

Per- and Poly-Fluoroalkyl Substances in the Petrochemical Industry in Africa: The Need for Regulatory Framework

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ABSTRACT

Africa contributes about 10% of the global energy supply. This figure is projected to increase to 20% by 2030 as more oil discoveries are made and countries intensify oil investments to meet their energy and economic interests. In petroleum exploration and production, a significant amount of chemicals broadly known as additives and surfactants are used with formulations containing legacy and chemicals of emerging concern (CEC). The management of legacy contaminants is regulated in the petroleum industry by national legislation, but chemicals of emerging concern (CEC) like per- and poly-fluoroalkyl substances (PFASs) are not regulated despite growing evidence of their persistent nature, transboundary scope and known effects on biota and human health. As the rest of the world races to protect public health by implementing policy and enacting legislation to restrict and ban the use of certain CECs in industrial operations including in the petrochemical industry, this paper calls for the urgent need for awareness, national legislation, and continent-wide regulation for the management of PFASs and other emerging chemicals in the petrochemical industry in Africa. This is important to further the global monitoring and regulation of CECs as demonstrated in the petrochemical industry in developed economies.

Keywords: chemical regulation, risk assessment, emerging contaminants, PFASs, Africa

INTRODUCTION

The petroleum industry has played a critical role in the economic development of the 20th century and will continue to do so in the future despite significant investment in alternative sources of energy. Since the 1950s, crude oil has become the most important energy source to society. The exploration, production, refining, distribution and consumption of petroleum represents the largest industrial sector in the global economy. It is estimated that the world consumes about 80 - 100 million barrels of oil each day (EIA, 2020; EIA, 2022). Annual consumption of oil is put at 36 billion barrels with developed economies responsible for significant consumption globally (Sönnichsen, 2020). According to BP, oil and natural gas are responsible for 55.9% of global energy supply and consumption (Figure 1), far exceeding coal and other alternative sources of energy (BP, 2021). In the United States alone, petroleum accounts for 40% of total energy consumption and about 90% of vehicular fuel comes from crude oil (EIA, 2017). Global oil reserve is put at 3.74 trillion barrels given the current consumption rate, oil will remain relevant to the global economy for almost a century (Oil and Gas Middle East, 2020). The major producers of oil include the United States, Russia, and Saudi Arabia (EIA, 2023). About 69% of oil production comes from the top ten countries, while OPEC is responsible for 38% of global production (EIA, 2022; EIA, 2023).

Aside from energy sources, oil provides the raw materials for the production of several chemical products for industrial, commercial and domestic use. Petroleum provides the essential ingredients in the production of plastics, solvents, agrochemicals (fertilizers and pesticides), pharmaceuticals, fragrances and other new chemicals for the production of synthetic products. In this paper, oil and

gas and petroleum and gas may be used interchangeably, while petrochemical here refers to the petroleum and gas industry as well as the associated industries like refineries and petrochemical plants collecting feedstock from refineries and manufacturing chemicals for industrial and domestic uses.

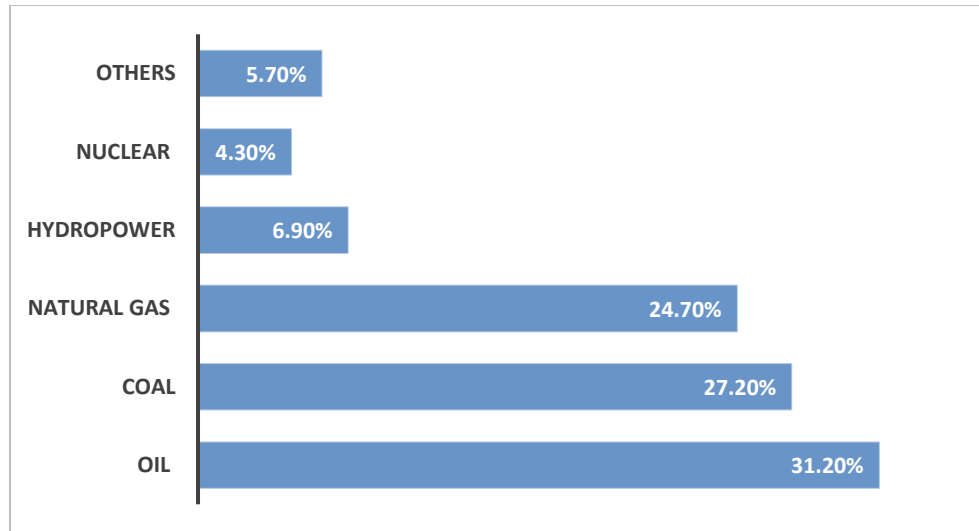


Figure 1. Global energy sources and consumption rate (BP, 2021)

THE PETROCHEMICAL INDUSTRY IN AFRICA

The petroleum and gas industry is growing rapidly in Africa. Since the 1980s, significant oil reserves have been discovered in several countries in Africa, changing their economic direction from solid mineral and agro-allied dependent to petro-economy. With a proven oil reserve of 125 billion barrels and a combined gas reserve above 500 trillion cubic feet, Africa accounts for 10% of the world's total oil output with the production coming mainly from 20 countries in the region. The amount is projected to increase to 20% by 2030 (APPO, 2023; Herman 2023). Petroleum and gas production are mainly concentrated in five countries namely, Nigeria, Angola, Algeria, Egypt and Libya. Production from these five countries together accounts for over 80% of Africa's oil

production (APPO, 2023; Offshore Technology, 2023). Oil and natural gas trade currently account for more than 75% of Africa's exports to the rest of the world (APPO, 2023). With the 4th largest gas reserves in the world and the instability in the global gas market due to the war in Europe and Asia, Africa is positioning itself as a major gas exporter. One of the key projects in the region is the West Africa gas pipeline project - a 678 km project starting in Nigeria and passing through Benin Republic, Togo and ending in Ghana. The next phase of the project is expected to take the pipeline to Senegal and Morocco with provision for countries along the pipeline receive or inject their gas into it when completed (APPO, 2023). Another ambitious project is the ongoing effort to supply gas to Europe with the commencement of the Nigeria trans-Saharan pipeline project. The continent's substantial gas reserve is a great source of hope for the future. It is expected that harnessing these reserves could help Africa to address its energy challenge, assist in poverty alleviation and unemployment, and build stronger economies (APPO, 2023).

Aside from petroleum and gas production and export, Africa is also emerging as a global petrochemical products producer. There are presently a total of 63 active petrochemical complexes in Africa with a further 49 announced and planned. The largest and upcoming petrochemical complexes are located in Egypt, Nigeria and Tanzania, the capacities of which together account for 84% of the region's upcoming petrochemical production (Offshore Technology, 2023). Population growth and the increased demand for consumer goods like plastics, paints, and other petrochemical products are the key drivers of the growth in the petrochemical industry in the region (Herman 2023). Industrialization and economic diversification are two other important factors driving the growth in the sector (Herman 2023). For example, the Dangote Refinery situated in Lekki, Nigeria started operations in February 2024. The refinery with an estimated cost of \$20 billion and a refining capacity of 650,000 barrels per day is reported as the largest single-train

refinery in the world (Figure 2). The refinery is expected to meet the energy needs for refined petroleum products in Nigeria and provide supply to the West African and other markets. The petrochemical component is expected to provide feedstock and several petroleum-derived products for local and export markets (www.dangote.com/our-business/oil-and-gas). To improve cooperation and a unified front, oil producers in the region established the African Petroleum Producers Organization in Lagos in 1987 with headquarters in Brazzaville, Congo (Atumah, 2017; APPO, 2022). The institutional capacity of APPO in matters related to the oil sector in the region is overshadowed by OPEC which has become the major institutional powerhouse for oil producers and exporters in Africa, Asia, the Middle East and South America.



Figure 2. The Dangote Refinery in Lekki Free Trade Zone, Lagos, Nigeria (Ubah, 2022)

PER- AND POLY-FLUOROALKYL SUBSTANCES (PFAS) AND THEIR APPLICATION IN THE PETROCHEMICAL INDUSTRY

Per- and polyfluoroalkyl substances (PFASs) are a large group of synthetic fluorinated compounds that are used in a wide range of industrial, commercial and domestic products (NIOSH, 2022). The carbon-fluorine backbone of PFAS confers their unique properties to resist heat, oil, stains, grease, and water (Buck et al., 2011). These unique properties make them suitable for the production of a wide range of products for aviation, medicine, military, construction, food production, petrochemicals and consumer goods. Some prominent products include non-stick cookware, personal care products, stain-resistant fabrics, firefighting foams and chemical additives (CDC, 2022; Evich et al., 2022). Chemical additives are essential ingredients in the petroleum and gas industry. From drilling operations to enhanced oil recovery, a significant quantity of additives ensures smooth operations in the industry. In petroleum exploration and production, a significant amount of chemicals broadly known as additives and surfactants are used with formulations containing legacy and chemicals of emerging concern (CEC), (Boudet et al., 2014). Chemical additives and formulations are expected to pass a rigorous ecotoxicological assessment before they are released into the market to guarantee their safe use and disposal towards the environment and human health. Despite existing regulations, certain approved chemical additives do turn out to be toxic, with consequential effects on the environment, biota and human health.

PFASs are used in a variety of petrochemical processes. Some of the uses of PFAS compounds include;

- 1. Coating of Pipelines and Equipment:** PFASs are used to coat pipes, valves, gaskets, seals and other related materials to protect them from corrosion and abrasion. PFAS-containing materials are used for the coating of storage tanks and other similar equipment in the petrochemical industry. Over time, these materials can degrade, potentially releasing PFAS into the environment.

2. **Firefighting Foams:** PFASs are used in firefighting foams to extinguish fires caused by flammable liquids in various sectors including petrochemical production plants and platforms. PFAS-containing firefighting foams are used in the petrochemical industry to combat hydrocarbon fires. Petroleum and its products are highly flammable and PFAS-containing firefighting foams like aqueous film-forming foams (AFFFs) are effective at extinguishing flammable liquid fires. The foams released into the environment with PFAS could contaminate soil, surface and groundwater.

3. **Refining:** PFASs are used in refining processes to remove impurities from crude oil and to produce high-quality fuels and other products.

4. **Petrochemicals:** PFASs are used as additives in the production of a variety of petrochemical products such as plastics, synthetic rubber, and fluorinated chemicals to improve their performance and durability.

5. **Hydraulic Fracturing (Fracking):** While conventional drilling requires many chemical additives including PFAS compounds, the increased reliance on enhanced oil recovery techniques particularly the controversial multi-stage drilling and hydraulic fracturing known as fracking has pushed the usage of more chemicals including PFAS substances in the oil and gas industry for oil extraction (Boudet et al., 2014). PFASs have been injected into more than 1,200 natural gas and oil wells in the US since 2012 (Hogue, 2021). PFASs are used as a mixture of water, sand, and chemicals under pressure to fracture underground geologic formations and reach trapped oil or gas in drilling operations known as fracking (Hogue, 2021). Several PFASs used as fracking fluids in the petrochemical industry are commonly listed as “non-ionic fluorosurfactants” in the national fracking chemical disclosure registry (Hogue, 2021).

PER- AND POLY-FLUOROALKYL SUBSTANCES AND THEIR ENVIRONMENTAL AND HEALTH IMPLICATIONS

The petroleum and gas industry is a major contributor to global environmental issues like climate change, oil spills, acid rain, exhaust emissions and volatile organic compounds. Also, efforts to reduce emissions from the energy sector have resulted in a 40% increase in clean energy investment since 2020 (IEA, 2023). However, there has been concern that the industry could also become a major contributor to persistent and emerging contaminants like plastics and PFASs in the global environment. The carbon-fluorine bond of PFAS is one of the strongest chemical bonds in organic chemistry, thereby making them highly persistent and resistant to biological and chemical breakdown. These unique properties and the difficulty of estimating the environmental half-life of PFAS compounds have earned PFASs the nickname of ‘forever chemicals’ (Jha et al., 2021; CDC, 2022; Evich et al. 2022). Due to their large numbers, environmental and ecotoxicology studies struggle to keep pace with the development and release of PFASs (Jha et al., 2021; Evich et al. 2022), thereby heightening scientific and public concern for PFASs due to their ubiquity in the global environment and their detection in everyday products, food and humans (Jha et al., 2021; CDC, 2022; Evich et al. 2022; Ekperusi et al. 2023). Widespread global persistence of PFAS has resulted in measurable concentrations in the blood of almost the entire population in developed economies with effects spreading globally among developing nations and in the arctic regions of the world (Butt et al., 2010; Stubbleski et al. 2016; Jian et al. 2018; Dartey et al. 2021; Fenton et al., 2021; CDC, 2022; Evich et al. 2022). Workers in certain industries like chemical manufacturing, firefighting, military and petrochemicals may be more exposed to PFAS than the general public (NIOSH, 2022).

Although the overall effects of PFASs on human health are not fully known, research has already established cascades of health effects from exposure to PFASs (CDC, 2022; NIOSH, 2022). PFASs have been associated with hypertension, immunotoxic, metabolic, carcinogenic, reproductive, neurotoxic and endocrine effects (European Environment Agency, 2019; Jha et al., 2021; Evich et al. 2022). PFASs have been shown to affect almost all vital human organs including unborn children during pregnancy with evidence of placental transmission (Jha et al., 2021). Health effects are only reported for a few PFAS compounds. Toxicological data is lacking for several new and short-chain PFASs in current use and the knowledge of their effects is unknown (Fenton et al., 2021).

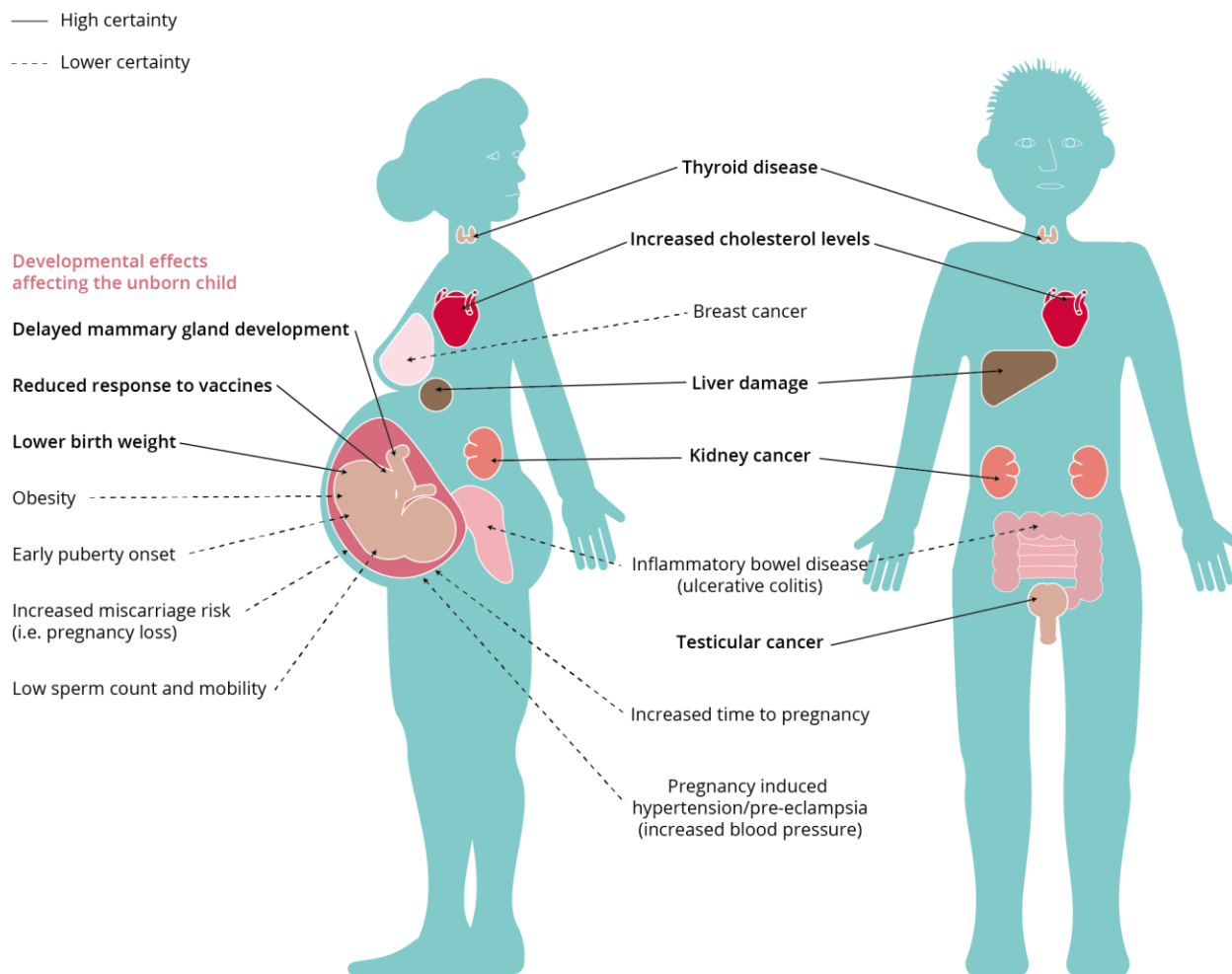


Figure 3. Human health effects associated with PFASs (European Environment Agency, 2019).

MITIGATIVE APPROACH FOR PER- AND POLY-FLUOROALKYL SUBSTANCES IN THE GLOBAL ENVIRONMENT

There has been a growing research effort within the last decade, to advance the science and knowledge of PFAS treatment in soil, water and groundwater, especially in North America, Europe and Asia, following the increased knowledge and awareness of PFAS to the environment, biota and human health (Buck et al., 2011). The treatment and remediation of PFAS-polluted media is difficult, given the strength of the C-F bond (Evich et al. 2022). Physical, chemical and biological treatment of PFAS-contaminated matrices are still in infancy. This is even made complicated by the fact that degradative products from PFAS parent compounds are more stable and resistant to degradation and could even cause more harm than the original compound in many cases. Terminal products like PFOS and PFOA from the degradation of sulfonic and carboxylic acids of PFAS are more stable, potent and toxic to the environment and human health compared to the parent compounds. Although some technologies have shown the potential to destroy select PFAS, none have demonstrated long-term performance capable of complete removal of PFAS on a practical field-scale approach (Evich et al. 2022). Mitigative action is geared towards a preventative approach to human health and the environment. The detection of PFAS has led to various mitigative actions in North America, Europe and Asia, but it is limited or no action in Africa and South America (Dartey et al. 2021; Jha et al., 2021; Ekperusi et al. 2023). Human exposure to PFASs has been identified as a general public health concern in developed countries. In 2017, regulators shut down a well water in a district in Maine due to PFAS contamination. This further led to the shutdown of a nearby integrated crops and livestock system with PFAS contamination

in soils, hay, milk and human blood samples (Jha et al., 2021). The United States Department of Agriculture via the Food Safety and Inspection Service suspended dairy production and shipment due to PFAS contamination in New Mexico's dairy until remedial action is carried out to guarantee cattle meat safety from the facility (Jha et al., 2021). Similar actions have been taken across Europe to safeguard human health in the face of increasing evidence about PFAS's effects on public health.

THE NEED FOR THE REGULATION OF PER- AND POLY-FLUOROALKYL SUBSTANCES IN THE PETROCHEMICAL INDUSTRY IN AFRICA

Realising the weight of the scientific evidence for PFAS, in 2009, the global community through the United Nations Environment Programme took a decisive step and listed certain PFASs (PFOS, PFOA salts and related compounds) under Annex A and C of the Stockholm Convention on Persistent Organic Pollutant (POPs) for their persistence and subsequent negative environmental and health impacts (UNEP 2021; Jha et al., 2021). The listing aims to eliminate and restrict the production and use of the listed PFAS compounds due to health complications (Jha et al., 2021). The United States Environmental Protection Agency (USEPA) has established a lifetime exposure of 70 parts per trillion (ppt) as the current health advisory level for PFOA and PFOS in drinking water (USEPA 2021; Jha et al., 2021). The USEPA has funded research to validate test methods for 29 PFAS compounds including the clean-up of contaminated groundwater. There is also the revision of existing frameworks to regulate the manufacture and import of PFOA and PFOS with the provision of support to states for the development of new tools for PFAS research and risk communications (USEPA, 2021; Jha et al., 2021). In 2020, the European Union banned the production and sales of PFOA salts and precursors for all industrial uses, while PFOA, PFOS, PFNA and PFHxS are now strictly regulated for food products in the EU. There are also strict

regulations for PFASs especially for PFOA and PFOS and their salts in Germany, Denmark and other European countries (Jha et al., 2021; Evich et al. 2022). Aside from global, continent-wide and national regulations, several institutions and professional bodies are taking action to protect members in the workplace. For example, the American Conference for Governmental Industrial Hygienists (ACGIH) has established threshold limit values for three PFAS in the air - perfluoroisobutylene, perfluorobutyl ethylene, and ammonium perfluorooctanoate, a salt of PFOA in a bid to protect workers from increased exposure to PFASs (ACGIH, 2022; NIOSH, 2022). As PFAS risk communication increases especially from the scientific domain, public awareness and regulatory concern will increase (Evich et al. 2022; Ekperusi et al., 2023).

In Africa, no regulatory framework exists for PFASs in any sector, but given the increased evidence and the implication for industrial sectors consuming chemical products like the petrochemical industry, there is a need to establish a national and where necessary continent-wide legislative framework, given the transboundary nature of persistent organic pollutants like PFASs. There is limited data on the levels of PFASs in the environment and human populations in Africa. However, a few studies have found PFASs in water, soil, seafood and blood samples from humans in Africa, demonstrating the ubiquity of PFAS in the African continent (Hanssen et al., 2010; Müller et al., 2019; Arinaitwe et al., 2020; Ssebugere et al., 2020; Dartey et al. 2021; Barhoumi et al., 2022; Ekperusi et al., 2023). More research is needed to understand the extent of PFAS contamination in Africa and the potential risks to human health. However, the available evidence suggests that PFASs are a concern, particularly from sectors like the petrochemical industry with a long history of consuming PFAS products. Some of the challenges to managing PFASs in Africa include:

1. Limited awareness: The low level of evidence from scientific research in the region and the inadequate communication of PFAS in the media provide limited awareness and knowledge of the dangers of PFASs to the general public. This general lack of awareness can make it difficult to implement effective management strategies.

2. Limited resources: Many African countries lack the resources needed to monitor and enforce PFAS regulations. Many of the bench and laboratory work carried out for the few studies on PFAS in Africa are undertaken in Europe or North America. While research-based institutions lack the equipment for PFAS analysis, many of the international oil companies and petrochemical plants operating in the region have state-of-the-art equipment which are outside the reach of research scientists. This lack of synergy between the industry and research-based institutions has hampered research efforts in the region.

Despite these challenges, several steps can be taken to manage PFASs in the petrochemical industry in Africa. Governments, regulatory agencies, scientists and the petrochemical industry in Africa should work together to:

1. **Raise awareness:** There should be increased awareness from regulators, scientists and the media to policymakers, environmental advocacy groups, and the general public. Raising awareness of the dangers of PFASs is essential among workers in the petrochemical industry and oil-producing communities.

2. **Monitor and assess PFAS contamination** in and around petrochemical facilities. There is a need to provide evidence-based science to policymakers on the prevalence of PFAS in the region. This is important to understand the overall burden of PFAS and the need to take appropriate action for their mitigation. The oil and gas sector should collaborate with research scientists to provide

research facilities for supporting research related to PFAS in the region, especially in oil field operations for the protection of the environment, and human health.

3. Implement best practices for handling PFAS-containing materials and wastes. Regulators should work with stakeholders in the petroleum industry, scientific domain and environmental advocates to develop best practices for handling contaminated materials and sites for effective and safe mitigation of PFAS-contaminated environment.

4. Develop and enforce regulations to limit PFAS use and emissions. From the growing evidence, policymakers and regulators should take appropriate action to protect drinking water, food and human health. African governments need to develop regulations to control the use and release of PFASs. These regulations should be based on the latest scientific evidence and should be designed to protect human health and the environments.

5. Invest in research and technology to remediate PFAS-contaminated sites. The petroleum and gas industry, including petrochemical plants and the government should invest in PFAS treatment technologies to remove PFASs from wastewater and contaminated environment.

6. Promote the responsible use of firefighting foams and alternatives. The petrochemical industry should encourage and pursue the use of PFAS-free alternatives and limit the use of products with PFAS formulations.

Given the potential environmental and health risks associated with PFAS, the petrochemical industry in Africa must prioritize the management of these substances to minimize their impact on the environment and public health.

CONCLUSION

As oil and gas activities and petrochemical operations increase in Africa, so also is the potential environmental burden due to the increased consumption of chemical additives. The wide use of PFAS-related compounds for coating pipelines, firefighting equipment, refining, and fracking will lead to the long-term release of PFAS into the environment with potential contamination of surface water, soil, groundwater, and food products. Human exposure to PFASs has been identified as a public health concern. While there are global efforts to regulate PFAS in various sectors, no regulatory framework exists for PFASs in any sector in Africa. There is a need for stakeholders in the region to increase awareness and resources towards PFAS mitigation, especially for workers and oil-producing communities in the region. African governments need to take steps to reduce PFAS pollution from the petrochemical industry. Management action could include increasing awareness among the general public, improving research funding and facilities and enacting environmental regulations at the national and regional levels while encouraging the use of PFAS-free alternatives in the sector.

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