high ozone concentrations (Zunckel et al. 2006). A study published in 2006, modelled ozone concentrations between October 2000 and April 2021 indicating concentrations between 20 and 50 ppb. The concentrations are highest in a broken band that stretches from west-Namibia, across southern Botswana, into north-eastern South Africa and into Mozambique. The highest concentrations (80 ppb) occurred in Zimbabwe, north-eastern South Africa, and northern Namibia (Fig. 13) in most months (Zunckel et al. 2006).

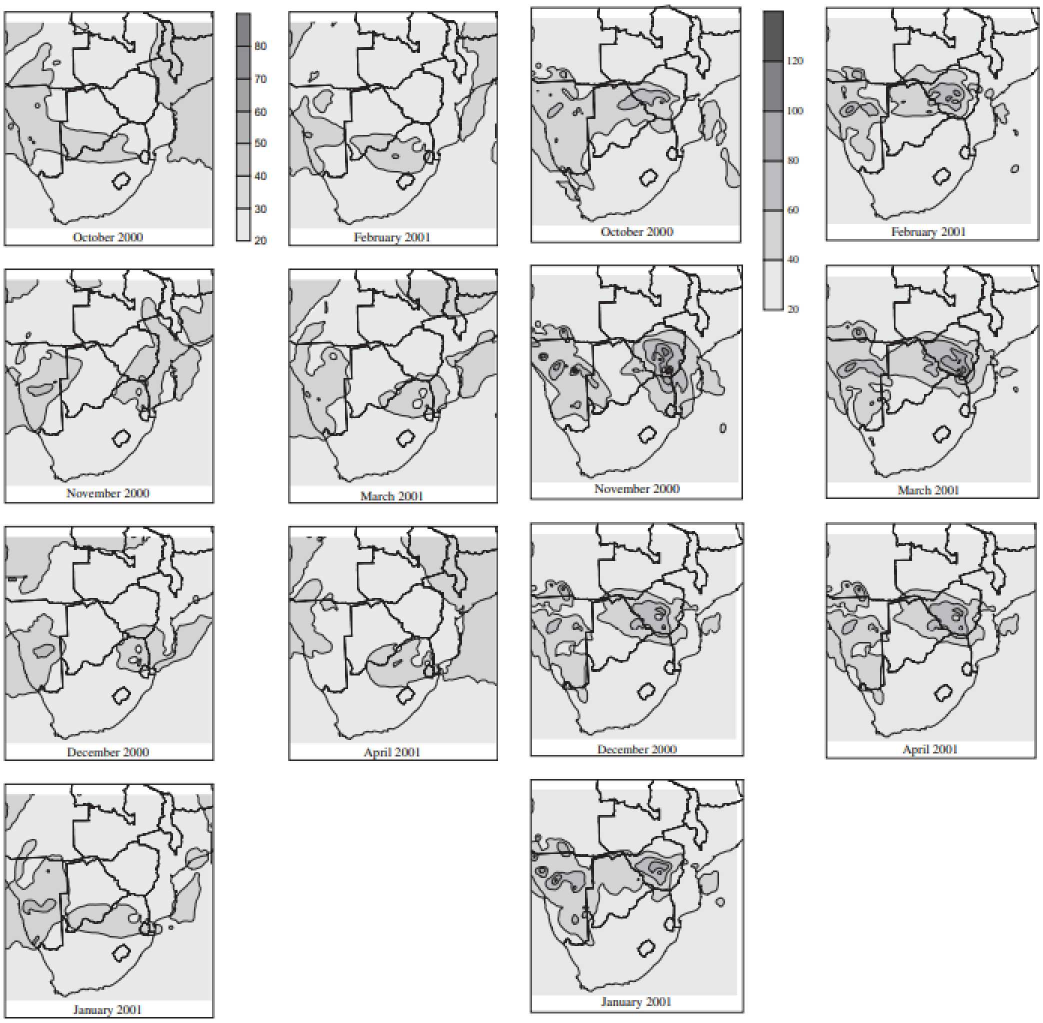


Figure 13. Average (left) and maximum (right) ozone concentrations in Southern Africa collected in a 5-day period between October 2000 and April 2001 (Source: Zunckel et al. 2006).

More recent information from 2019 (Fig. 14) confirms heightened ozone concentrations in south-west Africa and Namibia ranging on average between 42 - <50 ppb. In Namibia, deaths per 100,000 people due to high ozone concentrations range between 2 to <5 (Health Effects Institute 2020).

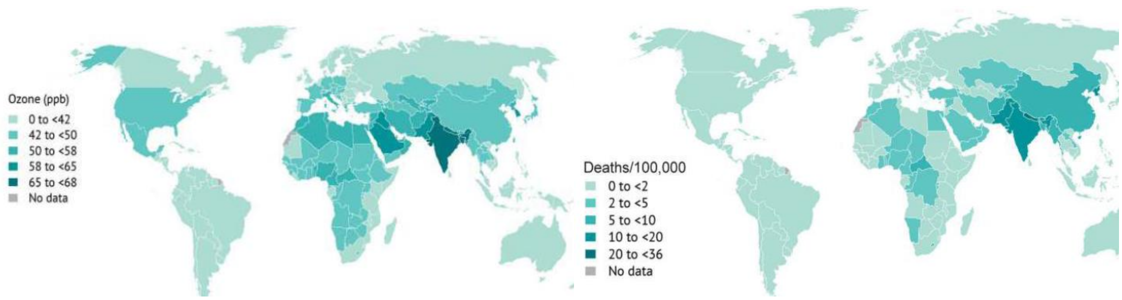


Figure 14. Population-weighted average seasonal 8_hours daily maximum ozone concentrations (left) deaths attributable to ozone (right) in 2019 (Source: Health Effects Institute 2020).

Methane: Methane is a potent greenhouse gas with 28 times the global warming potential over 100 years of CO_2. However, methane only remains in the atmosphere for about a decade compared to centuries for CO_2 molecules. This makes the reduction of methane to limit temperature increases to 1.5°C one of the most cost-effective strategies. More than 50% of methane emissions are caused by humans mainly through agriculture (40% - manure, enteric fermentation, rice cultivation), fossil fuels (35% - gas and oil extraction, coal mining) and waste (20%, mainly from landfills and wastewater). Methane is not dangerous to human health but contributes to the formation of ozone with considerable impacts on human health (especially cardiovascular and respiratory diseases), ecosystems and crops (CCAC & UNEP 2021).

Other major **Greenhouse Gases** include carbon dioxide (CO_2), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and hexafluorocarbons (HFCs). CO_2 is a natural gases, but concentrations increased to unsustainable levels by burning biomass and fossil fuels, industrial processes and changing land uses. It is the main greenhouse gases shifting the earth's radiative balance and causing global warming. Nitrous oxide has 310 times the global warming potential of carbon dioxide and is mainly caused by fertiliser use, fossil fuel combustion, burning of biomass and nitric acid production. SF_6 is a synthetic gas with 22 800 times the global warming potential of CO_2. It is mainly used in electrical distribution or transmission and in electronics. PFCs are also anthropogenic gases. They are often used as alternatives to ozone depleting substances and emitted as by-products of industrial processes. HFCs were also introduced as alternatives and are less harmful to the ozone layer but are a powerful greenhouse gas. HFCs are mainly produced in industrial processes (EPA n.d. *a*). Figure 15 shows Namibia's greenhouse gas emissions based on the latest greenhouse gas inventory submitted to the UNFCCC (Republic of Namibia 2021). Greenhouse gas emissions have been relatively stable in terms of total emissions. Increasing emissions of carbon dioxide were compensated by reductions in methane, nitrous oxide, and carbon monoxide emissions.

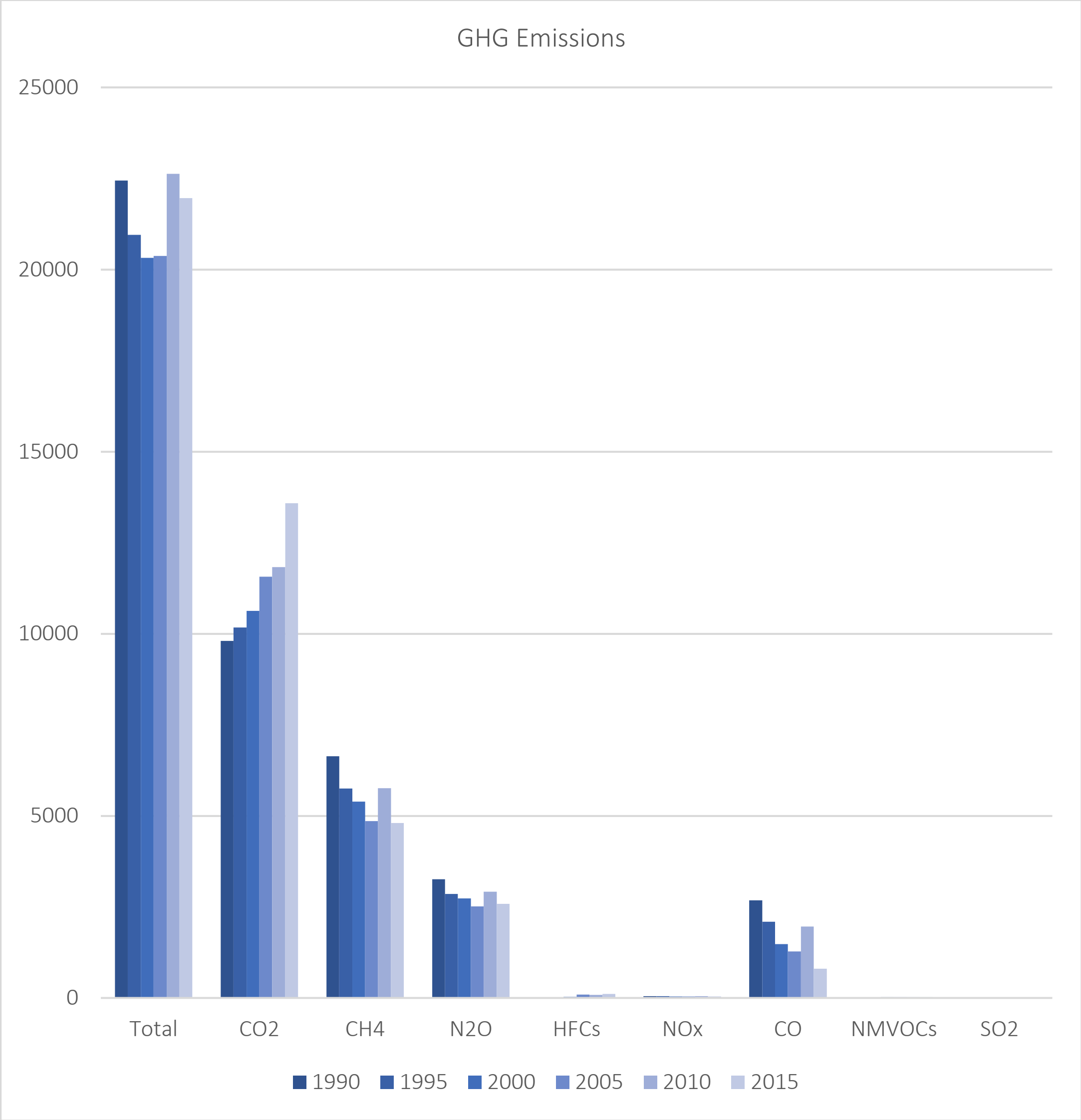


Figure 15. Emissions of the main greenhouse gases in Namibia between 1990 and 2015 (Republic of Namibia 2021).

Ammonia emissions mainly originate from the agricultural sector, for example from livestock production (44%), fertilisers (17%) and biomass burning (11%). Ammonia emissions are estimated to be more acidifying than nitrogen oxides and sulphur dioxide (Bruinsma 2003).

Fine Particulate Matter are particles measuring less than 2.5 micrometres (PM2.5). Fine particulate matter and chemicals that lead to the formation of PM2.5 are emitted from coal power plants, vehicles, waste burning, industrial processes, as well as other natural and anthropogenic sources. In 2019, 90% of the world population was exposed to PM2.5 concentrations beyond the 10μg/m^3 threshold of the WHO. The highest concentrations are found in Africa, Asia, and the Middle East (Fig. 16). Continuous exposure to high fine particulate matter concentrations can lead to mortality from respiratory, cardiovascular, and other diseases (Health Effects Institute 2020).

Figure 16. Annual average PM2.5 concentrations (left) and death attributable to PM2.5 (right) in 2019 (Source: Health Effects Institute 2020).

A study on the particulate matter concentrations in Windhoek found high PM levels above thresholds of American, German and EPA standards. There was a high prevalence of cough (43%), breathlessness (25%), and asthma (11.2%) among surveyed participants, and particulate matter was considered a major risk (Hamatui & Beynon 2017).

Dust: Namibia also has naturally high dust levels. Episodic dust storms due to easterly winds are common in the western parts of the country throughout the winter months. The easterly winds transport dust over long distances towards the Atlantic Ocean. High dust levels from anthropogenic, biogenic, and natural sources (such as fires) can contribute to air pollution. Most windblown dust contributing to global aerosol loads has natural origins (75 – 89%). About 8% of global dust emissions are from anthropogenic sources, for example extraction or mining sites. In Southern Africa, Namibia is the main source of mineral dust driven by mining and disturbed soils (Liebenberg-Enslin et al. 2020).

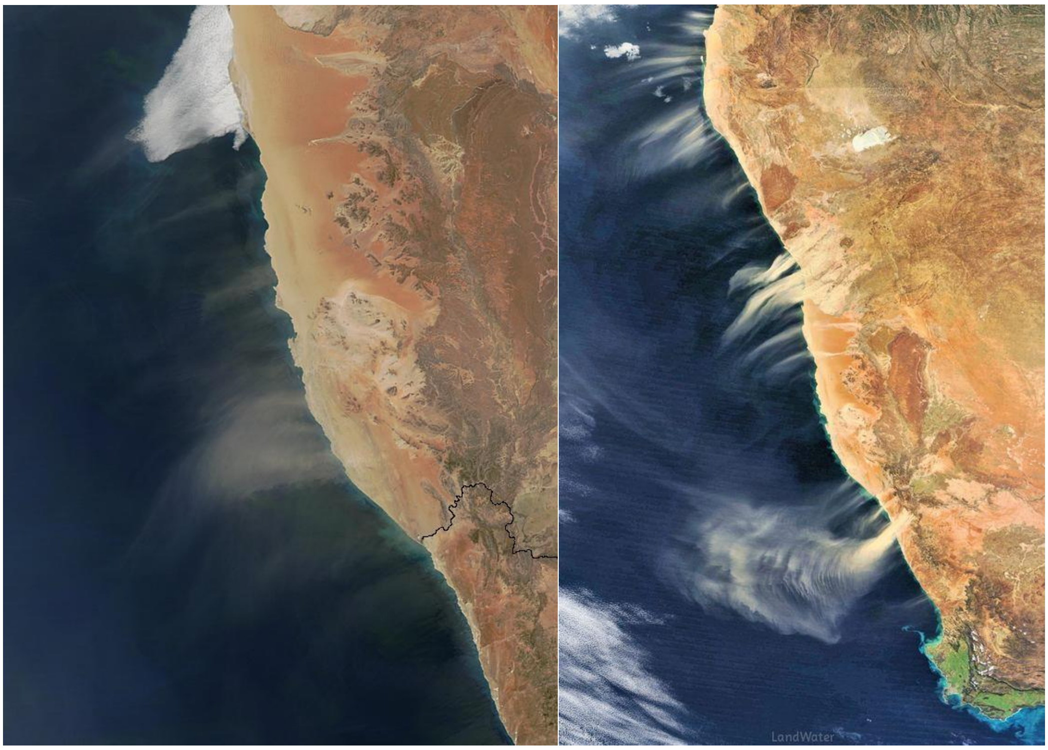


Figure 17. Dust storms off the coast of Namibia, the dust on the left image is more evenly spread, while the dust on the dust on the left seems to originate from point sources (Source: NASA Visible Earth).

The dust consists of particulate matter and can include radioactive gases and particles. High levels of particulates in the air can have a negative impact on human health, especially children and elderly. Liebenberg-Enslin et al. (2019) measure particulate matter concentrations (PM2.5 and PM10) over 26 months at five monitoring stations (Jakalswater, Henties Bay, Walvis Bay, Swakopmund and Roessing Mine). Both $PM_{2.5}$ and PM_{10} concentrations were elevated, but below WHO guidelines. The main sources of $PM_{2.5}$ and PM_{10} emissions was from vehicles, as well as mining and quarrying operations. The highest PM_{10} concentrations were measured during easterly winds, which can influence modelling (Liebenberg-Enslin et al. 2020).

Unintentionally Produced POPs (U-POPs), such as dioxins and furans, are created when burning certain materials, for example waste, and from some industrial and chemical processes. In Namibia, the most common sources of U-POPs include medical waste incineration, accidental fires, coal fired power stations and sewage treatment. Smaller quantities of U-POPs can also be emitted from copper smelting and copper production. U-POPs in Namibia are mainly produced in medical waste incineration. Around 174.03 gTEQ of dioxins are emitted per annum (Republic of Namibia 2014).

4.3.2 Main Sources

Major sources of air pollution in Namibia include:

Fires: are a natural phenomenon in savannah landscapes and are used as a management tool. Emissions from fire include carbon dioxide (CO_2), sulphur dioxide (SO_2), carbon monoxide (CO), nitrous oxide (NO_x), hydrocarbons, oxygenated organic compounds and halocarbons, which can be transported over vast areas and increase ozone (O_3) concentrations. Peak ozone concentrations from fires over Namibia increased with height and are comparable to a polluted urban environment (Sinha et al 2003).

Generally, fires have declined in most ecosystems, but seem to increase in some African countries, where it is often used by agricultural communities or poachers. While fires can have negative impacts, it can also have positive impacts on primary productivity, habitats, soil organic carbon, enhance resilience to climate change and biodiversity. Tear et al. (2021) even suggest that good fire management can substantially reduce emissions at a large scale (Tear et al. 2021). Figure 18 below shows a count of active fires detected by the Verra (MODIS), 1 (VIIRS), N (VIIRS), and Aqua (MODIS) satellites. In total, 2874 Early Dry Season (EDS) fires (between May to July) compared to 22 260 Late-Dry Season (LDS) fires (August to November) in 2021. Ideally, controlled fires should be used in the early dry season, when it is quite cold, and the grass fuel is not too dry to ensure fires burn fuel without becoming uncontrollable wildfires.

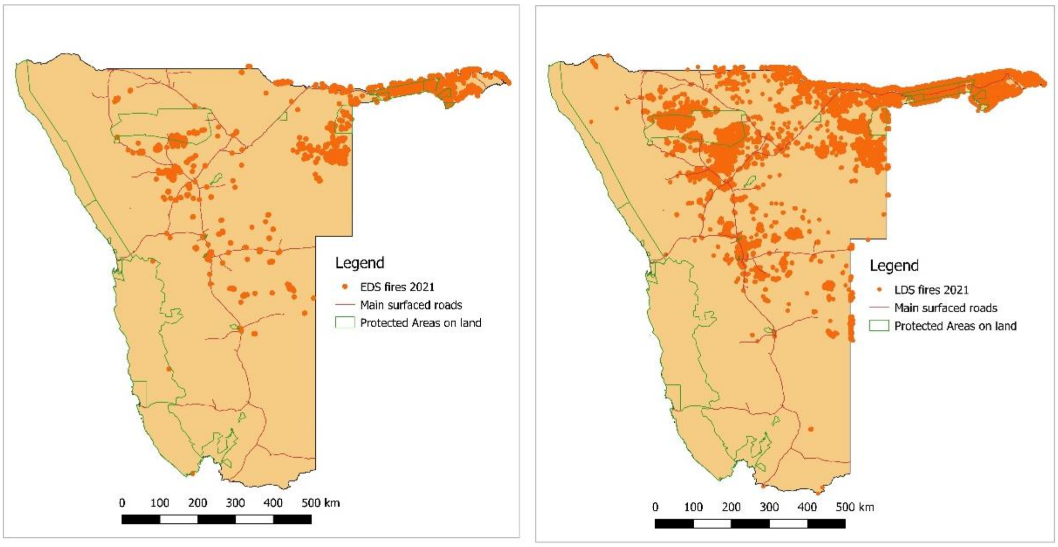


Figure 18. Early Dry Season (left) and Late Dry Season (LDS) fires in Namibia in 2021.

Fires can also contribute to considerable smoke, dust, and particulate matter levels, which can travel vast distances. The image on the left shows the smoke from fires around Namibia's Etosha National Park in 2012 (NASA LANCE/EOSDIS Rapid Response 2012*).*

Figure 19. Smoke from fires burning close to the Etosha National Park in 2012 (Source: NASA Visual Earth)

The burning of different fuels by households for cooking or heating creates various pollutants (such as carbon monoxide, black carbon and $PM_{2.5}$) detrimental to human health. Household air pollution is common in Sub-Saharan Africa (Fig. 20) (Health Effects Institute 2020). The majority of Namibian households (62%) cook indoors, and more urban households (81%) cook indoors than rural households (45%). Most households depend on firewood (55%). The use of firewood is much more common in rural areas (89%) compared to urban areas (16%).

Almost all households in Namibia (97%) cook using an open fire or use a stove with no chimney or hood (NSA 2007).

Using biomass as dominant household fuel exposes people to black soot containing various pollutants. Especially women and children breathe in these pollutants throughout the day, which can have a negative impact on their health. Particulate matter – PM_{10} and $PM_{2.5}$ – are indicators of indoor pollution. PM10 concentrations during cooking can reach peaks of up to 10 000 µg/m^3. Outdoor limits by the US Environmental Protection Agency and European Union are and annual average of 50 µg/m^3 or 40 µg/m^3 respectively. Especially PM2.5, very fine particulate matter, can enter the lungs and cause inflammation, impair immune response and lead to various diseases (WHO 2006). Acute Lower Respiratory Infections (ALRI) is one of the major causes of childhood death with about 845 000 deaths globally in 2010. Sub-Saharan Africa accounted for 378 000 of these deaths, mainly due to pollution from fuel use, malnutrition, limited access to healthcare (Buchner & Rehfuess 2015). Women exposed to household pollution are more likely to suffer from chronic obstructive pulmonary disease (COPD) and lung cancer (WHO 2006).

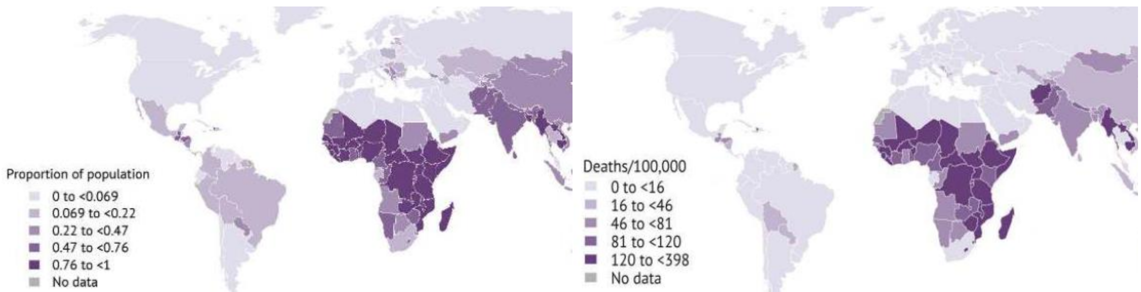


Figure 20. Proportion of the population cooking with solid fuels (left) and deaths attributed to household air pollution (right) in 2019 (Source: Health Effects Institute 2020).

In most areas in Namibia, more than 75% of people (Fig 21) still depend on wood as main fuel, although the proportion has slowly decreased over the years (Atlas of Namibia 2022).

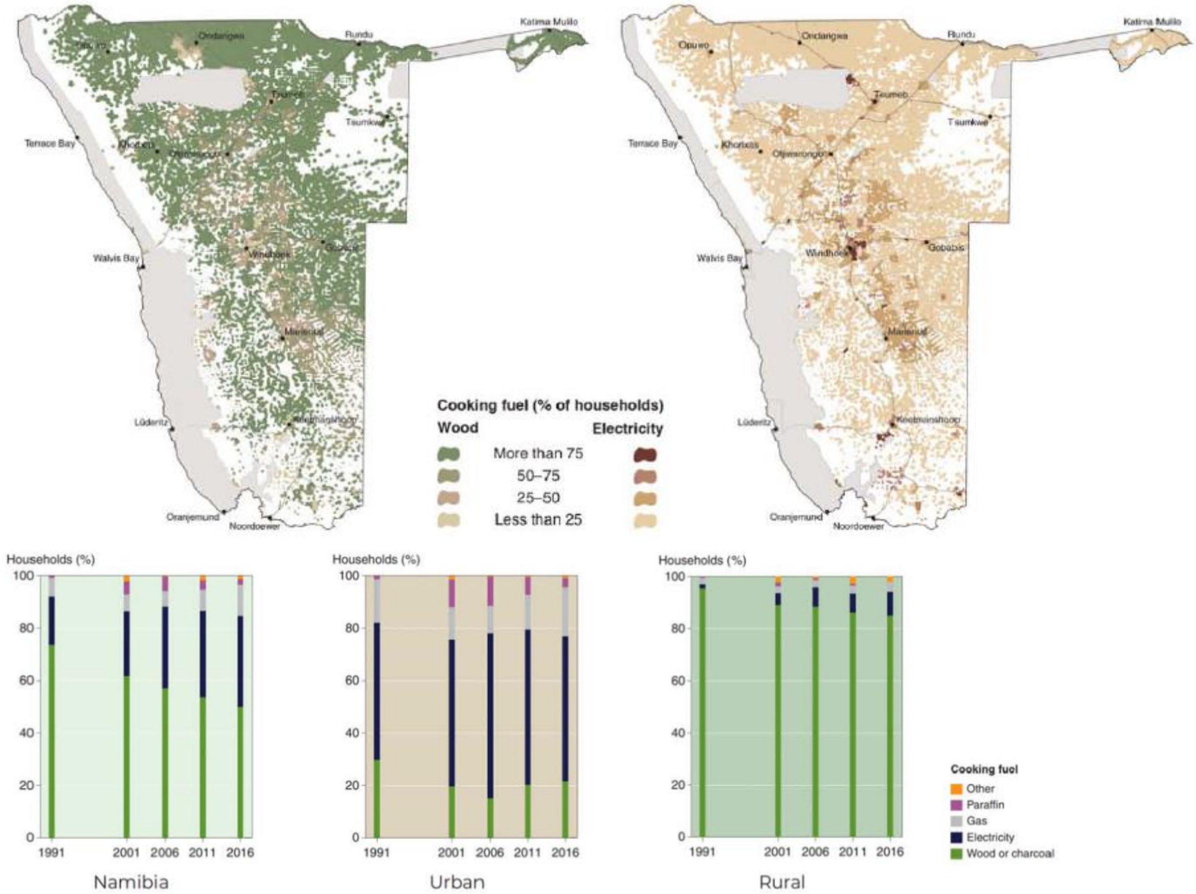


Figure 21: Households in Namibia using wood and electricity as main cooking fuel (Source: Atlas of Namibia 2022).

Mining

The mining industry can also contribute to air pollution. Pollutants from mining and smelting activities can have an impact workers and the surrounding communities (Fry et al. 2020). For example, studies have proven increased concentrations of arsenic and lead in the blood and urine living around the Tsumeb copper smelter after being exposed to dust fallout and gaseous emissions (Kribek et al. 2016).

Dust from mines and smelters can create plumes of increased trace elements causing local and regional air and soil contamination. Especially fugitive smelter dust can threaten humans and the environment due to the high levels of toxic elements and fine-grained composition. A study by Fry et al. in 2020, demonstrated contaminated dust from the Tsumeb smelter in Namibia poses a health risk to local residents. The dust distributed arsenic, copper, and lead throughout the city (Fry et al. 2020).

Charcoal

Namibia's charcoal industry has grown considerably over the years. Charcoal is produced by around 6,000 to 10,000 small-scale producers (UNIDO 2019). The majority of charcoal is exported – and Namibia supplies about 10% of the charcoal demand of the EU market. Namibia is well known for its green FSC certified charcoal using encroacher bush and contributing to the rehabilitation of rangeland (Zahnen et al. 2020).

Charcoal dust can cause air pollution and have a negative impact on the health of people working in the sector and area. Charcoal processing activities can lead to charcoal dust exposure. A study by Hamatui et al. (2016), evaluated charcoal dust exposure at 6 different charcoal sites in Namibia employing around 307 charcoal workers. The study found an increased risk for adverse respiratory impacts among workers with higher dust exposure. The dust exposure levels exceeded the US OSHA recommended limit of 3.5 mg/m^3 for carbon-black-containing dust types. The highest dust exposure levels were found in the packing and weighing areas (median 27.7 mg/m^3) followed by sieving (17.9 mg/m^3) (Hamatui et al. 2016).

Agriculture

As outlined in previous chapters, unsustainable agriculture can be a major cause of pollution. Excessive use of synthetic nitrogen fertilisers alters biological processes and releases nitrous oxide (N_2O) into the atmosphere (FAO & UNEP 2021). Most of these emissions are caused by manure management, enteric fermentation (jointly about 32% of global anthropogenic emissions in 2021) and rice cultivation (8% of global anthropogenic emissions) (CCAC & UNEP 2021). Figure 22 shows the GHG emissions of Namibia's AFOLU sector between 1990 and 2015. The AFOLU sector is Namibia's single largest emitting sector producing 80% of Namibia's total emissions. They have remained relatively stable over time with CO_2 emissions increasing slightly.

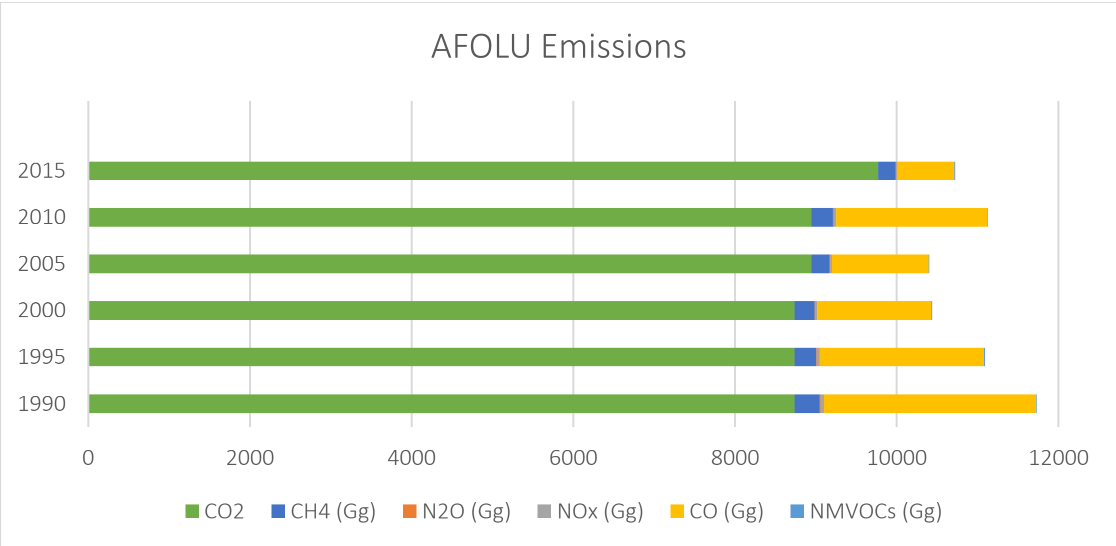


Figure 22. AFOLU GHG emissions between 1990 and 2015 (Republic of Namibia 2021).

The main impacts of agriculture on air quality and air pollution include:

1) Greenhouse gases and particulate matter released when land clearing with fire or burning agricultural residues. Biomass burning releases dust, soot, and trace gases into the atmosphere. Slash-and-burn practices are often used to stimulate grass growth, clearing land and to get rid of crop residues.
2) Methane emitted from rice or livestock production.
3) Nitrous oxide from manure and fertilisers.
4) Ammonia from urine and manure (Bruinsma 2003).

Pesticides used in agriculture have also been used for human health considerations. In the past, vast areas in Namibia were sprayed with DDT to control malaria. Dieldrin is used for

TseTse fly control (Republic of Namibia 2014). There are concerns around the long-term exposure of children to such pesticides and some authors have linked early-onset of leukaemia on pesticides. These pesticides are often sprayed in rooms and unsafe concentrations can linger in the air for up to 24 hours. They can bio-accumulate in humans and cause serious harm (Mapani & Ellmies 2011).

Industry

Industry in general and construction in particular can contribute to emissions and dust. Grit blasting of ships during repairs for example creates dust that can be carried offsite by wind and water. Vehicles in general produce particulate matter and NOx emissions. The dust can be toxic, due to paints, copper grit, harmful chemicals (e.g. anti-biofouling chemicals) and other materials on the surface. Hospital incinerators and metal processing facilities may release dioxins (Republic of Namibia 2014).

Waste Management

Landfills account for about 20% of global anthropogenic emissions (CCAC & UNEP 2021). Landfills through the anaerobic and aerobic biodegradation of municipal solid waste emit a number of greenhouse gases including methane, nitrous oxide, and carbon dioxide. Methane from landfills is the largest contributor to GHG emissions (1-2% of total anthropogenic emissions), followed by methane and nitrous oxide from leachate treatment systems (Zhang et al. 2019).

According to Namibia's latest GHG inventory, emissions from waste have increased considerably between 1990 to 2015 with considerable increases in carbon dioxide, methane, and carbon monoxide emissions (Fig. 23).

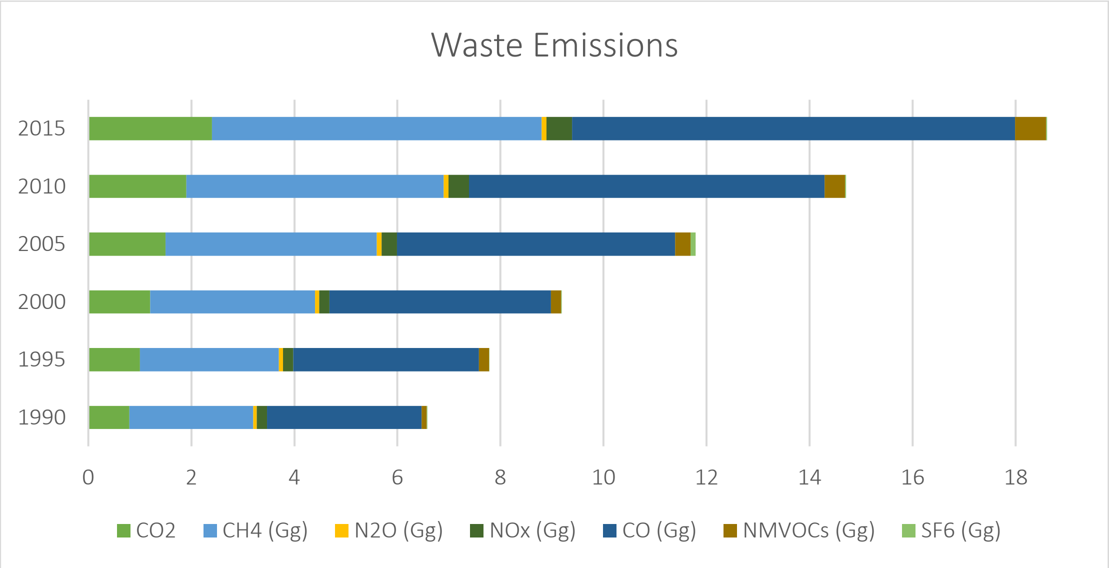


Figure 23. GHG emissions from waste between 1990 and 2015 (Republic of Namibia 2021).

4.3.3 Drivers

Key drivers of air pollution in Namibia include limited monitoring. Most African countries lack air quality monitoring capacities and stations (Agbo et al. 2021, Zunckel et al. 2004). Namibia also has various legislative and regulatory documents to manage chemicals contributing to pollution, but these are fragmented and there is limited implementation and enforcement of rules (Republic of Namibia 2014).

Main Threats / Impacts

- Health
- Global warming and climate change.
- Degradation of ecosystems and their services.
- Food insecurity

Main Pollutants

- Ozone
- GHGs
- Ammonia
- Fine Particulate Matter
- Dust
- U-POPs

Main Sources

- Natural and Anthropogenic Fires
- Mining
- Charcoal
- Agriculture
- Industry
- Waste Management

Drivers

- Monitoring & Evaluation
- Limited Implementation and Enforcement of Legislation and Regulations

4.4 Water

The health of people is closely tied to the quality of drinking water. Economic development, the natural environment and human wellbeing cannot be sustained without high quality, reliable water supply. So far, Namibia has been unable to supply its entire population with piped water (Lewis & Claasen 2018). Except for some of the northern parts and the Tsumeb-Otavi-Grootfontein area, Namibia is a water stressed country with high evaporation rates, limited water resources and a heavily reliance on groundwater resources (Mapani et al. 2005). Groundwater is the country's main source of water supply and over 100,000 boreholes are drilled country-wide to provide access to drinking water for people, livestock and game, crop production and to supply mines (Christelis & Struckmeier, 2011). About 60% of Namibia's population depends on groundwater (Mapani & Ellemies 2011). Groundwater in Namibia is often not treated, which makes the cleanliness of the water a major concern (Lewis & Claasen 2018).

Namibia is the most arid country in Southern Africa, which makes available ground- and surface water resources all the more important and vulnerable to pollution, climate change and overutilisation (Lohe et al. 2021). Less rainfall under climate change conditions will reduce groundwater recharge, while increased and more erratic rainfall causing and flooding causing pollution of shallow aquifers (Hamutako et al. 2016).

Some of the main issues making water unfit for human consumption in Namibia include nitrates, fluoride, sulphate, and total dissolved solids. Contamination with E.coli bacteria is common in livestock watering wells (Wanke et al. 2014). Water is a great solvent. It interacts with different substances as these move through rocks and the soil. Thus, groundwater often has more dissolved substances than surface water resources. High concentrations of dissolved solids are associated with hypertension and kidney problems, especially in children and adults with pre-conditions (Wanke 2014).

4.4.1 Main Pollutants

Key pollutants threatening Namibia's groundwater and surface water resources include:

Nutrients: Nutrients such as nitrate and phosphate can contaminate ground and surface water. This is often caused by agricultural activity including increasing fertiliser and manure use, disposal or agricultural waste and land use changes; wastewater disposal; and oxidisation of animal and human faeces for example in septic tanks (NGOWP 2021, WHO 2011). The release of nitrogen and ammonia can cause acidification and eutrophication of water bodies. High nutrient contents can stimulate plant growth, which restricts light penetration and depletes dissolved oxygen (NGOWP 2021). Eutrophication disrupts nitrogen fixation, nutrient availability and microbial processes and considerably impact ecosystems and species richness (Bruinsma 2003). Phosphates are commonly found in fertilisers, manure, organic waste, industrial effluent, and sewage and can contribute to eutrophication in quantities above 25 mg/l (NGOWP 2021).

High nitrate concentrations can have an impact on human health. The algal blooms characterising eutrophicated water release toxins harmful to humans and fish (Bruinsma 2003). Nitrate concentrations as low as 10 to 15 ppm can be toxic to humans. They are highly soluble and easily leach into groundwater (Wanke 2014). High nitrate concentrations in drinking water restrict oxygen transport in the blood, which can cause birth defects, thyroid diseases and are associated with certain cancers. The World Health Organisation recommends nitrate levels below 50 mg/l to ensure safe drinking water. Phosphates only become a health concern at excessive quantities of >1000 mg/l (NGOWP 2021).

Hydrogeological observations around Windhoek have found sodic to aluminium nitrate deposits on the surfaces of faults, which is a sign of nitrate percolation and subsequent crystallisation. The dry weather conditions in Windhoek support the crystallisation of nitrates before they reach the water table (Mapani 2005). A study in the northern regions of Namibia indicated a very low water quality of the shallow perched aquifers. High nitrate and phosphate concentrations originated mainly from agricultural activities, for example manure (Wanke 2014).

Fig. 24 shows nitrate levels in Southern Africa around 2001. High nitrate concentrations were found especially in the south-eastern areas of Namibia and extend into South Africa and Botswana. Some of these high nitrate concentrations -for example in the Kalahari – were ascribed to natural causes. In other areas, the high concentrations were mainly pollution related (Tredoux & Talma 2006). Seasons with exceptionally high rainfall (for example in 1955, 1969, 1974 and 2006) are often associated with nitrate poisoning and high stock losses (Lewis & Claasen 2018, Tredoux & Talma 2006). Exceptionally high rainfall events can change the recharge patterns of an area. Crystallised pollutants (including nitrate) or salts can dissolve and leach into the sub-surface (Tredoux & Talma 2006). Salinisation is commonly linked to irrigation mismanagement and the build-up of dissolved solids (Bruinsma 2003).

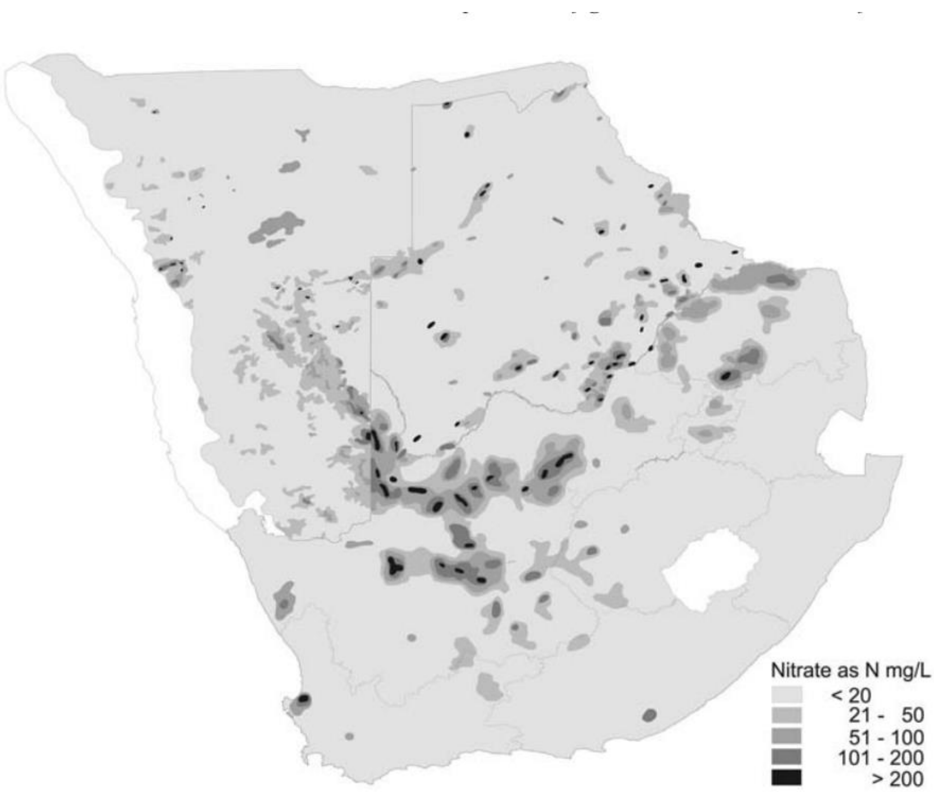


Figure 24. Distribution of nitrate in groundwater. Areas in white indicate a lack of data (Source: Tredoux & Talma 2006).

Faecal Coliforms: A study conducted in the Hardap Region of Namibia identified nitrates and coliform bacteria as the main parameters threatening water quality in the region. Both are by-products of faecal contamination by livestock and people over long-periods of time (Lewis & Claasen 2018). Microbiological contamination with E. coli was also identified in a water quality study in northern Namibia. Untreated water from these shallow aquifer was also suggested as a cause for the cholera outbreaks (by *Vibrio cholerae*) in the Kunene Region in 2013 and in Ohangwena (Wanke 2013).

Pesticides such as organophospates, N-methyl carbomates, triazines and chloroacetanilides also contribute to water pollution. Certain pesticides considerably threaten groundwater and surface water resources because they break down into highly toxic and persistent substances. They are often used continuously (for example, to control weeds in airfields, paved areas, sports grounds etc.), which can have a cumulative effect (Mapani 2005). Alkane liquids and gases such as ethane, propane, butane, pentane, and others are especially difficult to deal with. They do not degrade easily and are lighter than water creating a thin coat on top of water (Mapani 2005). The treatment of drinking water mainly removes biological threats and often does not specifically address pesticides. The mixing of pesticides from different point sources can create completely different mechanisms of toxicity. About 95% of herbicides and 98% of insecticides reach unintended destinations including water resources. Once they have entered the hydrological cycle, they are very difficult to remove. Some pesticides may be trapped by clay minerals (Mapani & Ellmies 2011). Livestock drinking pesticide contaminated water can lead to bioaccumulation in animal tissue moving further up the food chain. Pesticides also undergo “biomagnification” in the food chain, which means that the threat increases over time reaching a maximum contaminant level (MCL) in an organism. Thus, pesticide contaminated water is especially a threat when groundwater is used for livestock slaughtered for food (Mapani & Ellmies 2011).

Heavy Metals: Some soils (e.g. humic soils) effectively retain heavy metals, diesel, and paraffin from spillages on the surface. In many part of Namibia, especially Windhoek, the very thin soil cover does not have a humic layer making groundwater vulnerable to large industrial spillages (Mapani 2005).

4.4.2 Main Sources

Key sectors contributing to water pollution in Namibia include:

Agriculture

Agriculture is the largest consumer of water and the main source of nitrate pollution in surface and groundwater and ammonia pollution. It also contributes considerably to phosphate pollution of waterways (Bruinsma 2003). Manure and fertilisers can increase nitrate content in groundwater and water bodies causing eutrophication. Other pollutants in water caused by livestock are fluoride, sulphate, and dissolved solids. Namibia also has evidence of contamination by E. coli in some wells in the North. The danger from pesticide contamination by farming activities is also a concern in Namibia (Wanke et al. 2014).

Humans can ingest pesticides through water, fruits, and vegetables, as well as dust and other aerosols. Spray drift of pesticides can be carried by wind over long-distances contamination water resources. The use of pesticides to maximise crop yields has become common in Namibia and threatened communal farmers in the north and commercial farmers in the south. Farm workers are the most exposed to pesticides. Residues of pesticides can also have a negative impact on ecosystems by degrading soils – especially by impairing the nitrogen fixation capabilities, which often causes farmers to add more nitrogen fertilisers. Key pesticides with known negative impacts on natural processes include DDT, pentachlorophenol and methylparathion (Mapani & Ellmies 2011).

It is estimated that around 98% of sprayed insecticides and 95% of herbicides reach an unintended destination, including surface and groundwater (Miller et al. 2004). Application of pesticides and herbicides have become the norm in much of Namibia to maximise crop yields in rural areas and on commercial farms. Commercial agricultural activities are undertaken along the riverbanks of the Okavango and Zambezi rivers (Mapani et al. 2011).

Pollution and the Okavango River

The Cubango and Okavango River Basin (CORB) is a network of rivers flowing though Namibia, Angola, and Botswanan. The Okavango River is the border between Angola and Namibia and flows into the Okavango Delta in Botswana. The area is internationally recognised as an important biodiversity conservation area with high biological productivity, iconic biodiversity, and diverse habitats. The Okavango Delta is a Ramsar and World Heritage Site (OKACOM n.d.).

A recent expedition by the National Geographic Okavango Wilderness Project in 2021, indicates limited changes in the abundance of wildlife, but considerable increases in human (3-fold compared to 2017) and agricultural activity - especially livestock (5-fold compared to 2017). Water abstraction for agriculture increased considerably, especially for larger irrigation schemes. 74% of the water abstracted from the Okavango River is used for agriculture. “Green schemes”, which are large, irrigated areas, account for 59% of total abstraction, followed by small scale agriculture (15%), municipal water (6%), lodges (4%) and fish farms (4%). In addition, nitrate levels were high and there were signs of plastic pollution (NGOWP 2021).

Livestock – mainly cattle – numbers increased considerably. Between Katwitwi and the Cuito confluence, livestock numbers increased from 2,342 in 2017 to 11,396 in 2021. Livstock contributed to erosion (through trampling) and overgrazing in certain areas and their excrements are suggested to have a negative impact on the quality of the water. The negative impact is predicted to spike at the beginning of the rainy season, when animal excrements are washed into the river. The annual flood, which depends on rainfall in the Angolan highlands, comes several months after the start of the rainy season (NGOWP 2021).

High nitrate (average 67 mg/l), pH, salinity, electrical conductivity and total dissolved solid (TDS) readings are a concern. In addition, five members of the expedition fell ill due to E.coli and typhoid contaminated river water, although the water was filtered with a specialised system. Close to urban centres and irrigated areas there was a brown foam on the water and tests indicated high nitrate and phosphate concentrations above recommended standards. Other pollutants in the river included sanitary pads and nappies, discarded fishing nets and plastics (NGOWP 2021).

The researchers and the expedition report suggest that the Okavango River is reaching pollution levels, which can have a negative impact on ecosystem services and biodiversity. There is a considerable risk of severe eutrophication, which could considerably diminish fish stocks. Currently, the cleaner water of the Cuito is “saving” the Okavango by diluting the downstream water. Poor rains in the Cubango catchment could have considerable impacts on the environment, water supply and people’s livelihoods (NGOWP 2021).

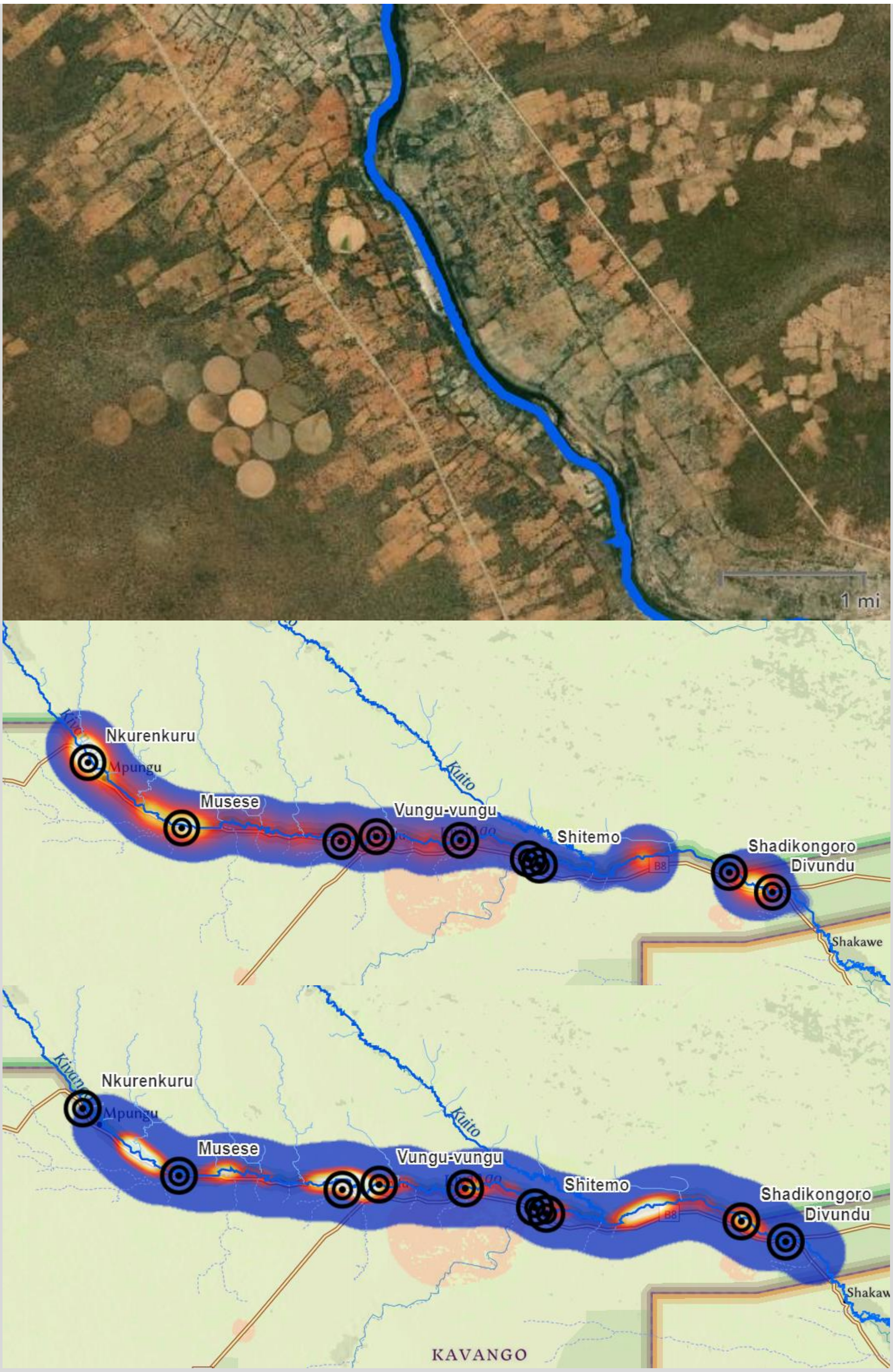


Figure 25. An irrigation scheme along the Okavango River (Top). Nitrate (Middle) and phosphate (bottom) concentrations and the location of major green schemes (Source: National Geographic Okavango Wilderness Project ArcGIS Maps).

Large-scale irrigation schemes introduce large volumes of agro-chemicals into and environment, especially large amounts of nitrogen-based chemicals. These can runoff and leach into groundwater and water bodies. If agro-chemical compounds are not biodegradable, they can accumulate in groundwater and water bodies with long-term consequences for the ecosystem. The excessive use of nitrogen is often associated with eutrophication by favouring nitrogen-fixing weeds and algae (SLR 2018). Irrigation water that percolates into the soil can also transport pesticides into groundwater. Depending on the nature of the aquifer this can take 10 (for fractured aquifers) to 50 years (in semi-arid conditions). Once the pesticides have contaminated groundwater, they are very difficult to remove (Mapani & Ellmies 2011). Within the Tsumeb Karst Aquifer, high chloride, sulphate, nitrate, and sodium contents also indicate irrigation return flows. The groundwater has a higher salinity due to overfertilisation paired with high evapotranspiration (Lohe et al. 2021). Other industries causing notable pollution in Namibia are tanneries and feedlots. Globally, the tanning industry is among the largest sources of hazardous wastes. In Namibia cattle production is about 2,370,000, while processed raw hides amount to 162,459.

Water Management & Sanitation

The City of Windhoek is classified as a high-risk aquifer zone, due to the thin soils and faults that expose the groundwater table. Pipe and sewer bursts are a major contamination problem in addition to chemicals spilled by different industries or oil spills from filling stations (Mapani 2005). Informal settlements do not have a central sewer system and rely on pit latrines or open defecation, which can be transported into surface and groundwater when it rains (Mapani 2005). Many aquifers in Namibia, especially with moderate to high potential, are fractured or porous, which makes them vulnerable to pollution (Fig. 26).

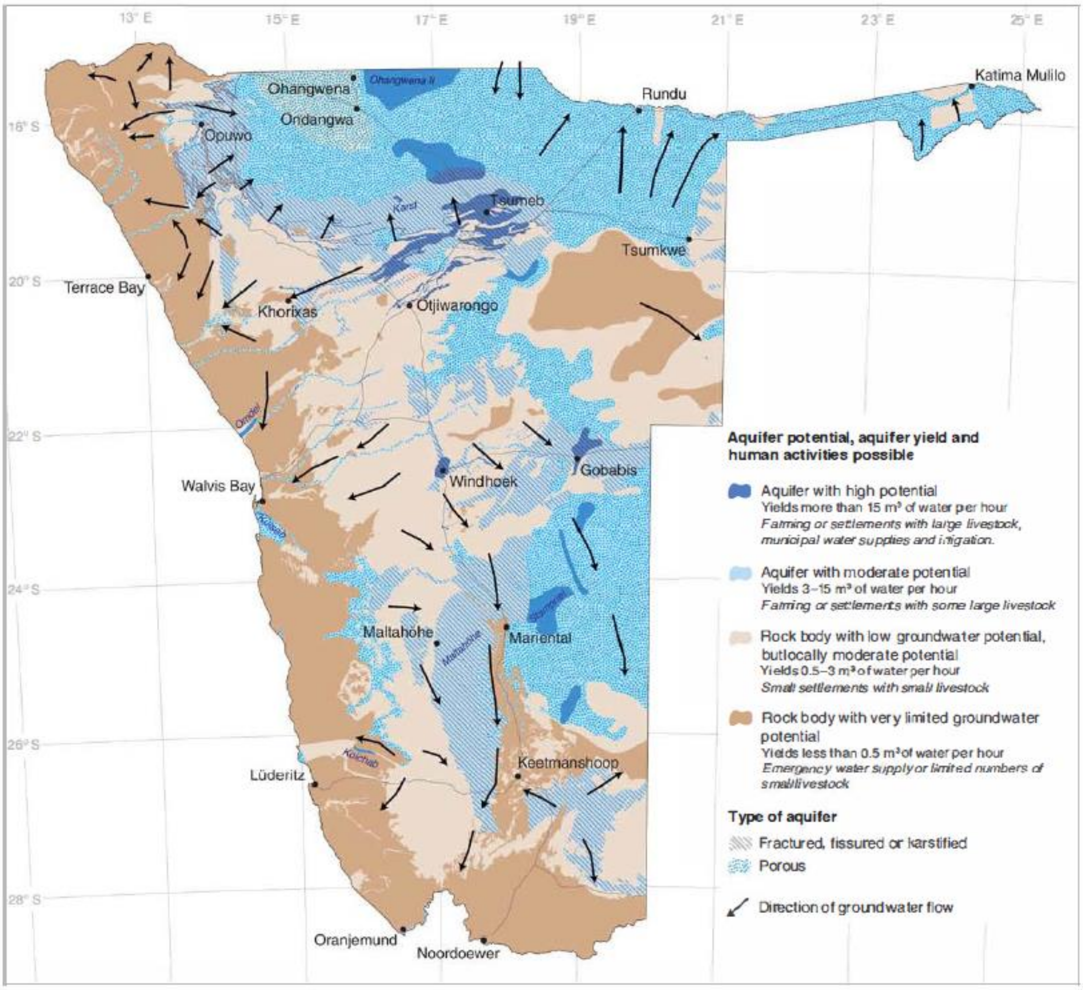


Figure 26. Types of aquifers in Namibia (Source: Atlas of Namibia 2022)

Public defaecation in green spaces and riverbeds is a considerable problem. It can contaminate water and is a source for diseases. In Windhoek, about 16,344 homes use "bush" for their toilet requirements in 2011. Extrapolations estimated an increase to about 30,000 homes with an average of 4 people in 2017 (Weber & Mendelsohn 2017). Migration into urban centres has increased over the years and driven sanitation problems (Mapani 2005). Fig. 27 below shows that the use of "bush" as toilet facility has steadily decreased in rural areas, although it remains at a high level, and increased in urban areas (Atlas of Namibia 2022).

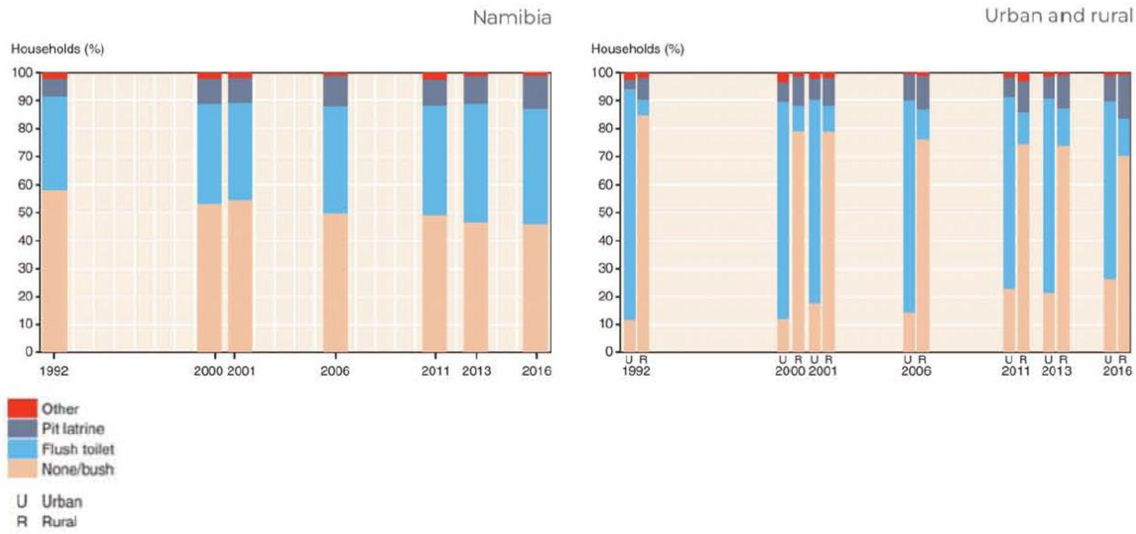
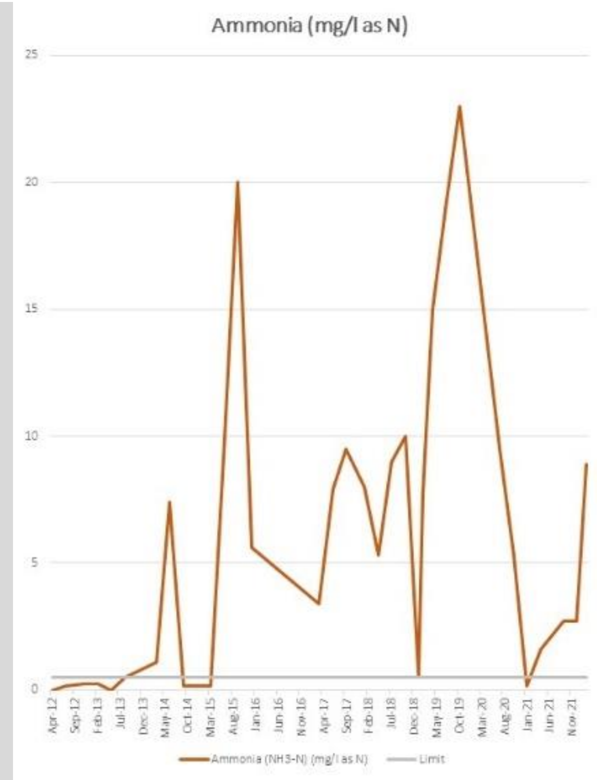


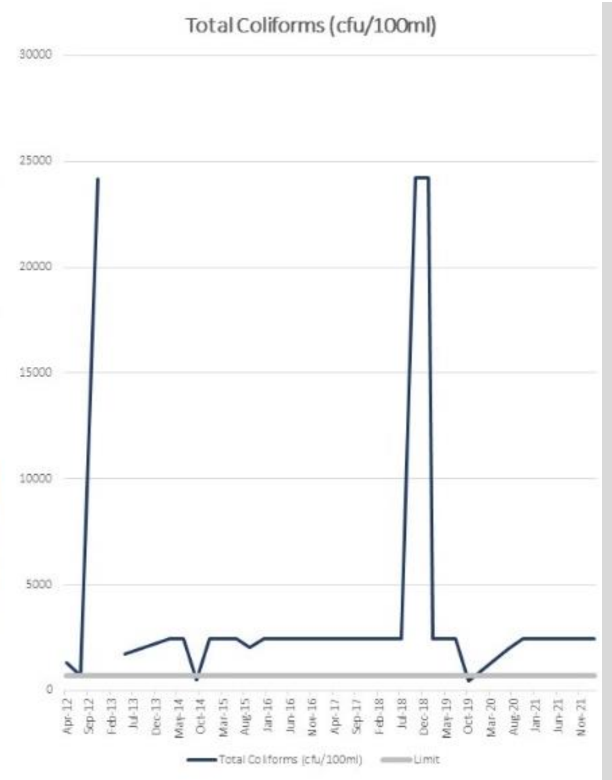
Figure 27. Access to sanitation facilities (Source: Atlas of Namibia 2022).

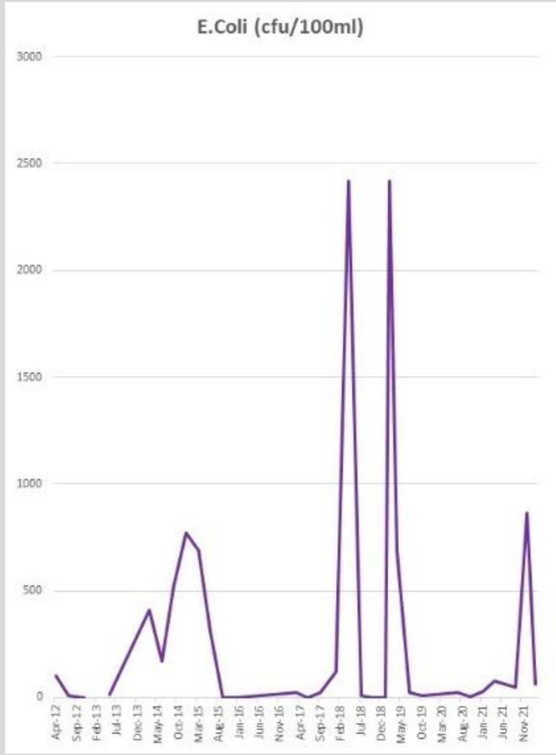
Failure to provide sanitation facilities can have significant consequences on water resources and the health of the population. Poor drinking water due to limited sanitation can lead to diseases such as diarrhoea, polio, and cholera, especially among young children, the elderly and those with weak immune systems (Lewis & Claasen 2018). Namibia's National Planning Commission (NPC), non-functional water infrastructure and inadequate water supply are a key threat to human health (Lewis & Claasen 2018). The design of water infrastructure can have a considerable impact on pollution levels. Open wells or unsealed manholes often become dumpsites for garbage and other deleterious materials (Hamutoko et al. 2016).

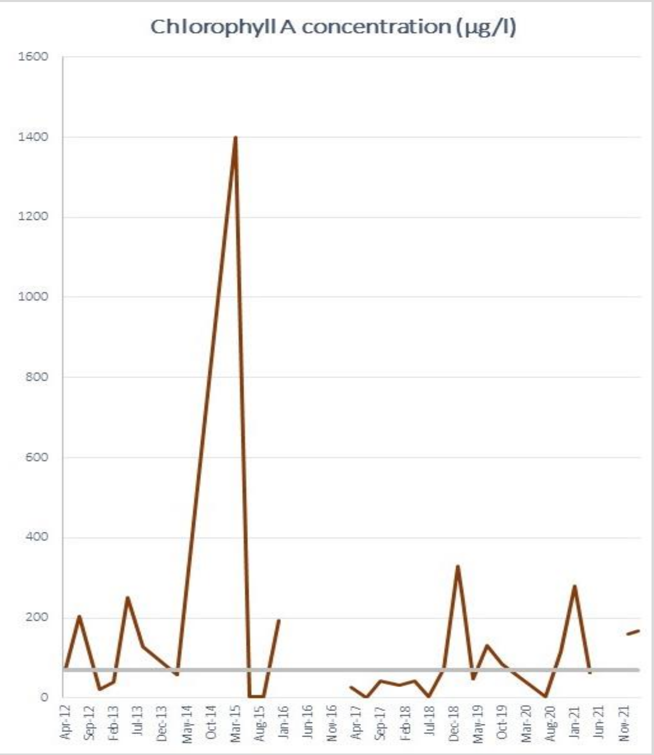
Sanitation and Health: Hepatitis E Outbreak in Informal Settlements
Between 2017 and 2020, Namibia was struggling with a Hepatitis E epidemic that started in the Khomas region and spread to the entire country. Hepatitis E is a liver disease caused by a virus with symptoms of acute jaundice. The epidemic mainly spread within informal settlements with poor sanitary conditions. Increasing rural to urban migration has driven the establishment of informal areas with substandard housing and poor sanitation facilities. Informal settlements have been growing at 8 % to 15% per year, compared to the average national population growth of 1.5%. Around 40% of households in Namibia's urban centres live in these informal settlements with no access to piped water, latrines, or other infrastructure (Bustamante et al. 2020).

Sanitation and Water Resources: Goreangab Dam
The Goreangab Dam in Windhoek is severely polluted by domestic and human waste, especially from the surrounding informal settlements which have limited access to sanitation facilities. The pollution of the Gorengab Dam contaminated the Swakoppoort Dam after heavy rains washing large amounts of waste into the Dam and remains so contaminated that the water can only be used when diluted. The Swakoppoort Dam is one of the main sources of water for Windhoek. The contamination of the dam can have serious impacts on water supply especially in poor rainfall years (Weber & Mendelsohn 2017).


Ammonia (mg/l as N)
25
20
15
10
5
0
Apr-12
Sep-12
Feb-13
Jul-13
Dec-13
May-14
Oct-14
Mar-15
Aug-15
Jan-16
Jun-16
Nov-16
Apr-17
Sep-17
Feb-18
Jul-18
Dec-18
May-19
Oct-19
Mar-20
Aug-20
Jan-21
Jun-21
Nov-21
Ammonia (NH3-N) (mg/l as N)
Limit


Total Coliforms (cfu/100ml)
30000
25000
20000
15000
10000
5000
0
Apr-12
Sep-12
Feb-13
Jul-13
Dec-13
May-14
Oct-14
Mar-15
Aug-15
Jan-16
Jun-16
Nov-16
Apr-17
Sep-17
Feb-18
Jul-18
Dec-18
May-19
Oct-19
Mar-20
Aug-20
Jan-21
Jun-21
Nov-21
Total Coliforms (cfu/100ml)
Limit


E.Coli (cfu/100ml)
3000
2500
2000
1500
1000
500
0
Apr-12
Sep-12
Feb-13
Jul-13
Dec-13
May-14
Oct-14
Mar-15
Aug-15
Jan-16
Jun-16
Nov-16
Apr-17
Sep-17
Feb-18
Jul-18
Dec-18
May-19
Oct-19
Mar-20
Aug-20
Jan-21
Jun-21
Nov-21


Chlorophyll A concentration (µg/l)
1600
1400
1200
1000
800
600
400
200
0
Apr-12
Sep-12
Feb-13
Jul-13
Dec-13
May-14
Oct-14
Mar-15
Aug-15
Jan-16
Jun-16
Nov-16
Apr-17
Sep-17
Feb-18
Jul-18
Dec-18
May-19
Oct-19
Mar-20
Aug-20
Jan-21
Jun-21
Nov-21

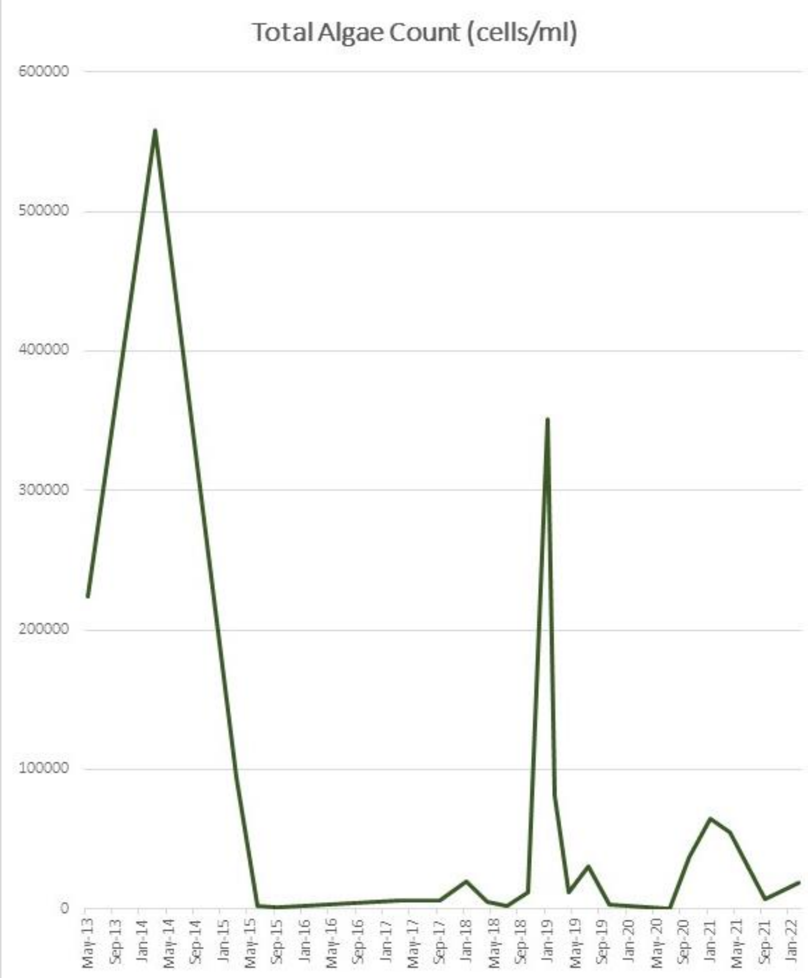


Figure 28. Ammonia, faecal coliforms, E.coli, chlorophyll a and algae in the Goreangab Dam in Windhoek (based on City of Windhoek data).

The City of Windhoek regularly takes water samples at the Goreangab Dam. Some of the results are shown in the graphs above. The pale grey line indicates acceptable limits. The graphs clearly show high levels of faecal coliforms, ammonia and E.Coli which are all signs of faecal contamination, for example by sewage overflows. City of Windhoek officials have indicated that at times around 80% of the inflow into the dam is from overspills of the Gammams Reclamation Plant, often caused by blocked sewage lines. High levels of faecal coliforms themselves are not necessarily a risk to human health, but they often indicate the presence of bacteria or viruses. Faecal coliforms should not exceed levels of 150 cfu/100ml. In the graph below, a limit of 700 cfu/100ml was chosen, which is the limit for very poor water quality and human contact with the water should be avoided (Waterwatch n.d.). The faecal coliforms in the Goreangab dam often exceed this limit considerably. Higher concentrations of ammonia are also a sign of faecal pollution. Natural levels of ammonia are normally not higher than 0.2 mg/l, while the EU limit for drinking water is 0.5 mg/l. Surface water bodies can have concentrations of up to 12 mg/l (WHO 2003). Goreangab Dam has considerably higher concentrations. In addition, there is a considerable presence of algae and chlorophyll a in the water, which suggests eutrophication. Chlorophyll a concentrations between 40 to 70 µg/l indicate narrowly managed or over-fertilised water bodies (Petter 2017, EPA n.d. *b*). The majority of algae found in the Gorengab Dam are Microcystis, which are the most common cyanotoxins. When the algae die, they release toxins into the water, which are very stable and difficult to break down. The toxins seldomly cause human deaths but can lead to illness. Animal poisoning and deaths are more common, and animals tend to be attracted to cyanobacteria and dried algae. Researchers suggest that there are negative impacts on fish species from 25 000 cells/l (WHO n.d.).

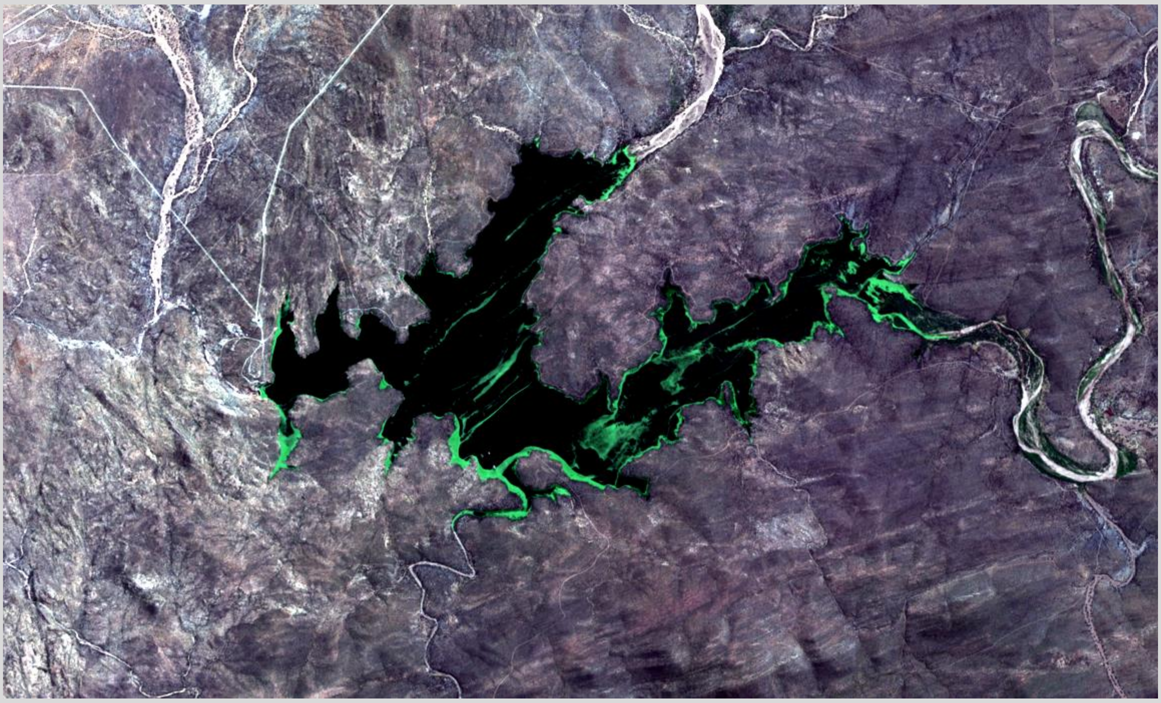


Figure 29. Sentinel satellite image of the Swakoppoort Dam, one of the major water suppliers for Windhoek, downstream of Goreangab Dam is eutrophicated (taken 7 March 2022).

A study in the Hardap Region of Namibia, indicated that pit latrines are not an environmentally sound way of sanitation. The high nitrate and coliform bacteria in groundwater indicated contamination of groundwater by both human and animal excrements. The study found that drinking water in some areas of the informal settlements is not safe for humans, mainly due to high levels of nitrate, total coliforms and E. coli bacteria. Main drivers were unhygienic practices at water points, poor resource management, as well as infrastructure layout and conditions (Lewis & Claasen 2018).

The management of sewage and wastewater from tourist establishments can also become an issue. Many tourism establishments are located in remote areas and use septic tanks for sewage and wastewater. In the Okavango Delta, the permeability of the sandy soils and low water table allow pollutants to travel considerable distances and the discharge of effluent into groundwater is common (McCarthy et al. 1994).

Waste Management

Especially rural water supply is at risk of being polluted by human or animal waste, and solid waste disposal (Lewis & Claasen 2018). Local authorities in Namibia are responsible for solid waste management and often have limited resources to collect solid waste in a regular and systemic way. Uncollected waste accumulates and become a source of pollution and disease transported offsite and into water bodies during heavy rains (Weber & Mendelsohn 2017).

Landfills are the most common solution for waste disposal in Namibia. They are used for solid waste, ash, building rubble and sewage sludge from industrial and municipal wastewater treatment plants. Toxic, hazardous, and radioactive waste are also disposed of in landfills. The landfills are often located on the edges of villages, towns, and mining settlements. The unsorted waste is dumped in any depression, valley, lowlands, or quarries. The sites are often located close to water supply zones and residential areas, which exacerbates pollution and health risks. Rain can lead to runoff or leaching from uncovered and buried waste. The leachate can have high concentrations of inorganic and organic compounds and drain into surface and groundwater causing long-term contamination. When leachate and groundwater mix, they create a plume which flows into the direction of groundwater (Lohe et al. 2021).

Cemeteries are special “dumpsites”. In Windhoek, some cemeteries are located close to the Aquifer Protection Zone (APZ). There is limited information on potential adverse impacts in the case of flooding or submersion of graves (Mapani 2005).

Mining

The Mining industry can also contribute to water pollution. Uranium mining for example may release residues of radioactive elements into groundwater, for example through effluents (Mathuthu et al. 2021). Contact with water or air can lead to the long-term production of sulphuric acid by bacteria causing the leaching of uranium or other contaminants for centuries. Other potential pollution parameters from uranium mining include TDS, TSS and heavy metals. The weathering of dimension stones such as marble or shist can lead to minerals leaching into water and soils. Poor handling of copper mining waste can also threaten water resources. There is also always some risks of hazardous substances or chemicals spilling from machinery and/or storage facilities. Water quality assessments at the Kombat, Tsumeb and Abenab mines have revealed unacceptable levels of lead, aluminium, iron, cadmium, calcium, and magnesium. Even if, as the Tsumeb Municipality indicated, the heavy metals can be removed, and that treated water can be used for domestic supply (Lohe et al. 2021), it still places an additional burden on the systems.

Industry

Larger cities in Namibia are growing fast. Windhoek has seen new industries develop – for example the textile industry – which introduced new types of effluents. There is often very limited information on their potential impacts on ground and surface water (Mapani 2005). Ramatex, a large textile company, has been one of the largest foreign direct investments in Namibia since independence. From the investment decision and throughout operations, there were considerable concerns around the water consumption of the factory (50% of Windhoek’s total consumption), pollution from contaminated waste and wastewater as well as health and safety of factory workers. In 2002, the company made headlines when several workers got skin rashes and swollen hands from dust and cotton particles in the air (Jauch & Shindondola 2003). The City of Windhoek later confirmed that chemicals used in the dyeing of fabric leached into groundwater and increased salinity (The New Humanitarian 2006, Isaacs 2007).

Observations around Windhoek also indicate spills of fossil fuels, which can seep into the groundwater. Especially filling stations have been urged by the Windhoek Municipality to regular inspect their tanks. Fossil fuels residues have been found in the Avis River, which pass through the entire city when it rains (Mapani 2005).

The Graph below shows the raw effluent feeding into the Ujams Reclamation Plant, which mainly treats industrial effluent from surrounding industries, which include meat processing, abattoirs, a brewery, and a tannery. The water is treated in the reclamation plant and discharged into the river. Fig. 30 below shows the average water parameters (between June 2017 and February 2022) going into the reclamation plant, and the percentage of the “raw in” concentrations discharged into the river after treatment. While phosphates, ammonia, and suspended solids were easily treated by the plant, the conductivity remained almost the same, nitrate as NO_2 increased and NO_3 increased by over 400%.

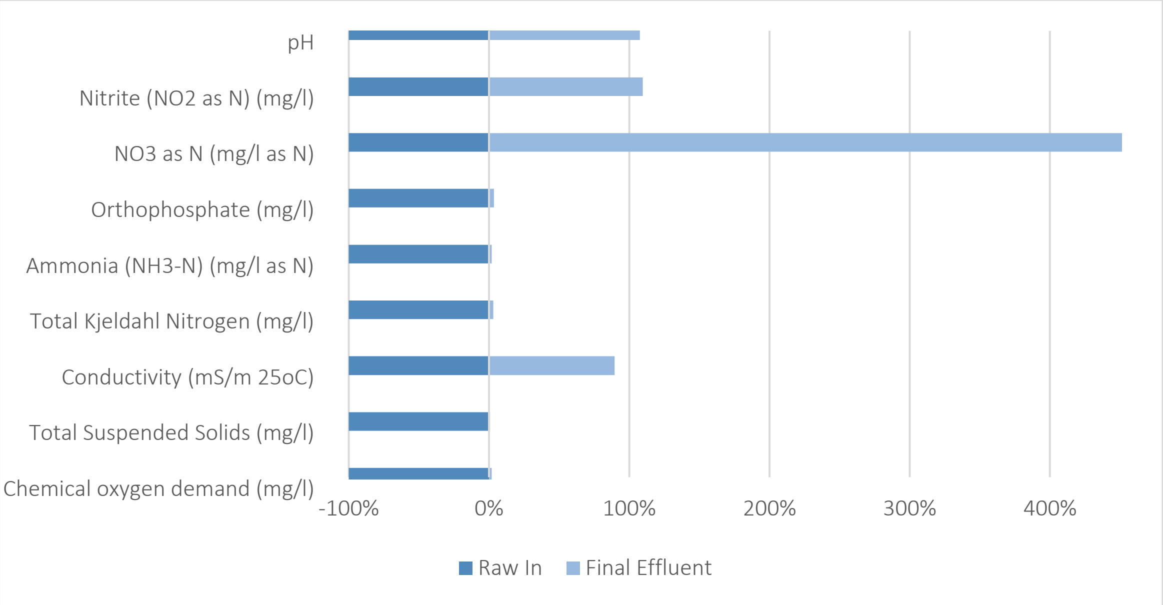


Figure 30. Industrial effluent treated at the Ujams Reclamation Plant in Windhoek and the final treated water discharged into the river (based on City of Windhoek data).

4.4.3 Drivers

Rapid urbanisation is driving water pollution issues. The fast growth of informal settlements with no sewage systems increases the risk of pollution from sewage, dumpsites, filling stations and cemeteries. Urban areas in Namibia had about 140,000 informal households in 2017, which is likely to double until 2024/2025 if not addressed. This trend is threatening the Windhoek aquifer (Mendelsohn 2016). Poor planning is another key component exacerbating pollution. For example, livestock pens or feedlots are built at higher elevations than boreholes, which enhances leaching of nitrates into groundwater of the boreholes (Lewis & Claasen 2018).

There is also a limited awareness of the importance of sanitation and water conservation (Lewis & Claasen 2018). Water security will become more and more important with population growth and climate change. Water management and climate change early warning and adaptation are important to minimise water losses (Reju & Kgabi 2018). Appropriate water monitoring and management systems are important to ensure a good water quality and quantity for future development (Lewis & Claasen 2018).

Main Threats / Impacts

- Health
- Water security and availability
- Drinking water quality
- Eutrophication and acidification
- Bacterial contamination
- Vulnerability to climate change

Main Pollutants

- Nutrients
- Faecal Coliforms
- Pesticides
- Heavy Metals

Main Sources

- Agriculture
- Water Management and Sanitation
- Waste Management
- Mining
- Industry

Drivers

- Urbanisation
- Growth of Informal Settlements
- Poor Planning
- Lack of Awareness

5. Risk Overview

The risk assessment below attempts to provide a first overview of the pollution risk to land and soil, biota, air, and water (outlined in the Chapter above) clustering the impacts according to the different pollution categories identified by the IUCN. These include:

- Agricultural and Forestry Effluents
- Airborne Pollutants
- Domestic and Urban Wastewater
- Garbage & Solid Waste
- Industrial and Military Effluents
- Excess Energy

The risk levels are assessed based on a scoring system, which considers the impact intensity, scale, and duration (jointly the consequences of pollution), the probability of the impact occurring, the impact significance (considering the consequences and the probability of an impact occurring), and the potential for mitigation. Impact scenarios were defined to guide the assessment of the impacts. However, the assessment remains subjective and should in the future be based on quantitative baselines and assessments. The detailed methodology and assessment are presented in Annex 1.

Table 1. Risk assessment of the pollution risk to land and soil, biota, air, and water. The impacts are clustered according to the different pollution categories identified by the IUCN. The risk levels are assessed based on a scoring system, which considers the impact intensity, scale, and duration (jointly the consequences of pollution), the probability of the impact occurring, the impact significance (considering the consequences and the probability of an impact occurring), and the potential for mitigation. High (H) impact significance is where pollution categories have considerable damage to land, biodiversity, water, and air quality, tend to affect relatively large areas and persist in the environment for a long time. Pollutant categories with a High (H) impact significance and Low (L) mitigation potential are shaded red (i) to indicate where the overall impact has been risk assessed as

high. Pollutant categories with a Low (L) impact significance and High (H) mitigation potential are shaded green (iii) to indicate where the overall impact has been risk assessed as low.

IUCN Category	Pollutants	Source	Impact: Significance	Impact: Mitigation Potential
Agricultural & Forestry Effluents	Pesticides & POPs Ammonia Nutrients (Nitrogen & Phosphorus) Soil Erosion / Sedimentation	Health Irrigated Agriculture Cropping Livestock Land Clearing	**H (i)**	**M (ii)**
Airborne Pollutants	Ozone Other GHGs Ammonia Particulate Matter / Dust	Uncontrolled Fires Burning of Waste / Waste Management Household Fuel Mining Charcoal Agriculture Industry	**H (i)**	**L (i)**
Domestic & Urban Wastewater	Faecal Coliforms E.Coli	Open Defecation Water and Sewage Management Sanitation Agriculture	**M (ii)**	**M (ii)**
Garbage & Solid Waste	Microplastics Hazardous Waste Heavy Metals	Industry Waste Management	**M (ii)**	**H (iii)**
Industrial & Military Effluents	Heavy Metals Phenols Salts / Dissolved Solids	Mining Hunting	**M (ii)**	**L (i)**
Excess Energy	Noise Light	Mining Industry Transport	**L (iii)**	**H (iii)**

Most pollution categories with a high impact significance have the potential to create considerable damage to land, biodiversity, water, and air quality, tend to affect relatively large areas and persist in the environment for a long time. The potential impact is often exacerbated by limited monitoring and enforcement of rules, unclear guidelines, and limited collaboration between sectors. Mitigation potential was discussed within the Namibian context.

In many cases, the mitigation potential is limited due to the high costs, lack of budget, old infrastructure, and little centralisation, which would reduce costs of building new infrastructure (e.g. sewage systems, housing, and sanitation facilities). Other areas are easier to address for example developing and implementing improved land fill standards e.g. site location, lining of landfills, other disposal systems. The mitigation of air pollution is more complex due to its transnational nature. In the risk assessment, airborne pollutants rank high due to the considerable global impacts – especially on global warming. However, Namibia has limited influence over the scale of impact and the intensity: Namibia has a relatively small economy, contributes little to global emissions and is considered a net sink. Thus, Namibia's mitigation potential is limited (although Namibia has committed to a 91% reduction in emissions in the recently submitted NDC) and adaptation finance and thus the capacity to adapt to climate change impacts is well below current and projected damages / actions necessary.

Ideally, a detailed risk assessment should be done for every pollutant. This requires a better baseline on current quantities used and their impacts.

6. Conclusion & Recommendations

Namibia faces significant environmental threats such as land degradation, biodiversity loss, declining marine resources, pollution of scarce water resources and climate change. Due to Namibia's vast landscapes and low population density, issues of pollution have long been overlooked. Increasing economic activity and fast urban growth pose major threats to the environment. The natural environment is one of Namibia's greatest assets and the majority of Namibia's population depends on natural resources for survival. Pollution has considerable impacts on Namibia's land and soil, biodiversity, air, and water quality, as well as human health, sectors that are very vulnerable to climate change.

Economic development without appropriate social and environmental standards and enforcement for industrial processes, mining and agriculture can have considerable negative impacts on the environment but is also necessary to address issues and pollution impacts caused by aging infrastructure and rapid urbanisation (e.g. a lack of sanitation, appropriate housing, and sewage systems).

This report provides a starting point towards assessing and addressing pollution in Namibia. The report provides a higher-level overview of pollution and available information of pollution, which can help to guide future interventions and programmes. Stakeholder engagement clearly indicated the urgency and increasing awareness on pollution issues. There is a considerable need to improve the understanding of pollution in Namibia and develop integrated solutions to govern, monitor and mitigate pollution across its landscapes. This includes:

- Conducting further research and quantifying the pollution problem and its impacts. There is a considerable need to establish baselines on different pollutants to assess their risk, quantify potential economic losses (or costs of inaction) and identify priorities.
- Establishing inclusive systems and building the capacity to monitor pollution and its impacts on health and biodiversity under climate change conditions.
- Supporting the Namibian government to enhance and revise the governance of pollution in line with other environmental commitments on biodiversity and climate change.
- Building knowledge and capacity on suitable pollution mitigation strategies.
- Elevating pollution as a national priority that is integrated into national planning processes and development objectives.
- Building multi-sectoral partnerships for pollution control.

- Mobilising funding for pollution control to address health, biodiversity, and climate change impacts.

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8. Annex 1

Consequences of an impact are a function of the intensity, scale and duration of the impact.

Intensity of Impact	
H	Substantial deterioration. Recommended levels are violated. Irreplaceable loss of resources.
M	Moderate/measurable deterioration. Recommended level will occasional be violated. Noticeable loss of resources.
L	Minor deterioration. Change not measurable. Limited loss of resources.

Spatial Scale of Impact	
H	Far beyond site boundary. Regional/national
M	Beyond site boundary
L	Localized - within site boundary

Duration of Impact	
H	Long-term. >5 years
M	Medium term. 2-5 years
L	Short-term <1 year

Probability of Impact	
H	Definite/Continuous
M	Possible/Frequent
L	Unlikely/Seldom

Calculation Significance

*Significance = Consequence * Probability*

Average of the Consequence e.g. HHH = 3+3+3 / 3 = 3 ==> H

H	3
M	2
L	1

Rounding: 0.5 rounds up to 1. 0.3 and lower rounds down. To avoid being too conservative.

Consequence * Probability

HH	→	H
HM	→	H
HL	→	M
MM	→	M
ML	→	M
LL	→	L

IUCN Category	Pollutants	Source	Scenarios / Impact Description	Impact					
				Consequence			Probability	Significance	Mitigation Potential
				Intensity	Scale	Duration			
Agricultural & Forestry Effluents	Pesticides & POPs Ammonia Nutrients (Nitrogen & Phosphorus) Soil Erosion / Sedimentation	Health Irrigated Agriculture Cropping Livestock Land Clearing	▪ Pesticides are readily available at retailers and used. ▪ Considerable use of pesticides to control bush encroachment and pests / diseases such as malaria and tse tse fly. ▪ Considerable long-term impacts on health, biodiversity and water quality due to bioaccumulation and bio-magnification. ▪ Decreasing soil fertility and productivity may impact food production with impacts on health and food security. ▪ Loss of species diversity, especially of non-target species. ▪ Eutrophication of valuable water resources and negative impacts on water quality reducing climate change resilience. ▪ Driven my agricultural expansion and climate change impacts (e.g. recurring droughts that have degraded soils). ▪ Limited monitoring and enforcement, as well as understanding and awareness make timely mitigation or prevention difficult.	H	M	H	M	H	M
Airborne Pollutants	Ozone Other GHGs Ammonia Particulate Matter / Dust	Uncontrolled Fires Burning of Waste / Waste Management Household Fuel Mining Charcoal Agriculture Industry	▪ Considerable negative impacts in the long-term due to global warming threatening ecosystems, biodiversity, and food security. ▪ Namibia is a net carbon sink and has a fairly limited impact on global GHG budgets. ▪ Very likely to increase with industrial development and increasing mining activities. ▪ Limited resilience against climate change hazards and impacts, and disproportionally negatively impacted. ▪ Relatively easy mitigation at a national level by improving land management, promoting green development, and phasing out harmful technologies / products. Ultimately net carbon sink and dependent on synergised action by all	H	H	H	M	H	L

			countries, especially developed countries, to reduce global warming.						
Domestic & Urban Wastewater	Faecal Coliforms E.Coli	Open Defecation Water and Sewage Management Sanitation Agriculture	▪ Considerable negative impact on water supply. ▪ Even after water treatments grey water is transported into riverbeds. ▪ Often difficult and expensive to clean contaminated water sources, especially once contaminants reach groundwater. ▪ Driven by fast urbanisation and expanding informal settlements with limited budget availability and efforts to improve the situation.	M	M	M	M	M	M
Garbage & Solid Waste	Microplastics Hazardous Waste Heavy Metals	Industry Waste Management	▪ Considerable negative impacts on biodiversity and ecosystems. ▪ Toxic leachate can be transported offsite and into groundwater threatening Namibia's limited water resources with considerable impacts on human and animal health. ▪ Negative impact on human wellbeing due to unpleasant smell and visuals. Emissions from leachate.	M	M	M	M	M	H

Industrial & Military Effluents	Heavy Metals Phenols Salts / Dissolved Solids	Mining Trophy Hunting	▪ Heavy metals are often readily taken up by food crops. ▪ Considerable long-term health impacts: Bioaccummulation in animal and human tissue with negative impacts on biodiversity and human health. ▪ Often difficult and costly mitigation, especially for heavy metals and phenols and once infiltrated into groundwater. ▪ Mitigation possible and outlined in Environmental Management Plans: Monitoring and enforcement unclear. Need for industry standards.	M	M	H	L	M	L
Excess Energy	Noise Light	Mining Industry Transport	▪ Namibia is sparsely populated: Noise and light pollution are mainly issues in larger urban centres. ▪ Limited national guidelines and monitoring (e.g. noise standards for industry or the transport sector). ▪ Relatively simple mitigation (e.g. dimming lights or planting trees as noise filters along major roads).	L	L	L	L	L	H