CHEMICAL ALERT AFRICA (CAA)

LEAD 13000 OF THEM MERCURY CADMIUM BISPHENOLS (BPA) PHTHALATES PERC AND TCE PESTICIDES PFAS, PFOS FLAME RETARDANTS PLASTICISERS

A Situational Analysis of Endocrine Disrupting Chemicals and Emerging Contaminants of Concern in South Africa

2024

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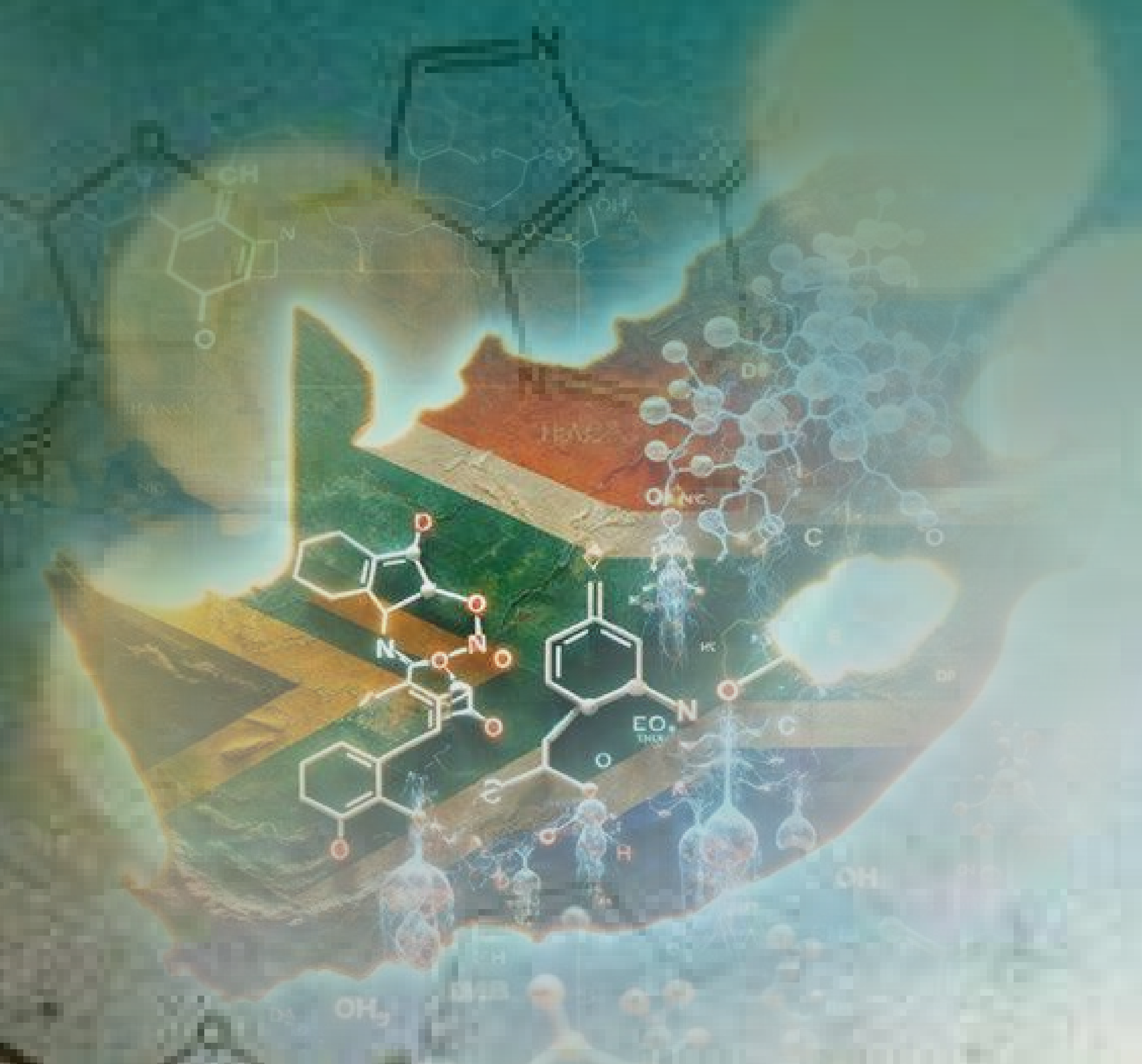

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EXECUTIVE Summary

This report sheds light on the widespread presence and impact of Endocrine Disrupting Chemicals (EDCs), substances known for interfering with hormonal functions and posing significant risks to human health and fertility, as well as the environment. The report delves into the properties and prevalence of various EDCs within the South African context, including Bisphenol A, Phthalates, Polychlorinated Biphenyl's (PCBs), Parabens, and Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS). Pesticides were excluded due to the extensive research already conducted on their endocrine disruptive properties and mechanisms of action. Highlighting the multifaceted challenges posed by these chemicals, the report underscores the need for an integrated approach to address their effects. It raises concerns about the current regulatory framework and the gaps in managing the risks associated with EDCs. The introduction sets the stage for the subsequent detailed exploration of these chemicals, emphasizing the necessity for informed policymaking, improved industrial practices, and heightened public awareness to mitigate the adverse effects of EDCs on both health and the environment in South Africa.

A comprehensive and multi-faceted methodology was used to analyse the impact of EDCs in South Africa. The approach integrates a literature review, data analysis, and case studies to provide a thorough understanding of these chemicals. This includes an assessment of their properties, prevalence, and regulatory status within the country. The methods focus on gathering and evaluating information from various scientific, governmental, and industrial sources, ensuring a well-rounded perspective on the issue. Additionally, the report utilizes established frameworks such as Drivers, Pressures, State, Impact, and Responses (DPSIR) to systematically evaluate the implications of EDCs on human health and the environment. This rigorous methodology underpins the report's findings and recommendations, aiming to inform effective policymaking and management strategies.

The report provides a detailed analysis of the presence and impact of EDCs in South Africa. It reveals the widespread occurrence of various EDCs like Bisphenol A, Phthalates, PCBs, Parabens, and PFAS in different environments and consumer products. The report highlights the significant health and environmental risks associated with these chemicals, including hormonal disruptions, reproductive issues, and ecological damage. The findings underscore the inadequacies in current regulatory frameworks and the lack of comprehensive strategies to address these risks effectively. The results also point out the gaps in public awareness and industry practices regarding the handling and management of EDCs, emphasizing the need for a multi-pronged approach to mitigate their impact.

In the discussion and recommendations section of the report, there is a detailed analysis of the implications of the findings on EDCs in South Africa. It emphasizes the need for stronger regulatory frameworks and more effective management strategies to address the risks posed by EDCs. The recommendations advocate for a multi-faceted approach, encompassing improved policymaking, adequate industry practices, and public awareness campaigns. The discussion also highlights the importance of further research to fill knowledge gaps and develop innovative solutions to mitigate the adverse effects of EDCs on human health and fertility, and the environment.

ACKNOWLEDGEMENTS

This report was conceived by the Board members of Chemical Alert Africa (CAA).

Sean Patrick identified relevant frameworks and carried out the analysis for the report, developed the structure and was the principal author, with inputs from Aqiel Dalvie and Bruce Dick.

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List of ABBREVIATIONS

Abbreviation	Definition
AHTN	Acetyl hexamethyl tetralin
BBP	benzyl butyl phthalate
BPA	Bisphenol A
BPF	Bisphenol F
BPS	Bisphenol S
CFCs	Chlorofluorocarbons
CSIR	Council for Scientific and Industrial Research
DBP	dibutyl phthalate
DHEP	di(2-ethylhexyl) phthalate
DPSIR	Driving Forces, Pressure State, Impact and Response
EDCs	Endocrine Disrupting Chemicals
ESOC	Emerging Substances of Concern
EU	European Union
EQUATOR	Enhancing the QUAlity and Transparency Of Health Research
FDA	Food and Drug Administration
GIS	Geographical Information Systems
IARC	International Agency for Research on Cancer
IVA	Integrated Vulnerability Assessment
NGOs	Non-Governmental Organizations
PAHS	Polyaromatic hydrocarbons
PBES	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated Biphenyls
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
PFOA	Perfluoro-Octanoic Acid,
PFOS	Perfluoro-Octanesulfonic Acid
POPs	Persistent Organic Pollutants
PPCPs	Pharmaceutical and Personal Care Products
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta Analysis – Scoping Reviews
PVC	Polyvinyl Chloride
SA	South Africa
SANBI	South African National Biodiversity Institute
UNEP	United National Environmental Programme
VOC	Volatile Organic Compounds
WHO	World Health Organization

INTRODUCTION

The United Nations Sustainable Development Goals (SDGs) provides a framework to address numerous global challenges, aimed at primarily reducing poverty, climate change, environmental degradation and health and well-being for all. More specifically, SDG 3.9 is aimed at reducing the adverse health effects associated with hazardous chemicals in water, and other environmental matrices.

Mounting evidence suggests that with the increase in developments in the chemical industry, there has been a simultaneous steady increase in male reproductive and developmental abnormalities (1). Environmental chemicals may possess endocrine mimicking properties and may interfere with normal functioning of the hormonal system. These environmental chemicals are persistent in the environment due to their slow degradation, the high volumes produced and/or their consistent production, thus posing a significant threat to the health of humans, animals, aquatic life and other living organisms for many years after they are released into the environment (2). Studies show that exposure to these environmental chemical pollutants may adversely affect human health in general, particularly human reproductive health and potentially fertility, by affecting the hormone-dependent pathways responsible for male and female gonadal development (3). These chemicals are referred to as endocrine disrupting chemicals (EDCs).

Endocrine disrupting chemicals are described as “exogenous agents that interfere with the production, release, transport, metabolism, binding, action, or elimination of the natural hormones in the body that are responsible for the maintenance of homeostasis”, resulting in adverse effects in the affected organ (4). EDCs can function as either androgenic or anti-androgenic, as well as estrogenic or anti-estrogenic substances, attaching or hindering the attachment of steroid hormone receptors found in Sertoli cells, germ cells and Leydig cells (5), thus causing disorders of the reproductive system, which may lead to infertility (6). Due to these reasons and more, studies on EDCs have been a centre of attention around the globe in recent years. Many underlying mechanisms have been proposed (7), although there are limited studies that explore the specific modes of action of EDCs.

EDCs can be classified into two categories: naturally occurring and synthetic (manmade). Naturally occurring EDCs can be present in foods containing phytoestrogens. (8, 9) Examples of synthetic compounds include plastics (e.g., bisphenol A (BPA)), pesticides (e.g., pyrethroids), fungicides (e.g., vinclozolin), plasticizers and some pharmaceutical agents (9). EDCs can also be grouped according to their origins, natural and synthetic hormones (e.g., contraceptive pills and thyroid medicines), drugs with normal hormonal side effects, industrial and household chemicals, side products of industrial and household processes (9).

Similar to hormones, EDCs can exert an effect at various times during the life-cycle - foetal development, infancy, childhood, puberty, adulthood and old age, known as critical windows of exposure (10). The timing of the exposure, especially during the male programming window (11), is critical as this can determine the degree of impact. Experimentally, in utero, during lactation and/or from direct exposure, EDCs can have detrimental health effects resulting in adult onset of disease, with possible transgenerational effects (12). Additionally, EDCs exist in complex mixtures and can exert additive or synergistic effects, particularly at low doses, resulting in the "something from nothing" phenomenon, where effects are only seen in complex mixtures and not individual exposure (13).

While the list of chemicals with known endocrine disrupting activity is growing, there are numerous replacement chemicals an that require further investigation (14). Emerging substances of concern (ESOC) are defined as naturally occurring or synthetic chemicals that are not routinely screened for in the environment but have the potential to cause adverse ecological and/or human health effects (15). Since these chemicals have been undetected in the environment, in most instances, limited information exists on their occurrence, fate, ecological and biological effects. Many of these ESOC may have endocrine disruptive properties and therefore potentially pose a threat to humans and wildlife (16).

Although international organizations and high-income countries are developing strategies and guidelines to detect, quantify and determine the effect of ESOCs; these strategies and guidelines may not adequately address the South African context. Sources of ESOCs can include everyday products such as cosmetics, personal care products, pesticides, and over the counter medications (17). These ESOCs and possible EDCs are not considered for routine screening under the South African Water Quality Guidelines unless local conditions indicate a potential for contamination. This has led to concerns about the presence, fate and regulation of these compounds in the environment and their classification as ESOCs.

AIM AND OBJECTIVES

The overall aim of this report was to conduct a situational analysis of EDCs and ESOCs in South Africa, and through comprehensive and multi-faceted approaches analyse the impact of these compounds in the South Africa context and propose feasible future actions.

The specific objectives were to:

- Synthesize available data and prioritize EDC by conducting a comprehensive scoping review to gather and summarize available data on endocrine-disrupting chemicals (EDCs) in South Africa, selecting priority EDCs using criteria-based methods, and outlining trends and data gaps.
- Explore the distribution and usage of EDCs in South Africa by accessing and analysing national and regional databases to retrieve detailed data.
- Visualize data effectively by utilizing Tableau Public to create visual representations of the geographical distribution and impacts of EDCs, making the data accessible and interpretable for various stakeholders.
- Apply the DPSIR framework (Driving Forces, Pressure, State, Impact, and Response) to understand the dynamics and interrelation of EDCs in South Africa.
- Analyse epidemiological impacts and assess vulnerability by drawing conclusions on the epidemiological situation and impacts of EDCs and identifying vulnerable groups by adapting the Integrated Vulnerability Assessment (IVA) framework to combine demographic and ecological data, forming a vulnerability index visualized using Tableau.
- Propose recommendations by conducting a comparative analysis with global benchmarks or regions with similar contexts, and design a conceptual framework outlining areas where future research would be most impactful in understanding EDCs in South Africa.

METHODOLOGY

The overall aim of this report was to conduct a situational analysis of EDCs and ESOCs in South Africa, and through comprehensive and multi-faceted approaches analyse the impact of these compounds in the South Africa context and propose feasible future actions.

Scoping Review

Aim: Conduct a thorough scoping review, which allows for a broad exploration of the epidemiology and eco-environmental impacts of EDCs in South Africa, identifies gaps, and summarizes a range of evidence to convey the breadth and depth of the field.

Search strategy and eligibility criteria

All article titles and abstracts from the literature search were manually screened, spanning 2000 to 2023. Reference lists of the retrieved full-text articles were reviewed. From these lists, relevant references aligned to the inclusion criteria not initially identified were retrieved and added. Peer-reviewed studies and reports published between 1 January 2000 and 01 October 2023 were reviewed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR). The PRISMA-ScR was developed according to published guidance by the EQUATOR (Enhancing the QUAlity and Transparency Of Health Research) Network to establish reporting guidelines.

A broad topic search was done first using Web of Science, Scopus, Science Direct, and Google Scholar, using keyword search strings including "emerging contaminants," "water contaminants," and "South Africa."

Thereafter a topic search using the "advanced search option" was performed within the ISI Web of Knowledge, Scopus, PubMed and Dimensions electronic databases and applying the following and Boolean operators (endocrine disrupting chemicals OR Endocrine disrupt* OR EDCs OR Endocrine Disrupting Chemicals OR EDCs AND emerging contaminants OR contaminants of emerging concern OR emerging pollutant OR personal care product OR pharmaceutical and personal care product AND Public Health OR Microplastic OR POPs OR Persistent Organic Pollutants OR Insecticide OR Pesticide OR organophosphate OR plasticizer AND pollutant OR Health OR ecological OR eco-environmental OR epidemiology OR cancer AND 2000 to 2023 AND South Africa).

Data Extraction

Data was extracted using a standardized data collection form. The variables for data extraction included inter alia: the country or location of study; year of study; study design; study aims; study outcome measures; results, and conclusion of the study.

Various matrices were recorded, including air, soil and water. Additionally, water samples were classified as either wastewater, surface water, or groundwater. Groundwater was made up of samples taken from boreholes and wells. Surface water included samples from rivers, lakes, springs, dams, and deltas. Chemicals were classified into one of eight categories: EDCs, hormones, inorganic ions, PFAS, pharmaceutical and personal care products (PPCPs), pesticides, pharmaceuticals, and polyaromatic hydrocarbons (PAHs). Further analysis was conducted on EDCs, hormones, PFAS, PPCPs, and pharmaceuticals if they were defined as emerging contaminants. Some compounds reported fell under multiple chemical categories. In such cases, the categorization made by the respective author was given preference. All chemicals and their assigned categories can be found in the open-source database.

Database Exploration

National and regional databases were accessed to retrieve more detailed data on EDCs' distribution and usage in South Africa.

1

Identified Relevant Governmental and Research Institutions: South African governmental departments and research institutions were identified that might hold relevant data. This included the Department of Environmental Affairs, Department of Health, and local environmental agencies. Universities and research institutions in South Africa that often conduct studies on EDCs were also identified.

2

Explore Publicly Available Databases: Many governmental and research institutions have publicly available databases. The South African National Biodiversity Institute (SANBI) and the Council for Scientific and Industrial Research (CSIR) were explored to identify relevant environmental data. These databases can be accessed through their respective websites.

3

Utilized International Databases: Besides national and regional sources, international databases such as the World Health Organization (WHO) or the United Nations Environment Programme (UNEP) had relevant data on EDCs in South Africa.

4

Data Mining and Analysis: Data on the types of EDCs used, geographical distribution, concentration levels, and usage patterns in different industries or regions within South Africa was extracted.

Criteria-Base Selection

Utilizing the discussions and the rationale below, criteria were used to prioritize and select a limited number of EDCs for further examination.

1

Prevalence and Usage Patterns: Contaminants were identified that are frequently used or prevalent in South Africa. This included substances in industrial processes, agricultural practices, consumer products, and pharmaceuticals. High usage often correlates with a greater likelihood of environmental and human exposure.

2

Environmental Persistence: Focus was placed on compounds that have suspected EDC activity or are deemed as ESOCs.

3

Toxicity and Health Impact: Compounds that have been identified in scientific studies as having potential or known toxic effects on humans and wildlife were included. This includes endocrine disruption, carcinogenicity, reproductive toxicity, and developmental impacts. Even when the full extent of health impacts was unknown, compounds were included where there was evidence of potential harm.

4

Lack of Existing Regulation[1]: Compounds that have little to no regulatory oversight in South Africa were included to focus attention on chemicals that might be slipping through existing safety nets and thus pose an unaddressed risk.

5

Detection and Monitoring Capability: One criterion was to include compounds that are feasible to be detected and monitored in the environment. This includes the availability of methods for measuring the presence and concentration of these substances in various environmental matrices (water, soil, air) and biota. Prioritizing contaminants that can be realistically monitored aided in creating the monitoring and evaluation plan and will help track their distribution and assess the effectiveness of any future regulatory interventions.

Selecting emerging contaminants based on these criteria made it easier to identify substances that pose a significant risk but are currently under-regulated, and guide policymakers and researchers in South Africa towards more effective environmental management and protection strategies.

Tableau public for visualization

Tableau Public was used as a data visualization tool, to represent geographical findings of EDCs distribution and impact, making the data accessible and interpretable for various stakeholders.

1

Data Preparation: Data on the chosen chemicals in South Africa, including their location, province, authors, concentrations (if available), chemical, chemical class and matrix was extracted into an excel database.

2

Creating a Geographical Map: A map was created by dragging the geographical field (provinces in South Africa) onto the canvas. Tableau Public created a map based on these locations.

3

Adding Data Layers: Layers such as number of chemicals, number of classes and concentrations were overlayed using the 'Marks' card. Tableau Public allows customization of these layers with assorted colours, sizes, and shapes to represent various data points effectively.

[1]Further details on existing policies, legislation and programmes related to EDCs in South Africa can be found in the CAA report by Kevin Dornbrack: CAA (2024) Situation Analysis of Endocrine Disrupting Chemicals in South Africa: Legislation, Policies and Programmes

Driving forces, pressure, state, impact, and response framework

The Driving Forces, Pressure, State, Impact, and Response (DPSIR) method is a comprehensive framework used for understanding and managing environmental issues (Figure 1). This method provides a systematic approach to analyse environmental problems, identifying their causes, effects, and potential solutions. It helps in creating targeted strategies for environmental management and policymaking.

The framework is structured as follows:

1. **Driving Forces:** These are the broader social, demographic, economic, or political factors that indirectly impact the environment. Examples include urbanization, industrialization, and economic growth.

2. **Pressure:** Stemming from the driving forces, these are the direct actions that cause changes in the environment. This includes pollution, land use change, resource extraction, and waste generation.

3. **State:** This refers to the condition of the environment because of the pressures. It includes various indicators such as air and water quality, biodiversity levels, and soil condition.

4. **Impact:** These are the effects of the environmental state on human health, ecosystems, and economic sectors. Impacts may include health issues due to pollution, loss of biodiversity, and economic losses due to reduced resource availability.

5. **Response:** These are the actions taken by governments, organizations, or communities to prevent, mitigate, or adapt to environmental changes. Responses can include legislation, technological innovation, changes in practices, and educational campaigns.

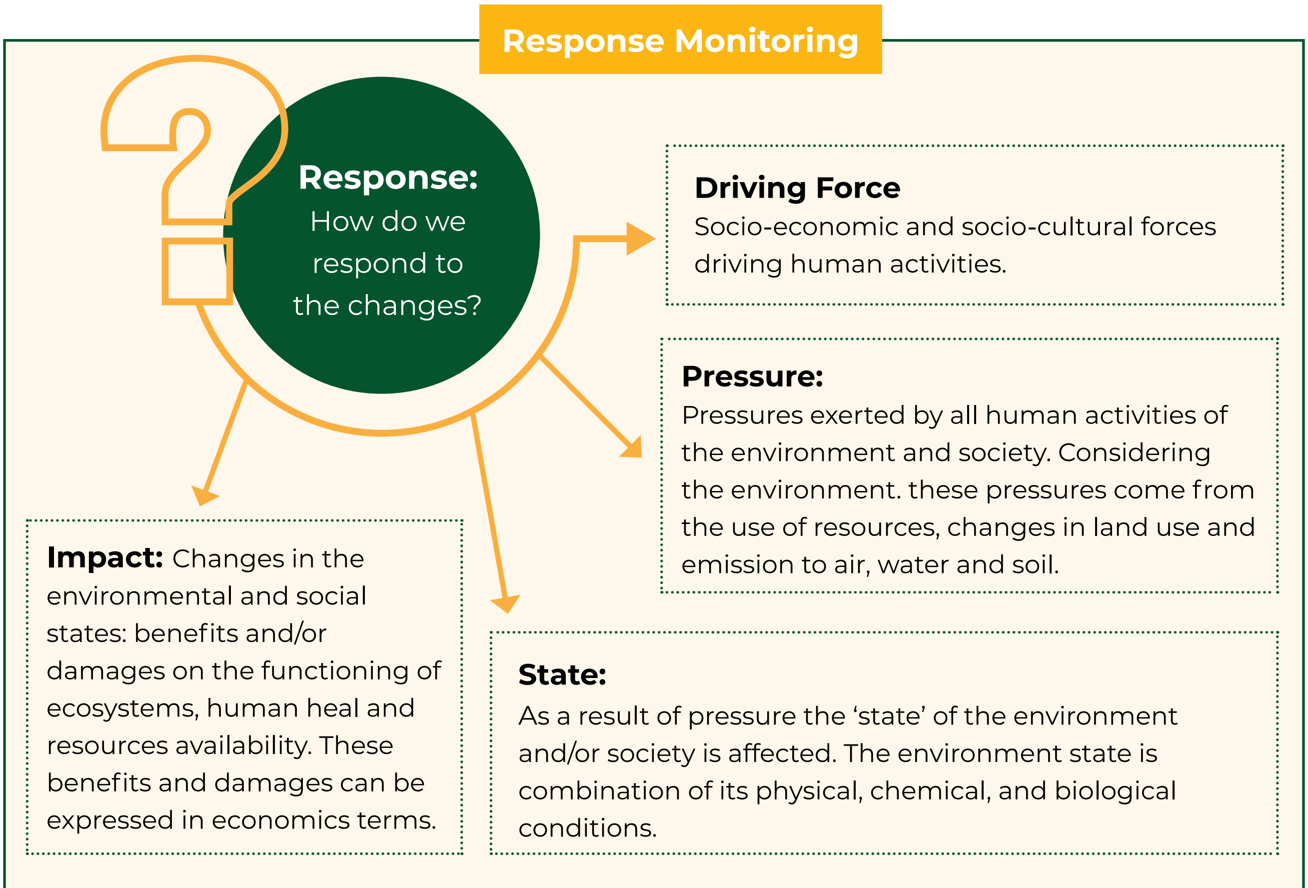

Figure 1: *Driving Forces, Pressure, State, Impact and Response Framework*

Integrative vulnerability assessment framework

The Integrated Vulnerability Assessment (IVA) Framework was modified to combine demographic and ecological data to pinpoint EDC threats in South Africa. The IVA framework evaluated exposure, susceptibility, and coping capacities. This is visualized using Tableau.

Framework Adaptation for EDC Threats:

- Exposure Assessment: The exposure levels were quantified using published data.
- Coping Capacities Evaluation: The ability of communities and ecosystems to cope with and adapt to the impacts of EDCs were evaluated.

Data Collection and Integration:

- Source data was used from national databases, environmental agencies, health departments, and scientific research.

Visualization Using Tableau:

- Data was imported into Tableau Public.
- Maps were created to visualize provinces with high vulnerability in South Africa.

Conceptual framework

A conceptual framework was designed that outlined areas where future research would be most impactful in understanding EDCs in South Africa.

Step 1: Define Objectives and Scope

- Objective Identification: The objectives of the framework were identified, which included identifying and managing EDC threats, assessing environmental and health impacts, and informing policy decisions.
- Scope Determination: Only studies in South Africa with the compounds of interest were included.

Step 2: Integrate DPSIR and IVA Models

- Combine Models: The findings of the DPSIR framework (Driving Forces, Pressure, State, Impact, Res apacities).
- Mapping Intersections: Each component of DPSIR was linked to elements of IVA — for example, linking 'Pressure' (from DPSIR) with 'Exposure' (from IVA) to identify any intersections.

Step 3: Data Collection and Integration Strategy

- Data Sources Identification: Potential future sources for data (government databases, international organizations, research studies) were identified.
- Data Integration Plan: A strategy for integrating demographic, ecological, and EDC-specific data was developed.

Step 4: Developing Criteria for Emerging Contaminants

- Criteria Formulation: The previously suggested criteria to identify and prioritize EDCs was used.
- Application of Criteria: These criteria were integrated into the conceptual framework to guide data collection and analysis.

Step 5: Conceptual Framework Construction

- Framework Design: The framework was created to visually represent the interconnections between DPSIR, IVA, and data visualization components.
- Feedback Loops and Interactions: Different elements interact and influence each
- other and illustrate potential feedback loops was created.

RESULTS AND DISCUSSION

Scoping review

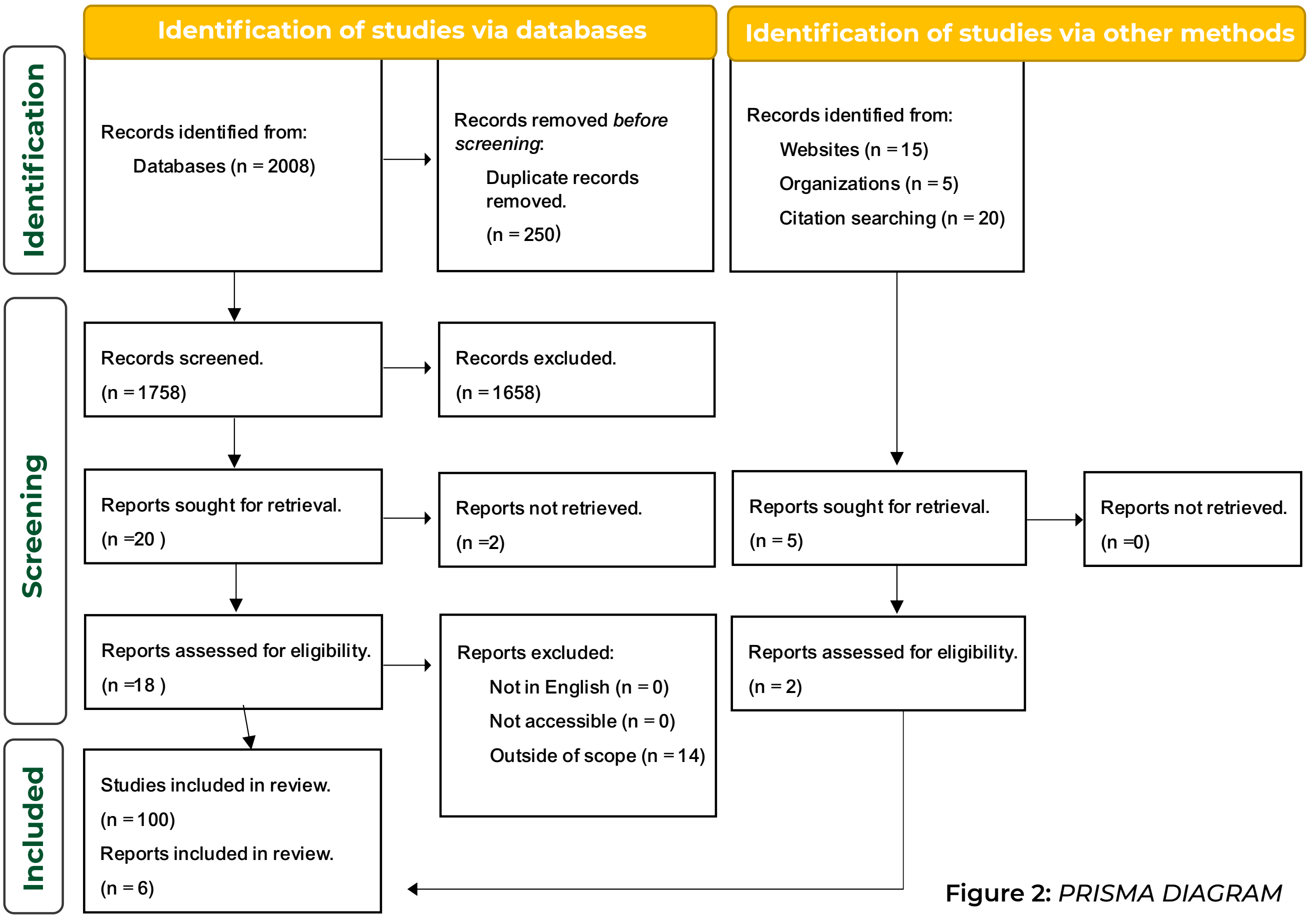

Figure 2: *PRISMA DIAGRAM*

Criteria-based selection

Using the criteria previously described to prioritize EDCs for examination in South Africa (prevalence and usage patterns, environmental persistence, toxicity and health impact, lack of existing regulation, and detection and monitoring capability), the following chemicals were chosen for inclusion in this report: Bisphenol A, F and S, Phthalates, Polychlorinated Biphenyls, Parabens, Perfluoroalkyl and Polyfluoroalkyl Substances, Tonalide, Polybrominated Diphenyl Ethers and Triclosan.

BISPHENOL A, F, AND S

Bisphenols, including BPA, BPF, and BPS, are industrial chemicals used primarily in the production of polycarbonate plastics and epoxy resins.

OVERVIEW AND PROPERTIES	Bisphenol A (BPA), Bisphenol F (BPF), and Bisphenol S (BPS) are industrial chemicals that play a crucial role in the production of polycarbonate plastics and epoxy resins. These compounds share a similar chemical structure, with two hydroxyphenyl functionalities, but they differ slightly in their chemical makeup (18). BPA, the most used of the three, has been integral in manufacturing a variety of consumer and industrial products due to its ability to make plastics clear and durable (19). However, due to health concerns, BPF and BPS have been developed as alternatives to BPA (20). These chemicals are known for their high performance in terms of mechanical strength, resistance to heat, and electrical insulating properties. This makes them ideal for use in a wide range of applications, including the production of water bottles, sports equipment, medical devices, and as coatings for food and beverage cans (21, 22). Despite their beneficial properties, the potential health risks associated with these chemicals have led to increased scientific scrutiny and regulatory review (23).
PRESENCE IN SOUTH AFRICA	In South Africa, bisphenols, particularly BPA, are prevalent in various consumer products (24). This includes everyday items such as plastic containers, food can linings, and thermal papers used in receipts (25). Given the global nature of the manufacturing and distribution of these products, South Africa, like many other countries, is exposed to these chemicals through imported goods as well as locally produced items . The widespread use of these chemicals in consumer products implies a significant level of exposure among the South African population. The presence of bisphenols in these products can lead to leaching, especially in conditions of high heat or when plastics are damaged, which increases the risk of these chemicals entering the human body. This is a concern particularly in food and beverage containers, where bisphenols can migrate into the contents and be ingested.
HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH AFRICA	Bisphenols, particularly BPA, are known endocrine disruptors. In South Africa, as in other parts of the world, there is growing concern about the impact of these chemicals on human health. Studies have linked exposure to bisphenols with a variety of health issues, including obesity, diabetes, and cardiovascular diseases. They are also associated with negative effects on the reproductive system, such as reduced fertility and developmental problems in children. The environmental impact of bisphenols is also noteworthy. These chemicals can leach into water sources and soil, affecting wildlife and ecosystems (26). In aquatic environments, bisphenols can disrupt the endocrine systems of various species, leading to reproductive and developmental issues, similar to their effects in humans.
REGULATORY STATUS IN SOUTH AFRICA	In South Africa, the Department of Health is under pressure to legislate a comprehensive ban on Bisphenol A (BPA) in all products that come into direct contact with food for babies and young children (27). This initiative has seen partial success, with the NUK Company setting a precedent by eliminating BPA from its baby products, a move that earned it the ‘Seal of Recognition as a Smart Choice’ from CANSA in 2010 (28). South Africa became the first country in Africa with legislation banning BPA usage in baby bottles (29), including prohibiting the manufacturing, importation, exportation, and sale

of infant bottles containing BPA. These regulations—R. 879 of 2011—are included in the Foodstuffs, Cosmetics and Disinfectants Act of 1972 (30). However, this legislation only applies to baby bottles, not other plastic food packaging. This action reflects a broader expectation that the food and packaging industries will proactively address health risks associated with their products, as seen in the past with the reduction of trans fatty acids by reputable food manufacturers (23).

South African consumers are protected by the Consumer Protection Act of 2008, which aims to safeguard them against safety and health threats and improves information provision facilitating informed choices (31). Since current legislation does not include other plastic items containing BPA, there is a call to action to prefer products that are clearly marked as BPA-free, either by the CANSA Seal of Recognition or recognized international safety symbols. Furthermore, it is advised to limit the purchase of canned foods unless it is verified that the cans do not use BPA in their lining, as a preventive measure until safer packaging alternatives are widely available. This approach not only safeguards the health of the youngest and most vulnerable but also encourages a shift towards safer packaging standards industry-wide (27, 28). International legislation restricts BPA in consumer products through regulations like the EU's REACH, banning BPA in food contact materials and children's items, and the U.S. FDA's bans on BPA in baby bottles and infant formula packaging.

PHTHALATES

Phthalates are a group of chemicals used to make plastics more flexible and harder to break, commonly found in polyvinyl chloride (PVC) plastics.

OVERVIEW AND PROPERTIES

Phthalates are a diverse group of chemicals primarily used to increase the flexibility, transparency, durability, and longevity of plastics, especially polyvinyl chloride (PVC) (32). These compounds, which are sometimes called plasticizers, are incorporated into plastics during the manufacturing process to make them more pliable and less brittle. Phthalates can be found in a wide range of consumer and industrial products, from flexible tubing and cables to softer plastic items like toys and teething rings (33). There are several types of phthalates, each with varying chemical properties and uses. Some common phthalates include di(2-ethylhexyl) phthalate (DEHP), dibutyl phthalate (DBP), and benzyl butyl phthalate (BBP) (34). The molecular structure of phthalates allows them to be easily processed with PVC, enhancing its flexibility and workability. This makes phthalates integral to numerous applications, but their widespread use has raised concerns about their potential impact on human health (33) and the environment (35).

PRESENCE IN SOUTH AFRICA

In South Africa, as in other parts of the world, phthalates are used in a variety of consumer products. These include bottled water (36), clingwrap (25), food composites (37) and packaging material (38). The prevalence of these chemicals in everyday items means that the general population is likely to be exposed to phthalates through direct contact or environmental sources (39-47). Given the global supply chains and import practices, many products containing phthalates enter South Africa from other countries. This widespread distribution complicates efforts to regulate and control exposure to these chemicals (48). The use of phthalates in products, particularly those intended for children, has been a subject of increasing concern due to potential health risks.

HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH AFRICA	Phthalates are known endocrine disruptors, meaning they can interfere with the normal functioning of the hormonal system in humans and animals (33). Some phthalates have been linked to reproductive and developmental issues, particularly in males. These include reduced sperm quality, changes in hormone levels, and developmental abnormalities. The environmental impact of phthalates is also significant (8). These chemicals can leach out of products into the environment, contaminating soil and water sources. Once in the environment, phthalates can affect wildlife, particularly aquatic organisms, by disrupting their reproductive systems and causing developmental problems (8, 49).
REGULATORY STATUS IN SOUTH AFRICA	In terms of environmental concerns and plastic packaging, South Africa promulgated new regulations in November 2020 concerning Extended Producer Responsibility (EPR) as part of the National Environmental Management: Waste Act of 2008 (50). The phthalates DBP, DHEP, diethyl phthalate, dimethyl phthalate, were included in the Regulations for Hazardous Chemical Agents, 2021 as part of the Occupation Health and Safety Act, 1993 (51). This regulation, however, is limited as it stipulates occupation exposure limits for the selected phthalates and excluded non-occupational exposure.
	Despite these positive steps, South Africa currently lacks specific regulatory standards for phthalates in its water systems, indicating a gap in the management of chemical contaminants (40). In 2021, South Africa produced 1,904,000 tonnes of plastic locally and recycled 344 527 tonnes of plastic (52). The prevalent disposal method for plastics in South Africa is through landfills, with a substantial portion of recycling being conducted informally by waste pickers (53). This situation underscores a critical need for comprehensive environmental regulations, not only to address the presence of hazardous substances like phthalates in water but also to manage the burgeoning issue of plastic waste more effectively. In comparison, international legislation like the EU's REACH and the US's TSCA regulates phthalates and plastic waste, setting strict standards for chemical contaminants and promoting recycling. South Africa's lack of similar regulations highlights the need for comprehensive environmental policies to manage hazardous substances and plastic waste effectively.

POLYCHLORINATED BIPHENYLS (PCBS)

PCBs are a group of synthetic organic chemicals consisting of carbon, hydrogen, and chlorine atoms.

OVERVIEW AND PROPERTIES	Polychlorinated Biphenyls (PCBs) are a group of synthetic organic chemicals that consist of carbon, hydrogen, and chlorine atoms (54). There are 209 different congeners of PCBs, varying in the number and location of chlorine atoms attached to the biphenyl molecule, which is composed of two benzene rings. PCBs were widely used in a variety of industrial applications due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties (55). These chemicals were commonly used in electrical equipment like transformers and capacitors, as well as in hydraulic systems, heat transfer fluids, lubricants, and plasticizers. They were also found in certain types of caulking and thermal insulation materials in buildings. The widespread use of PCBs in diverse applications made them ubiquitous in the environment (56).
PRESENCE IN SOUTH AFRICA	Although PCBs have been banned in many countries, their legacy persists due to their environmental stability and long half-life (55). In South Africa, PCBs can still be found in older electrical equipment , building materials (57), and in the environment The presence of PCBs in older infrastructure poses a risk of continued exposure, especially during the disposal, recycling, or renovation of old equipment and buildings. The environmental persistence of PCBs means that they can still be found in soil, water bodies, and in the food chain, long after their use has been discontinued (57-75). This ongoing presence poses a challenge for environmental management and public health in South Africa (76).
HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH AFRICA	PCBs are known to cause a variety of adverse health effects in humans and wildlife (77). They are classified as probable human carcinogens, meaning they are likely to cause cancer. Additionally, PCB exposure has been linked to a range of other health issues, including immune system suppression, reproductive disorders, and endocrine disruption (43, 69). PCBs can also have neurological effects, potentially affecting cognitive and motor function . In the environment, PCBs are highly persistent and can accumulate in the food chain, posing a risk to wildlife. They can cause reproductive, developmental, and immune system problems in animals, and their bio accumulative nature means that they can reach high concentrations in top predators (55).
REGULATORY STATUS IN SOUTH AFRICA	The National Environmental Management Waste Amendment Act, No. 26 of 2014, addresses the management of general, hazardous, and electronic waste. It is complemented by various legal frameworks, including the National Waste Management Strategy (2012) (78) by the Department of Environmental Affairs, the National Environmental Management Act, No. 107 of 1998 (NEMA, 1998) (79), the Environmental Conservation Act, No. 73 of 1989 (80), the Hazardous Substances Act, 1973 (81), the National Water Act, No. 36 of 1998 (82), the Atmospheric Pollution Prevention Act, No. 45 of 1965 (83), and the Occupational Health and Safety Act, No. 86 of 1993 (84). These legislations collectively address waste management issues from multiple perspectives, complicating the challenge of disposing electronic wastes, which contains PCBs.

The 'Regulations to Phase-Out the Use of Polychlorinated Biphenyls (PCBs) Materials and PCB Contaminated Materials' (PCB Regulations), published by South Africa's Minister of Environmental Affairs in Government Gazette 37818 on July 10, 2014, aim to eliminate the use of PCBs and PCB-contaminated materials (85). The regulations define PCB materials as those with a concentration over 500mg/kg and contaminated materials as those over 51mg/kg but under 500mg/kg. They prohibit the use, production, import, export, and sale of these materials unless registered and a phase-out plan is submitted within specified timelines. The phase-out must be completed by 2023, with possession banned by 2026, and includes mandates for testing, labelling, and reporting, with penalties for non-compliance including fines up to ZAR10 million or imprisonment up to 10 years. This initiative aligns with the Stockholm Convention's goal to phase out PCBs by 2025, reflecting global concerns over PCBs' adverse effects on health and the environment (76).

PARABENS

Parabens are preservatives used in many cosmetic, pharmaceutical, and food products.

OVERVIEW AND PROPERTIES

Parabens are a group of synthetic preservatives widely used in cosmetic, pharmaceutical, and food products (86). Chemically, they are a series of para-hydroxybenzoate or para-hydroxybenzoic acid esters. Parabens are favoured in the industry due to their effective antimicrobial properties, particularly against fungi and bacteria, and their low cost (87). Commonly used parabens include methylparaben, ethylparaben, propylparaben, and butylparaben (88). These preservatives are valued for their stability and are often used in combination to enhance the preservation of products. Parabens are effective in a variety of pH ranges, making them versatile for diverse types of formulations. They are used to extend the shelf life of products and prevent the growth of harmful microorganisms, which can spoil products and pose health risks to consumers (89).

PRESENCE IN SOUTH AFRICA

In South Africa, parabens are commonly found in a wide range of personal care products, such as shampoos, conditioners, lotions, facial and shower gels, and sunscreens (90). Their prevalence in these everyday products means that the general population is frequently exposed to these chemicals. The use of parabens in South Africa mirrors global trends in the cosmetics and pharmaceutical industries, where these chemicals are a standard component in many formulations. The widespread use of parabens in consumer products makes them a notable chemical of interest, particularly in terms of monitoring their safety and understanding their potential impact on health and the environment (91).

HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH AFRICA

Parabens are suspected endocrine disruptors, which means they may interfere with hormone function in the body (86). There is particular concern about their potential estrogenic activity, which could influence the development and progression of breast cancer (92). Some studies have also suggested a link between parabens and reproductive issues, including impacts on fertility and developmental effects in offspring. The environmental impact of parabens also raises concerns (93). These chemicals can enter water systems through sewage and personal care product runoff (94). Once in the environment, they can potentially disrupt the hormonal systems of wildlife, particularly aquatic organisms (95). The persistence and potential bioaccumulation of parabens in the environment add to these concerns, highlighting the need for further research and monitoring.

REGULATORY STATUS IN SOUTH AFRICA

The proposed amendments to the South African Foodstuffs, Cosmetics, and Disinfectants Act (Act 54 of 1972) introduce stricter regulations for the cosmetics industry, shifting from a self-regulated framework to a more controlled regulatory environment (96). The amendments focus on comprehensive areas such as:

Definition and Categorization: Cosmetics are defined broadly to include any substance applied to the body for beautifying, altering appearance, or cleansing purposes. The amendments clarify the categorization of cosmetics, distinguishing them from medical devices or medicines, as outlined in the Medicines and Related Substances Act (Act No. 101 of 1965) (97).

Role of Responsible Person (RP): A new role, the Responsible Person, is established, responsible for ensuring the safety and compliance of cosmetics on the market. This includes maintaining product information files (PIF), conducting safety assessments, and overseeing the quality and safety of cosmetics. (98)

Safety and Compliance: Regulation 4 emphasizes the need for safety assessments by appropriately trained individuals and establishes strict criteria for what cosmetics must not contain. It mandates good manufacturing practices, aligning with both national (SANS 22716:2011) and international standards (ISO 22716:2007).

Product Information File (PIF): Regulation 6 introduces the requirement for a PIF that documents the description, manufacture, compliance, and safety assessments of cosmetics, to be kept for 10 years post-market (98).

Labelling and Advertising: Amendments to the labelling rules (Regulation 8) require detailed information on cosmetics, including ingredients and their function, under strict guidelines from the Legal Metrology Act of 2014 (99). Advertising practices are regulated under Regulation 9, ensuring all marketing claims are scientifically substantiated.

Penalties for Non-Compliance: Regulation 12 outlines penalties for non-compliance with the new cosmetic regulations, which include fines, imprisonment, or both, emphasizing the serious commitment of the South African government to enforce these regulations (98).

The amendments lay out specific responsibilities for manufacturers, importers, and distributors to ensure product safety and compliance with new regulations. There are also stringent penalties for non-compliance, including fines or imprisonment. In comparison, international legislation on parabens is stringent and varies significantly across developed countries. The European Union, under Regulation 1223/2009, sets maximum allowable concentrations for parabens in cosmetics, with specific bans on certain types like isopropylparaben and isobutylparaben. The U.S. FDA regulates the use of parabens, allowing limited amounts based on product type and usage. Canada has banned specific parabens like isopropylparaben and phenylparaben while restricting others. These regulations aim to mitigate potential health risks associated with parabens, promoting safer alternatives and increasing transparency in cosmetic products (100).

PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES (PFAS)

PFAS are a group of synthetic chemicals used in a variety of industrial applications and consumer products.

OVERVIEW AND PROPERTIES

Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) are a large family of synthetic chemicals that have been used in a variety of industrial applications and consumer products since the 1950s (101). These substances are characterized by a chain of carbon atoms fully (perfluoroalkyls) or partially (polyfluoroalkyls) fluorinated. PFAS are valued for their ability to resist heat, water, and oil. Common PFAS include perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), and GenX chemicals (102). The unique molecular structure of PFAS makes them highly resistant to degradation, earning them the nickname "forever chemicals." (103) This persistence is advantageous for product performance but raises significant concerns regarding their environmental and health impact. PFAS are used in non-stick cookware, stain-resistant fabrics and carpets, water-repellent clothing, some firefighting foams, and products that resist grease, water, and oil (104).

PRESENCE IN SOUTH AFRICA

In South Africa, as in many other countries, PFAS can be found in a range of consumer products and industrial applications . These include non-stick cookware, water-repellent clothing, stain-resistant fabrics, and certain types of firefighting foams. The use of PFAS-containing products has led to widespread environmental contamination and human exposure (105, 106). The persistence of PFAS in the environment means that these chemicals can accumulate over time in water, soil, and living organisms (107, 108). In South Africa, where industrial and consumer use of PFAS-containing products is prevalent, there is a growing concern about the environmental presence and impact of these substances (109).

HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH AFRICA

PFAS have been associated with a range of adverse health outcomes in humans (110, 111). The concern is heightened by their bio accumulative nature and their ability to remain in the human body for extended periods (105, 109, 112).

The presence and impact of PFAS in South Africa are significant, with several studies highlighting their pervasive distribution across various environments and their potential health risks. A study from 2010 revealed PFAS in the maternal serum and cord blood of women from regions including the

Western Cape, Gauteng, Mpumalanga, and KwaZulu-Natal, indicating widespread exposure (113). Environmental studies have detected PFAS in the Orange-Senqu basin, with concentrations among the highest recorded globally (114). Subsequent research identified PFAS in river sediments, crocodile eggs, and dragonflies, pointing to a bioaccumulative nature that poses risks to both wildlife and humans . Notably, a 2018 study assessed the risk to humans through consumption of PFAS-contaminated fish in the Vaal River, suggesting health risks from dietary exposure exceed safe levels (108). The 2020 findings from wastewater treatment plants in Gauteng further underscored the environmental persistence of PFAS, highlighting their release during manufacturing and industrial uses (115). These studies collectively underscore the critical need for more robust regulatory measures and public health interventions to mitigate PFAS exposure in South Africa.

REGULATORY STATUS IN SOUTH AFRICA

In South Africa, the regulatory framework concerning PFAS (Per- and Polyfluoroalkyl Substances) is underdeveloped with no specific regulations directly addressing PFAS usage and presence in products (116). The primary reference to PFAS in a regulatory context is found in the broad regulations concerning persistent organic pollutants under the Regulations to Prohibit the Production, Distribution, Import, Export, Sale, and Use of Persistent Organic Pollutants (79). Perfluorooctanoic acid (PFOA) is the only PFAS compound specifically mentioned in these regulations and is considered relevant in the retail environment according to statements from Food Lovers Market. Despite this limited regulatory scope, there are indications of regulatory awareness and voluntary compliance by some South African retailers (116). For instance, Woolworths has prohibited the use of PFAS chemicals in their food packaging, aligning their policies with international standards even in the absence of local regulations (116). They ensure compliance by conducting third-party laboratory testing according to European regulations (EC1935 & EU 2019/1021). Other retailers, like Pick n Pay and Shoprite, are also exploring ways to address PFAS in their branded products, although a unified industry-wide strategy is lacking (116). For example, in South Africa, regulations require that PFOS-, POSF-, and PFOS-containing products be phased out by December 2021 (South African Government Gazette, 2019).

Studies of PFAS in Africa have only recently started (117). From an African viewpoint, most nations have trouble incorporating this new class of pollutants into existing environmental management frameworks. Although countries such as South Africa have environmental legislation that is well-structured for the regulation of hazardous substances, chemical-specific management nevertheless necessitates the creation of environmental quality criteria for such compounds (118, 119). In comparison, international legislation on PFAS is stringent, with the EU's REACH regulation banning several PFAS chemicals and the U.S. EPA setting enforceable drinking water standards for six PFAS, mandating monitoring and reduction measures. These comprehensive frameworks highlight the need for South Africa to develop specific PFAS regulations (120) .

TONALIDE

Tonalide is a synthetic musk used as a fragrance ingredient in many consumer products.

OVERVIEW AND PROPERTIES	Tonalide, a synthetic musk, is a widely used fragrance ingredient in many consumer products (121). Chemically known as Acetyl hexamethyl tetralin (AHTN), tonalide belongs to the family of polycyclic musk compounds. It is favoured in the fragrance industry for its strong musk-like scent, which is often described as warm, sweet, and amber-like (122). Tonalide is used primarily to add a long-lasting fragrance to products and to mask any undesirable odours. This synthetic musk is known for its stability and persistence, which is crucial in ensuring that the fragrances in which it is used remain effective over time (123). Tonalide is often used in higher concentrations in products compared to natural musk due to its synthetic nature and lower cost.
PRESENCE IN SOUTH AFRICA	Tonalide is an emerging contaminant in South Africa and there are limited studies that have been conducted (124). In Mpumalanga, the fragrances galaxolide and tonalide were found respectively around 3477 and 26 ng/L (125). In Kwa-Zulu Natal, Tonalide (163.7 ng/g) was found in all water samples at the sampling sites in the Inanda inlet (126). These studies provide crucial data on the environmental presence of Tonalide and underscore the need for effective filtration technologies and continuous environmental monitoring (125, 127).
HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH AFRICA	As a potential endocrine disruptor, tonalide has raised some concerns regarding its health impact, although research in this area is still limited (128). The limited research on tonalide specifically means that its potential effects on human health are not fully understood, warranting further scientific investigation. In terms of environmental impact, tonalide is persistent and can accumulate in the environment, particularly in aquatic ecosystems (129). This persistence raises concerns about its potential effects on wildlife, especially aquatic organisms, where it might disrupt hormonal and reproductive functions.
REGULATORY STATUS IN SOUTH AFRICA	On March 29, 2021, the Ministry of Employment and Labor of South Africa, following the directives of the Occupational Health and Safety Act, 1993, and in consultation with the Advisory Council for Occupational Health and Safety, issued the Regulation of Hazardous Chemical Agents (HCA) (51). This regulation supersedes the previous Hazardous Chemical Substances regulation from 1995 . This new regulation targets employers, self-employed persons, as well as manufacturers, importers, and suppliers who deal with HCAs in their workplaces. The regulation aligns with the United Nation's Globally Harmonized System (GHS) for the classification, labelling, and packaging of chemicals. Chemical agents must now be classified, and Safety Data Sheets (SDSs) and labels must be provided according to the GHS standards. Certain

chemical categories, however, are excluded from this regulation, including explosives, flammable gases, and chemicals hazardous to the aquatic environment, among others. The document references GHS Revision 8 from 2019 for classification guidelines and permits updates as GHS revisions occur. Additionally, the South African National Standard (SANS) 10234 (130) provides alternative guidance for the classification, preparation of SDSs, and labelling, with the requirement to conform to the most recent GHS Purple Book when discrepancies arise.

While this regulation does not explicitly mention Tonalide, it includes a broad reference to fragrances as potential environmental contaminants within its scope, underscoring the need to manage such substances with caution in industrial and commercial settings.

POLYBROMINATED DIPHENYL ETHERS (PBDES)

PBDEs are flame retardants used in a variety of consumer products.

OVERVIEW AND PROPERTIES

Polybrominated Diphenyl Ethers (PBDEs) are a group of flame retardants that have been widely used in a variety of consumer products to reduce the risk of fire (131). These chemicals are added to plastics, foam, textiles, and electronic equipment to slow the ignition and spread of flames. PBDEs are structurally like polychlorinated biphenyls (PCBs), consisting of two phenyl rings bonded together and attached to multiple bromine atoms. The use of PBDEs became popular because they can be easily mixed with other materials during the manufacturing process and are effective in reducing flammability (132). However, there are several diverse types of PBDEs, classified based on their molecular structure, including tetra-, penta-, hexa-, hepta-, octa-, nona-, and deca-BDEs. These compounds vary in their properties, uses, and toxicity (133).

PRESENCE IN SOUTH AFRICA

In South African indoor environments revealed a dominant presence of organophosphate esters (OPEs), with significant concentrations detected in dust from homes, offices, and vehicles, and even in pet cat hair. Median concentrations of 10 Organophosphate flame retardants (OPFRs) reached 44,800 ng/g in freshly collected dust in Kwa-Zulu Natal . The predominant compounds included tris(1-chloro-2-propyl) phosphate (TCIPP) and tris(2-butoxyethyl) phosphate (TBOEP), indicating extensive use and potential human exposure through ingestion of dust, especially in toddlers who might experience higher exposure levels than adults (134-136).This cumulative evidence points to a substantial and wide-ranging exposure of both humans and wildlife to flame retardants in South Africa, with significant implications for health and environmental policy. The data underscore the urgency of further investigations into the long-term effects of these compounds, particularly the risks associated with chronic exposure and their potential to accumulate in the environment.

HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH ARICA

In South Africa, discarded products containing PBDEs often end up in landfill sites, releasing these chemicals into leachates, providing an indirect measure of their environmental dissemination. For instance, the concentration of PBDEs in leachates from different landfill sites like Garankuwa, Hatherly, Kwaggarsrand, Soshanguve, and Temba varied significantly, with the highest recorded at 9793 pg/l at Temba. This site also exhibited the highest Biological Oxygen Demand suggesting a correlation between organic content and PBDE levels. The potential for these compounds to leach into groundwater over time is notably high, especially at inadequately lined sites (137).

REGULATORY STATUS IN SOUTH AFRICA

In South Africa, the regulation and management of chemicals and pesticides, including brominated flame retardants (BFRs), are primarily governed under two main pieces of legislation: the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No 36 of 1947 (138), and the Hazardous Substances Act No 15 of 1973 (81). Various government notices and regulations derived from these acts address issues related to fertilizers, feeds, agricultural remedies, stock remedies, and hazardous substances. Notably, the Hazardous Substances Act categorizes hazardous substances into four groups, declared by the Minister of Health, based on their nature and the level of danger they pose. While specific legislation targeting BFRs directly does not currently exist, section 2 (1) (a) of the Hazardous Substances Act is applicable for controlling BFRs. Additionally, the National Water Act 36 of 1998 (82) and The Customs and Excise Act 91 of 1964 (139) also provide regulatory frameworks that could be employed to manage BFRs (140).

Moreover, the Development of National Inventory For Ten New Persistent Organic Pollutants (POPs) in South Africa was initiated to compile information on the quantities of listed POP chemicals and products containing POP-PBDEs through a Tier I (initial assessment) approach (141). This initiative aims to quantify the presence of POP-PBDEs in various products, further enhancing the control and management of these hazardous substances. In comparison, international legislation on brominated flame retardants (BFRs) is more stringent than in South Africa. The EU's REACH regulation restricts several BFRs, including PBDEs and HBCDD, due to their toxicity and persistence. The U.S. EPA has phased out certain PBDEs and monitors BFRs in products and the environment (142)

TRICLOSAN

Triclosan is an antibacterial and antifungal agent found in many consumer products.

OVERVIEW AND PROPERTIES

Triclosan is an antibacterial and antifungal agent that has been widely used in a variety of consumer products (143). Its effectiveness in reducing or preventing bacterial contamination has made it a popular ingredient, especially in personal care and cleaning products. Chemically, triclosan is known for its broad-spectrum antimicrobial properties, which work by inhibiting fatty acid synthesis in microbes, thereby impairing cell membrane production and function. Triclosan's inclusion in products ranges from toothpaste and soaps to detergents and deodorants (144). It is also found in some textiles, kitchenware, and toys where antibacterial properties are desired. While triclosan has been valued for its ability to kill bacteria and prevent bacterial growth, its widespread use has led to concerns about its impact on health and the environment(145).

PRESENCE IN SOUTH AFRICA

Triclosan and triclocarban have been identified in various environmental samples from wastewater treatment facilities, reflecting concerns about their potential health impacts due to their historical use in consumer products. Concentrations of triclosan and triclocarban in influents, effluents, and sludge indicate differential removal efficiencies, with some facilities achieving up to 97% removal for triclocarban(146). This variability in removal rates suggests that residual levels of these chemicals might still pose a risk to human health. Studies in Kwa-Zulu Natal revealed that triclosan levels in influent water ranged from 1.906 to 73.462 µg/L, with triclocarban levels significantly lower, suggesting differences in their chemical behavior and persistence in treatment systems (147). Additionally, in Gauteng Province, both triclosan and triclocarban were consistently detected in various wastewater matrices, underlining the ubiquity and potential health risks of these compounds (148).

HEALTH AND ENVIRONMENTAL IMPACT IN SOUTH AFRICA

Triclosan has raised concerns over antibiotic resistance and endocrine disruption (149). The widespread use of triclosan could contribute to the development of antibiotic-resistant bacteria, a significant public health concern. Additionally, triclosan has been found to interfere with hormone function, particularly thyroid hormones, which could have various adverse health effects. The environmental impact of triclosan is also significant. Triclosan can persist in the environment and has been detected in water bodies, potentially affecting aquatic life (147). The environmental impact of TCS and TCC is notable, with their continuous detection in aquatic systems due to extensive use in personal care products. Research has shown that these compounds are not fully removed by conventional wastewater treatment processes, with TCS often found in higher concentrations than TCC in various samples. In the Umbogintwini Industrial Complex, advanced treatment techniques using molecularly imprinted membrane adsorbents demonstrated high removal efficiencies for TCS, indicating promising methods for reducing environmental exposure (146). However, the presence of TCS and TCC in rivers and sludge from treatment plants across Gauteng Province highlights the ongoing challenge of mitigating their environmental impact. Seasonal variations also affect the concentrations and treatment efficiencies of these compounds, further complicating their environmental management (148). This persistent environmental presence calls for improved treatment technologies and regulatory strategies to prevent ecological damage and protect water quality.

REGULATORY STATUS IN SOUTH AFRICA

In South Africa, while triclosan and triclocarban remain approved for use in various consumer products, there are new regulatory developments under consideration. The proposed regulations under the Foodstuffs, Cosmetics and Disinfectants Act (96) includes restrictions specifically on the use of triclocarban. This move reflects a growing concern about the safety and environmental impact of these chemicals, mirroring actions taken internationally, such as the United States FDA's restrictions on these antimicrobials in certain products.

Manufacturers in South Africa, many of which are global companies, are adapting to these changes. In 2016 some already removed or planned to phase out these chemicals from their products in response to both regulatory pressures and consumer preferences. various products, or even a ban on its use in certain applications. Such regulatory measures would be aimed at reducing the potential risks associated with triclosan while balancing its antimicrobial benefits (150).

Tableau public for visualization

The scoping review results were further categorized by location. Tableau Public was used to map the location of the studies that investigated the EDCs and ECOCs as discussed earlier. Annexure 1 includes Figures depicting the location of the EDCs, while Annexure 2 includes the table indicating the location of the studies as well as the matrices the chemicals were found.

Driving forces, pressure, state, impact, and response framework

DPSIR Framework Application to EDCs in South Africa (Summarized in Figure 3)

1.Driving Forces

- **Industrial Development:** The growth of industries such as plastics, electronics, and consumer goods in South Africa.
- **Consumer Demand:** Increased demand for products containing EDCs like BPA, phthalates, and parabens.
- **Economic Factors**: The role of EDCs in the economy, considering their widespread use in various sectors.

2. Pressure

- **Manufacturing and Use of EDCs:** Production processes involving EDCs exert pressure on the environment and public health.
- **Disposal and Emissions:** Improper disposal and emissions of EDCs into the environment.

3. State

- **Environmental Contamination:** Presence of EDCs in water bodies, soil, and air.
- **Human Exposure:** Levels of EDCs found in the South African population through products and environmental exposure.

4. Impact

- **Health Effects:** Potential endocrine disruption, reproductive health issues, and increased cancer risks.
- **Environmental Impact:** Bioaccumulation, ecological disturbances, and long-term persistence of EDCs.

5. Response

- **Regulatory Measures:** South African policies, laws, regulations and systems of monitoring regarding the use and disposal of EDCs.
- **Public Awareness, Education and Behaviour Change:** Efforts to inform the public about EDC risks and safe practices.
- **Research and Monitoring:** Ongoing studies to understand the full impact of EDCs and monitor their presence.

1. DRIVING FORCES

The dynamics of Endocrine Disrupting Chemicals (EDCs) in South Africa is extensively understood through the lens of various driving forces. These forces are multifaceted, encompassing industrial development, consumer demand, and broader economic factors.

Industrial Development: The industrial sector in South Africa has seen substantial growth in recent decades, particularly in areas such as plastics, electronics, and consumer goods manufacturing. These industries are major contributors to the presence of EDCs in the country. For example, the plastics industry heavily relies on chemicals like Bisphenol A (BPA) and Phthalates, which are known for their endocrine-disrupting properties. Similarly, the electronics sector uses various EDCs like Polychlorinated Biphenyls (PCBs) and Polybrominated Diphenyl Ethers (PBDEs) in their manufacturing processes. The growth of these industries correlates with increased production and use of EDCs, leading to their subsequent release into the environment.

Consumer Demand: The demand for consumer goods that contain EDCs has escalated, driven by the population's increasing purchasing power and the global trend of consumerism. Products ranging from plastic containers to cosmetics and personal care products, many of which contain EDCs like parabens and triclosan, are in high demand. This demand sustains the production of such goods, thereby perpetuating the cycle of EDC usage and exposure. Consumer behavior, influenced by lifestyle changes and market trends, plays a crucial role in this context.

Economic Factors: The South African economy, intertwined with global markets, finds EDCs playing a significant role in various sectors. The chemical industry, a substantial part of the national economy, involves the extensive use and trade of EDC-containing products. This economic reliance creates a complex scenario where the benefits of industrial and economic growth are weighed against the potential health and environmental risks posed by EDCs.

The interaction between these driving forces creates a challenging environment for managing the risks associated with EDCs. While industrial growth and consumer demand fuel the proliferation of these chemicals, economic considerations often complicate efforts to regulate and control their usage. The situation is further exacerbated by the global nature of chemical trade and the transboundary movement of these contaminants, necessitating a comprehensive approach to monitoring, regulation, and public awareness. This intricate web of driving forces highlights the need for a multi-faceted response strategy that addresses not only the chemical aspects but also the socio-economic dimensions of EDCs in South Africa and takes into consideration individual and political decisions.

2. PRESSURE

The Pressure component of the DPSIR framework addresses the direct stressors that EDCs impose on both the environment and public health in South Africa. These pressures are primarily the result of manufacturing processes, use, and disposal of EDCs.

Manufacturing Processes: The production of goods containing EDCs is a significant source of environmental pressure. Industrial activities in the plastics, electronics, and personal care sectors release a variety of EDCs during manufacturing. For instance, the process of producing PVC plastics releases Phthalates, and the production of electronic components can release PCBs and PBDEs into the environment. These emissions are often inadequately regulated and controlled, leading to direct contamination of air, water, and soil.

Use of EDCs: The widespread use of products containing EDCs constitutes a continuous source of exposure and release into the environment. For example, BPA is commonly found in plastic bottles and food containers, from which it can leach into food and drinks. Similarly, personal care products like shampoos and lotions containing Parabens and Triclosan contribute to daily human exposure and, eventually, to water systems after being washed off. The ubiquity of these products ensures an ongoing impact from EDCs on both health and the environment.

Disposal and Emissions: The end-of-life disposal of products containing EDCs poses a significant environmental challenge. Landfills are common destinations for such waste, where EDCs can leach into the ground and contaminate soil and groundwater. Inadequate waste management practices, especially concerning electronic waste, exacerbate this issue. Incineration of EDC-containing waste, while reducing the volume, can lead to the emission of toxic compounds into the atmosphere.

The pressures exerted by EDCs in South Africa are augmented by the lack of stringent regulatory frameworks, monitoring and enforcement mechanisms. The existing policies may not adequately address the specific challenges posed by EDCs, particularly in terms of emissions during manufacturing and disposal. Furthermore, the global nature of the chemical industry and the import of EDC-containing products add layers of complexity to managing these pressures. This situation underscores the need for comprehensive strategies that encompass stricter regulations, better waste management practices, and industry-wide changes towards safer alternatives. Effective mitigation of these pressures is crucial for protecting both public health and the environment from the adverse effects of EDCs.

3. STATE

The State aspect of the DPSIR framework pertains to the current condition of the environment and public health as influenced by EDCs in South Africa. This includes the concentration and distribution of EDCs in various environmental compartments and their bioaccumulation in the human body.

Environmental Contamination: EDCs, owing to their persistent nature, have infiltrated various environmental media in South Africa. Water bodies, notably rivers and lakes, are frequently found to contain residues of EDCs such as BPA, Phthalates, and PBDEs. These chemicals can originate from industrial effluents, agricultural runoff, and urban wastewater. Soil contamination is another significant concern, especially near industrial sites and landfills, where EDCs can accumulate over time. Air quality, too, is not immune to EDC contamination, with volatile EDCs being released from manufacturing processes and waste incineration.

Human Exposure: The South African population is exposed to EDCs through multiple pathways. Consumer products are a primary source, with EDCs present in everyday items such as plastic containers, cosmetics, and electronic devices. Dietary intake, particularly through contaminated water and food packaged in materials containing EDCs, represents another significant exposure route. Occupational exposure is also a concern, especially for workers in industries producing and using EDC-containing materials. The combined effect of these exposure pathways contributes to the bioaccumulation of EDCs in the human body, leading to potential health risks.

The presence of EDCs in various environmental media and their accumulation in the human body pose significant challenges to public health and the ecosystem. These challenges are compounded by the complexity of tracing and quantifying EDCs, given their diverse sources and the varying sensitivity of different populations and ecological receptors. Moreover, the lack of comprehensive monitoring and data collection systems in South Africa hinders the ability to fully understand the state of EDC contamination. This highlights the urgent need for robust environmental monitoring and health surveillance systems to assess and manage the risks associated with EDCs.

The State of EDCs in South Africa is characterized by widespread environmental contamination and significant human exposure. Addressing these challenges requires a multi-dimensional approach, involving enhanced monitoring, risk assessment, and the implementation of strategies to reduce EDC exposure and mitigate its impacts.

4. IMPACT

The Impact component of the DPSIR framework examines the consequences of EDCs on human health and the environment in South Africa. This includes both the immediate and long-term effects of exposure to these chemicals.

Health Effects: The impact of EDCs on human health is profound and multifaceted. Studies have linked exposure to EDCs with a range of health issues, including endocrine disruption, which can lead to hormonal imbalances and reproductive problems. For example, BPA and Phthalates have been associated with decreased fertility, altered development in children, and increased risk of certain cancers. The impact is not limited to direct health issues; it also encompasses the socio-economic burden of healthcare costs and productivity losses due to illnesses related to EDC exposure.

Environmental Impact: EDCs pose a significant threat to the environment, affecting wildlife and ecosystems. These chemicals can bioaccumulate in the food chain, leading to elevated levels in top predators and potentially causing reproductive and developmental problems in wildlife. The persistence of EDCs in the environment also means that their effects can be long-lasting, disrupting ecological balances and affecting biodiversity. In aquatic environments, EDCs can alter the reproductive systems of fish and other aquatic organisms, leading to population declines and altered ecosystem dynamics.

The Impact of EDCs is not isolated to direct health and environmental consequences; it also includes the broader implications for societal well-being and sustainable development. The presence of EDCs in the environment and their potential health effects raise concerns about the long-term viability of natural resources and the ability to maintain healthy communities. The challenge is further compounded by the transboundary nature of environmental pollution, which means that the impacts of EDCs are not confined to South Africa but have regional and global implications.

4. RESPONSE

The Response component of the DPSIR framework addresses the actions and strategies undertaken to manage and mitigate the risks associated with EDCs in South Africa. This includes regulatory measures, public awareness, education, and research initiatives.

Regulatory Measures: The South African government's response to the challenges posed by EDCs is critical. This includes the development and enforcement of policies and regulations aimed at controlling the production, use, and disposal of EDCs. Adherence to international guidelines, such as those set by the United Nations Environment Programme (UNEP), is essential for aligning national standards with global best practices. The government is also responsible for establishing safe thresholds for EDC exposure and ensuring compliance with these standards.

Public Awareness and Activism: Educating the public about the risks associated with EDCs and promoting safe practices is vital for reducing exposure. Public awareness campaigns, educational programs, and community outreach initiatives play a crucial role in disseminating information about the health and environmental impacts of EDCs. These efforts also empower consumers to make informed decisions and advocate for safer products and practices.

Research and Monitoring: Ongoing research is necessary to deepen the understanding of the impacts of EDCs on human health and the environment. This includes epidemiological studies, environmental monitoring, and toxicological research. Collaborations between government agencies, academic institutions, and international organizations are crucial for advancing scientific knowledge in this area. Monitoring programs help track the presence and concentration of EDCs in various environmental media, providing essential data for risk assessment and management strategies.

The Response to EDCs in South Africa requires a multi-faceted approach, integrating policy, public engagement, and scientific research. It is a dynamic process that needs to evolve with emerging knowledge and technological advancements. The goal is not only to mitigate the current impacts of EDCs but also to prevent future risks, ensuring the health and well-being of both the population and the environment. Addressing this challenge is a shared responsibility, requiring the participation of government bodies, industry stakeholders, non-governmental organizations, and the public.

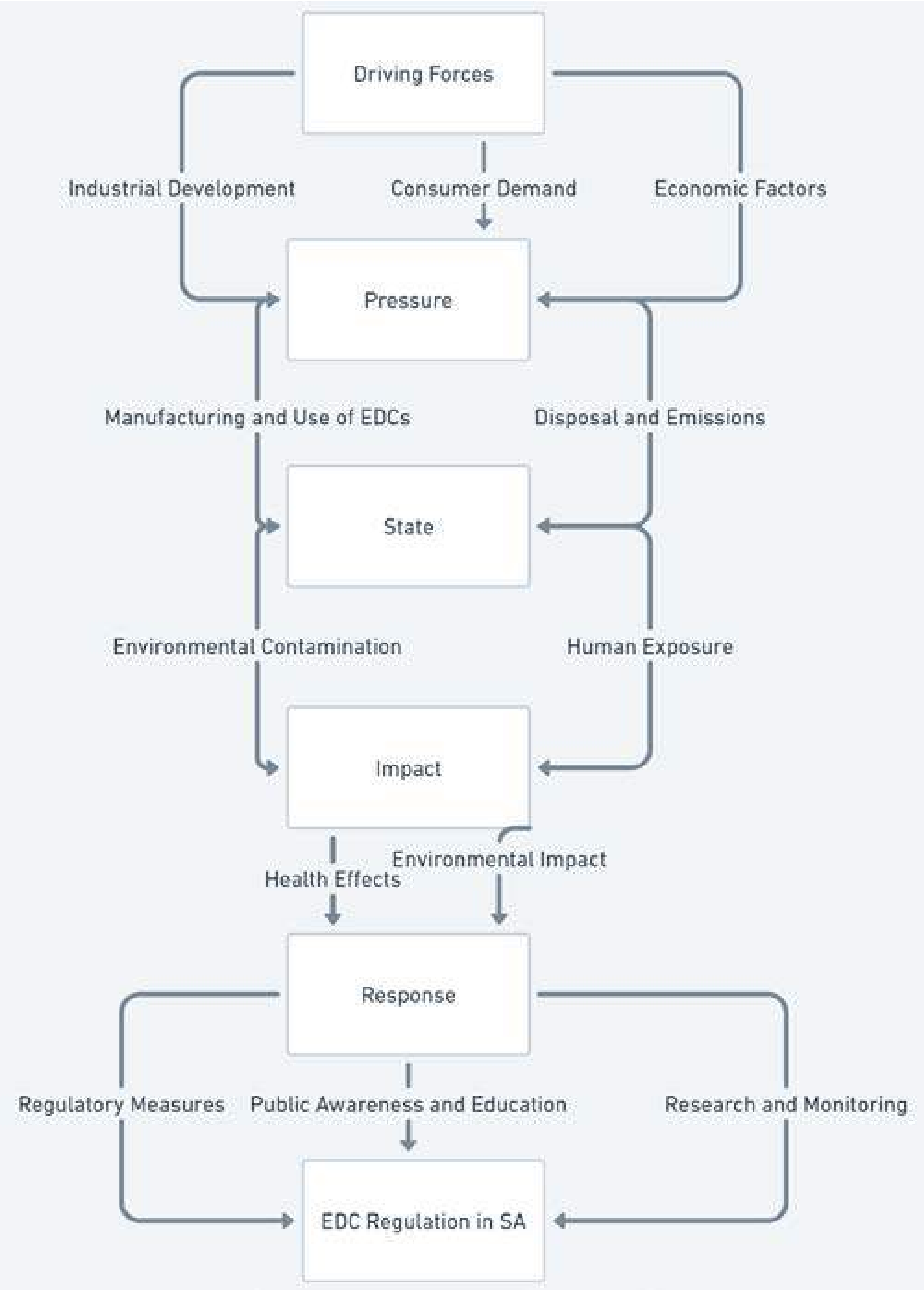

Figure 3: *Integrated DSPIR Framework towards improving EDC regulation in SA*

Integrative vulnerability assessment framework

An adapted Integrated Vulnerability Assessment (IVA) Framework was used to combine demographic and data to pinpoint EDC threats in South Africa.

EXPOSURE ASSESSMENT

- ***Environmental Exposure to EDCs:*** The concentration and distribution of EDCs in various environmental media (water, soil, air) was assessed using the 'State' data from the DPSIR Framework. Geographic mapping of potential EDC contamination hotspots was subsequently based on known EDC presence in water, soil, and air, and areas with significant industrial activities and consumer product usage.
- ***Population Exposure:*** Evaluating the extent to which different demographic groups are exposed to EDCs. This includes assessing the usage patterns of EDC-containing products and occupational exposures in industries dealing with such chemicals. The widespread use of EDC-containing products among different demographic groups was considered, with a focus on regions having high industrial and consumer activities.

SUSCEPTIBILITY ASSESSMENT

- ***Ecological Sensitivity:*** Determine the ecological areas most sensitive to EDC contamination, such as regions with high biodiversity, endangered species, or essential ecosystems.
- ***Health Impact***: Reflecting on the 'Impact' data from the DPSIR framework which links EDC exposure to health issues like endocrine disruption, reproductive health problems, and cancer risks – vulnerable communities such as those living on farms, close to disposal sites, or in peri-urban poverty with few choices for avoiding or mitigating the impact of EDCs.

COPING CAPACITIES ASSESSMENT

- ***Regulatory Framework and Enforcement:*** Evaluated the strength and effectiveness of existing regulations and policies on EDCs (as outlined in the 'Response' section of the DPSIR framework). Analysed the effectiveness of existing EDC regulations in South Africa, considering the guidelines set by UNEP and safe chemical management practices.
- ***Public Awareness and Activism:*** Assessed the level of public awareness about EDC risks and the availability of educational resources. Evaluated the extent of public awareness and availability of information on EDC risks and safe practices.
- ***Research and Monitoring Infrastructure:*** Considered the existing infrastructure for ongoing EDC research and environmental monitoring. Consider the capacity for ongoing EDC research and environmental monitoring, including government and academic institutions' involvement.

VULNERABILITY

- ***Geospatial Analysis:*** Visualize the vulnerability across different provinces in South Africa, considering the moving average of the highest concentrations of EDCs found.

FRAMEWORK APPLICATION AND POLICY IMPLICATION

- ***Risk Management and Mitigation Strategies:*** Use the vulnerability to identify and prioritize risk management and mitigation strategies, focusing on the most vulnerable areas and populations.
- ***Policy Recommendations:*** Based on the assessment, propose a strategy for future action items.

Integrated Vulnerability Assessment Framework towards EDC regulation in SA is proposed in Figure 4

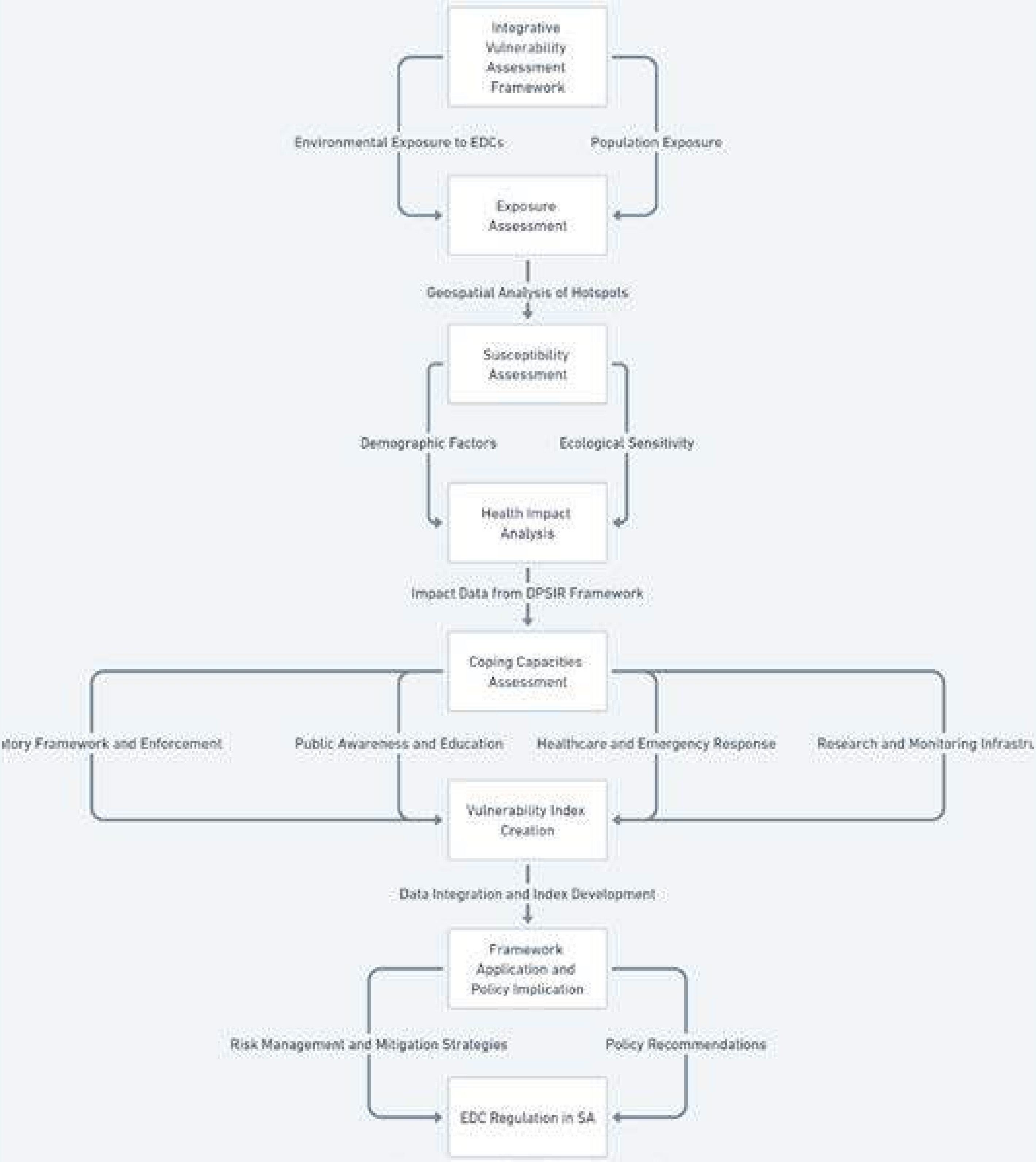

Figure 4: *Integrated Vulnerability Assessment Framework towards EDC regulation in SA.*

A conceptual framework

Figure 5 outlines a strategic approach for managing emerging endocrine-disrupting chemicals (EDCs) in South Africa, emphasizing the need for research, community awareness, and regulatory actions. The goal is to ensure the safe chemical management of EDCs in Africa while contributing to the Sustainable Development Goals (SDGs), particularly those related to health and the environment.

Research and Assessment: The initial phase focuses on conducting thorough research and assessment to build a strong knowledge base on EDCs:

01 **Research on Health and Environmental Effects:** This involves investigating the distribution and impacts of EDCs on human health and the environment in South Africa. Such research provides critical data for understanding the extent and severity of these effects.

02 **Publish Findings:** Disseminating research findings to the public and stakeholders is essential for transparency and informed decision-making. Published findings help raise awareness and guide policy development.

Community Awareness: Raising community awareness is crucial for fostering public understanding and engagement in managing EDCs:

01 **Public Education Campaigns:** These campaigns aim to educate the public about the risks associated with EDCs and promote safe practices. Awareness campaigns are vital for empowering communities to take proactive measures.

02 **Community Engagement in Policy Discussions:** Engaging communities in community-based research and policy discussions ensures that they are empowered and that their voices are heard and considered in decision-making processes. This participatory approach helps build engagement, trust and support for regulatory measures.

Regulatory Actions: Regulatory actions form the backbone of effective EDC management by establishing and enforcing safety standards:

01 **Develop and Update Safety Regulations:** Formulating new regulations and updating existing ones based on the latest research ensures that policies are effective and reflective of current scientific understanding.

02 **Enforce Compliance in Products:** Ensuring that products comply with safety regulations is critical for protecting public health and the environment. Robust enforcement mechanisms are necessary to maintain high standards and prevent non-compliance.

The framework integrates these activities to contribute to the SDGs, particularly those focusing on health and environmental sustainability. The overarching goal is the safe chemical management of EDCs in Africa, achieved through coordinated efforts in research, community engagement, and regulation. This approach not only addresses the immediate challenges posed by EDCs but also contributes to the broader goals of public health and environmental protection, aligning with the SDGs.

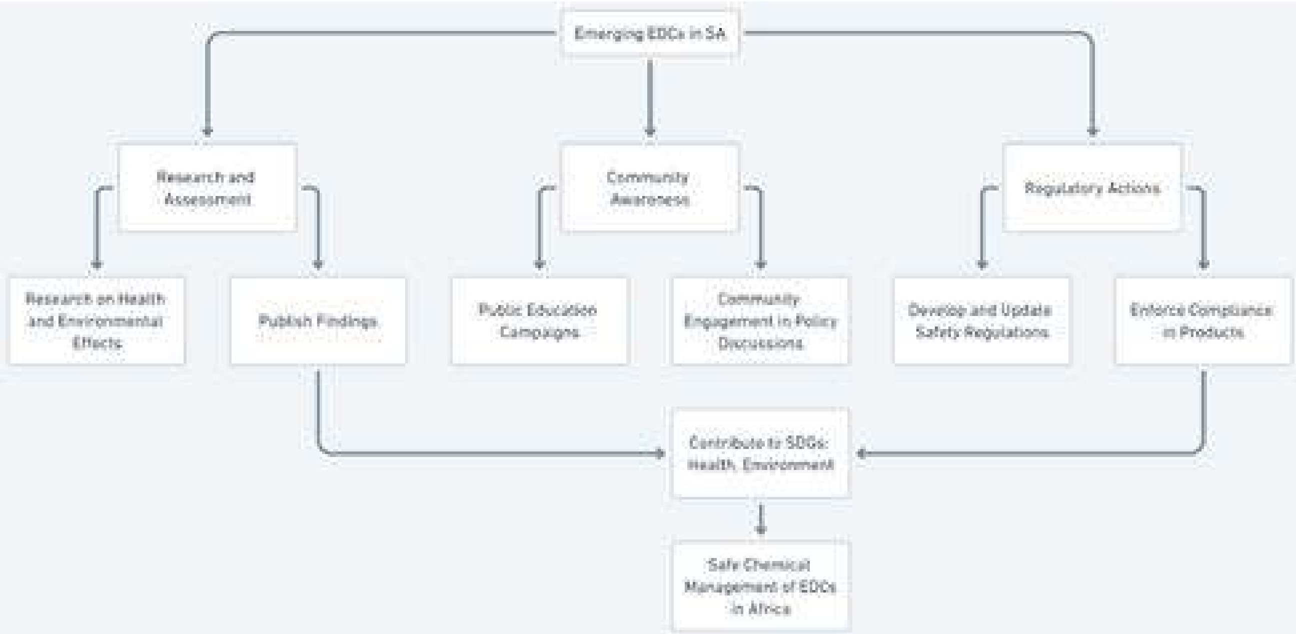

Figure 5: *Conceptual Framework to establish safe chemical management in South Africa*

Action Items/Monitoring & Evaluation

Figure 6 presents an action plan for managing emerging contaminants in South Africa, structured around a strategic approach involving short-term, medium-term, and long-term objectives. This plan underscores the importance of a multi-faceted approach involving research, training, community engagement, and regulation to effectively address the challenges posed by emerging contaminants.

Short-Term: Research: The initial phase focuses on research, which is fundamental for understanding and managing emerging contaminants. Key activities include:

01

Identify and Assess Emerging Contaminants: This involves detecting new contaminants and evaluating their prevalence and potential risks.

02

Study Health and Environmental Impacts: Researchers study the effects of these contaminants on human health and the environment, providing critical data for risk assessment.

03

Collaborate with International Research Bodies: Collaboration with global research organizations enhances the understanding of emerging contaminants through shared knowledge and methodologies.

Medium-Term: Training Programs and Awareness: Building on the research phase, the medium-term actions emphasize training and public awareness to foster informed and proactive management of contaminants:

01

Develop Training Programs for Professionals: Creating specialized training programs ensures that professionals are equipped with the necessary skills and knowledge to manage emerging contaminants effectively.

02

Implement Public Awareness Campaigns: These campaigns aim to educate the public about the risks associated with emerging contaminants and promote safe practices – such campaigns benefit from specific research from South Africa but can also be implemented in the short-term based on what is already known about EDCs globally..

03

Engage Communities in Participatory Research: Involving communities in research activities helps gather diverse data and enhances public understanding and activism, involvement in managing contaminants and monitoring the implementation of policies.

Long-Term: Regulation: The long-term phase focuses on establishing robust regulatory frameworks to ensure the sustainable management of emerging contaminants:

01

Formulate New Regulations Based on Research: Developing new regulations grounded in research findings ensures that policies are effective and scientifically sound.

02

Update Existing Safety Standards: Regular updates to safety standards are necessary to incorporate new knowledge and address evolving risks.

03

Ensure Compliance and Enforcement: Effective enforcement mechanisms are critical to ensure that regulations are followed, and safety standards are maintained.

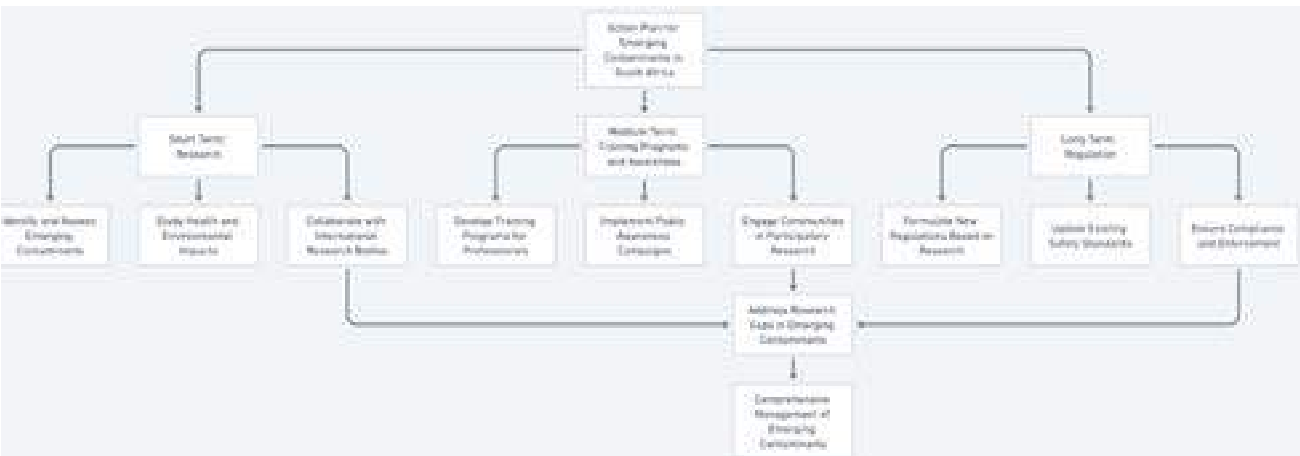

Figure 6: *Proposed action Items and Monitoring and Evaluation Plan to Manage Emerging Contaminants in SA*

Conclusions and RECOMMENDATIONS

Figures 7 outlines a comprehensive framework for the management of EDCs and ESOCs in South Africa, emphasizing the roles and responsibilities of various stakeholders. This framework is divided into four primary categories of responsibilities: researchers, the community, non-governmental organizations (NGOs), and the government.

Researcher Responsibilities: Researchers play a critical role in understanding the distribution and impacts of EDCs/ESOCs. Their responsibilities include conducting risk assessments to identify potential hazards associated with chemicals, monitoring the presence of these chemicals in communities, studying long-term effects to understand the chronic impacts, and publishing findings to inform other stakeholders and the public. This scientific basis is essential for informed decision-making and policy formulation. Research is also needed to better understand the levels of knowledge, and the social and economic dimensions of preventing and mitigating the impact of EDCs/ESOCs.

Community Responsibilities: The community's involvement is vital for the successful management of chemicals. Responsibilities here include educating and informing the public about chemical risks and safety practices, participating in surveys and studies to provide data and insights, and advocating for safe practices to ensure community health and safety. This grassroots involvement helps to ensure that the measures taken are relevant and effective at the local level.

NGO Responsibilities: NGOs are pivotal in bridging the gap between the community, researchers, and the government. They advocate for safe practices and lobby for regulatory changes that protect public health and the environment. Additionally, NGOs conduct awareness campaigns to increase public understanding and engagement with chemical safety issues. Their advocacy work is crucial in driving policy changes and ensuring accountability.

Government Responsibilities: The government holds the ultimate responsibility for regulating chemicals and ensuring compliance with safety standards. Their roles include implementing regulations, monitoring compliance to ensure adherence to these regulations, and providing funding for research to support ongoing assessment and management efforts. The government also supports community initiatives that align with safety goals.

The framework also outlines a series of integrated actions to manage chemicals effectively. Short-term actions focus on immediate measures and public awareness, while medium-term actions involve monitoring and regulatory adjustments. Long-term actions are aimed at policy revisions and the implementation of sustainable solutions. An overarching goal is to contribute to the Sustainable Development Goals (SDGs) by ensuring safe chemical management, particularly for endocrine-disrupting chemicals (EDCs). This comprehensive approach to chemical management in South Africa highlights the interconnected roles of various stakeholders. By fostering collaboration among researchers, the community, NGOs, and the government, this framework aims to create a safer environment and promote public health. The emphasis on both immediate and long-term actions ensures a balanced approach to addressing chemical risks, contributing to sustainable development and improved quality of life.

Figure 7: *Conclusions and Recommendations*

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Appendix 1: Tableau Public For Visualization

The scoping review results were further categorized by location. Tableau Public was used to map the location of the studies that investigated the EDCs and ECOCs as discussed earlier. Annexure 1 includes Figures depicting the location of the EDCs, while Annexure 2 includes the table indicating the location of the studies as well as the matrices the chemicals were found.

Figure 8: *Geographical location of studies in South Africa investigating Bisphenol A.*

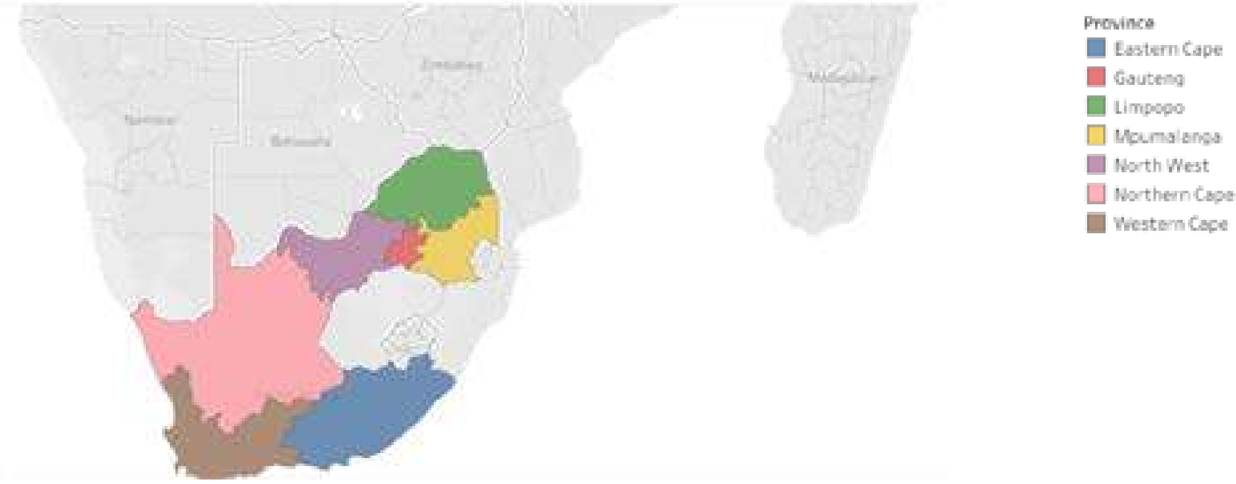

Figure 9: *Geographical location of studies in South Africa investigating Phthalates.*

Figure 10: *Geographical location of studies in South Africa investigating PCBs*

Figure 11: *Geographical location of studies in South Africa investigating Parabens.*

Figure 12: *Geographical location of studies in South Africa investigating PFAs.*

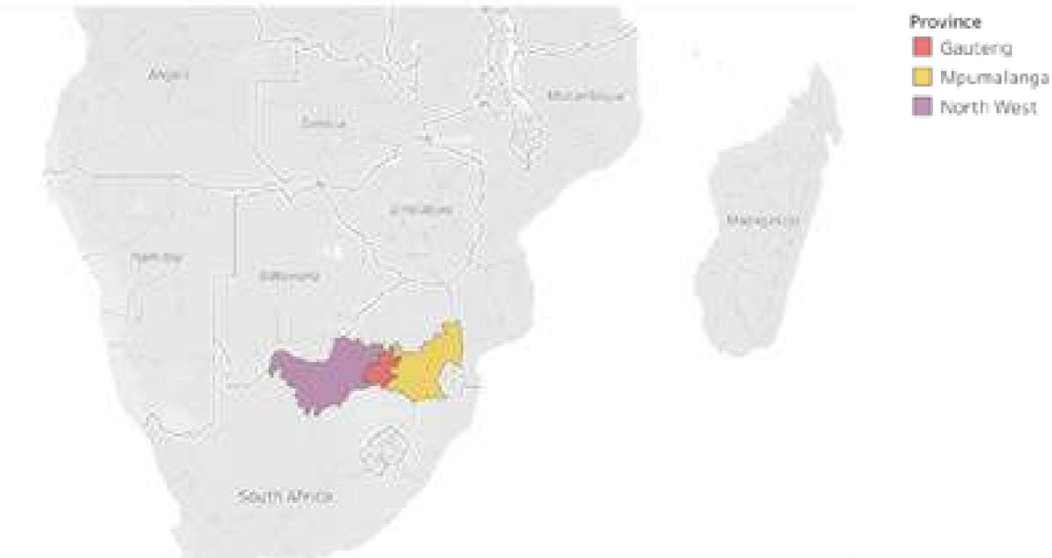

Figure 13: *Geographical location of studies in South Africa investigating Tolanide.*

Figure 14: *Geographical location of studies in South Africa investigating PBDEs.*

Table 1: Summary of EDCs and ECOCs in South Africa showing various matrices.

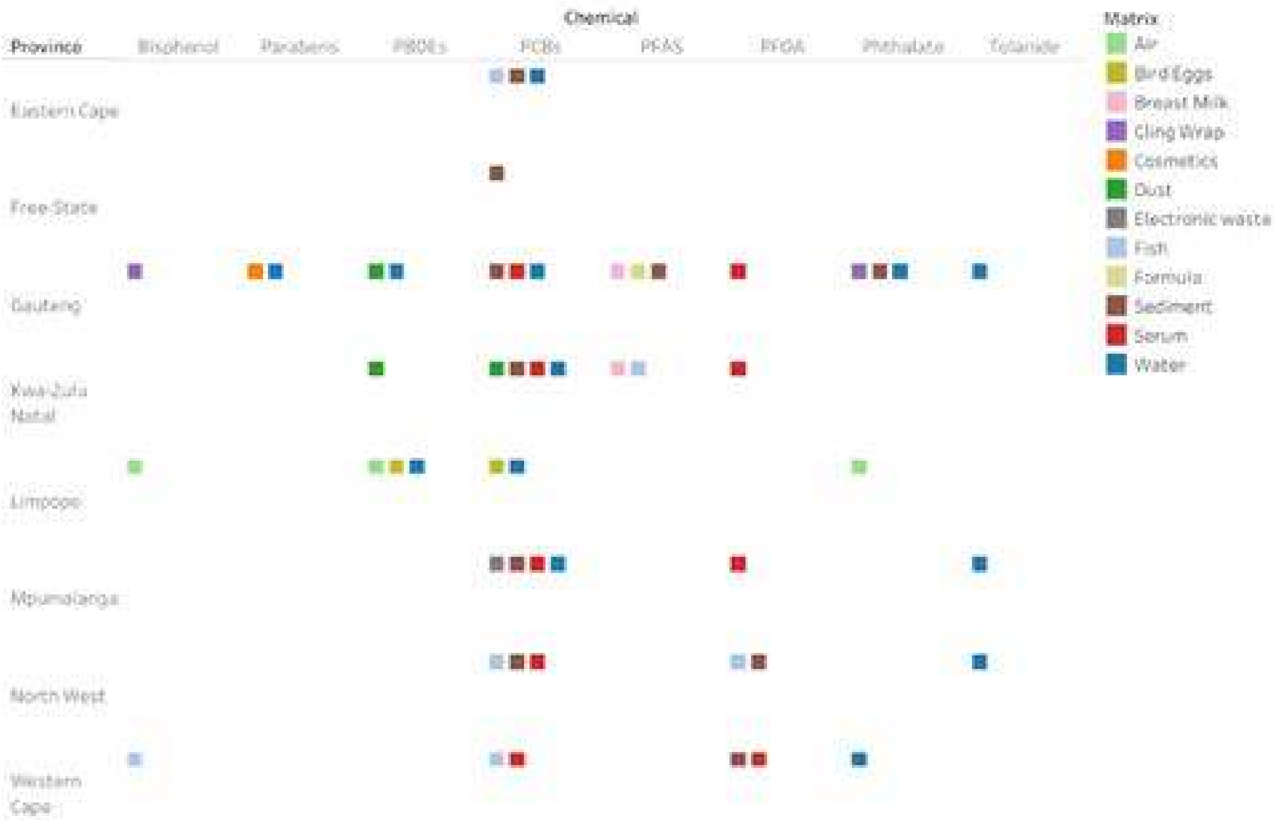

Figure 15: *Geographical location of studies in South Africa investigating Triclosan.*