GROUNDWATER

Better the devil you know: Durban aquifers come in for close scrutiny

Groundwater, despite its importance, hasn't received the attention it deserves. A new study focusing on contaminants of emerging concern is helping correct this. Matthew Hattingh reports.

"Stille waters, diepe grond. Onder draai die duiwel rond." The Afrikaans proverb refers to the mysteries and psychological depth sometimes lurking below the surface of shy or seemingly placid people. Alerting us that deep within, a secret, perhaps even tempestuous nature, may be roaming.

This familiar piece of wisdom could well apply to groundwater. Our subterranean stores, a vital supplement to our water supply, remain something of a mystery. Do we really know what aquifers contain? And are the contents as pure as some of us would like to think? Ought we to be more on guard, to protect the resource?

A recent Water Research Commission (WRC) funded study tested the waters of greater Durban, with particular attention to a relatively new, unregulated bedevilment, known as contaminants of emerging concern (CECs). These include pesticides, potions and lotions, drugs, legal and otherwise, and "lifestyle" compounds, like caffeine and nicotine.

Hydrogeologists Siphesihle Ndlovu and Molla Demlie are the authors of 'Study of the occurrence, distribution, and fate of contaminants of emerging concern in groundwater in the Greater Durban Region' (**WRC Project No. C2023/2024-01416**).

It presents an overview of the eThekwini metro region's groundwater and river systems, the climate and topography, and rock and soil formations that hold the groundwater. The authors collected, analysed and compared samples drawn in different seasons from 54 boreholes and seven surface water sites. Over three years, they developed a broad picture of the state of groundwater in the region, encompassing rural, peri-urban, residential, informal settlements and industrial land.

Ndlovu and Demile, a University of KwaZulu-Natal doctoral fellow and professor respectively, believe their study is timely. CECs have long been an area of research worldwide, but the focus has been on surface water. More recently, attention has shifted to groundwater, and South Africa needs to catch up. Only a handful of studies have been completed on contamination of the country's groundwater, with sampling limited to a few boreholes. Yet, we are increasingly dependent on groundwater as a supplement or alternative to surface water stretched thin by a growing urban population. eThekwini is now using more groundwater than ever before.

In a ***Water Wheel*** interview, the authors of the study spoke of extensive private borehole use, with limited regulation, including north of the city in new developments such as Cornubia and Umhlanga Ridge. In the popular imagination, groundwater is thought to be protected, as it's buried beneath soil and rock. Depending on the hydrogeological setting, however, it can be "highly vulnerable to contamination".

The authors are keen to correct such misconceptions, providing "comprehensive evidence of the occurrence, distribution, and controlling processes of CECs in water". CECs are increasingly found in surface and groundwater, a headache water authorities and regulators need to come to grips with, especially because CECs are hard to pin down. Chemically, they can be complex, particularly in combination with other contaminants, and their sources can be diverse.

As far as CECs go, the study reminds us that "low-level mixtures of pharmaceuticals and other organics can have additive or synergistic harmful effects on aquatic organisms".

To gauge the threat in Durban, water samples were collected from groundwater and surface water. These included 35 private and community-owned boreholes, at schools, clubs, mosques and churches; two Department of Water and Sanitation regional monitoring boreholes; and 17 municipal landfill monitoring boreholes. This was done at the end of the dry season (August), the start of the wet season (after the first flush of rain), and at the end of the wet season (April).

The study focused on groundwater in the greater Durban area, where especially private borehole use is increasing.

Samples were painstakingly filtered and prepared with the help of two Master's candidates and two Honours graduates (part of the project's capacity-building component). Researchers at specialised laboratories then looked for CECs, major ions, trace elements, environmental isotopes, and microplastics. Major ions are electrically charged ions found dissolved in water and include calcium, magnesium, sodium, chloride, sulphate, and bicarbonate. These dictate the salinity of water and ionic balance (essential salts) – all crucial to water quality. Major ions and trace elements provide clues to the origins of groundwater. They indicate the soils and rock the water has passed through and suggest how quickly aquifers were recharging.

Chromatography was used to identify and measure major ions in the samples. Mass spectrometry helped analyse trace elements and isotopes. Isotopes are versions of a given element, with greater or fewer neutrons than the norm, and as a result, different masses. The ratios of isotopes change with different environmental processes. Lighter water molecules have weaker bonds and so evaporate more readily. Heavier water molecules condense more and so rain down sooner.

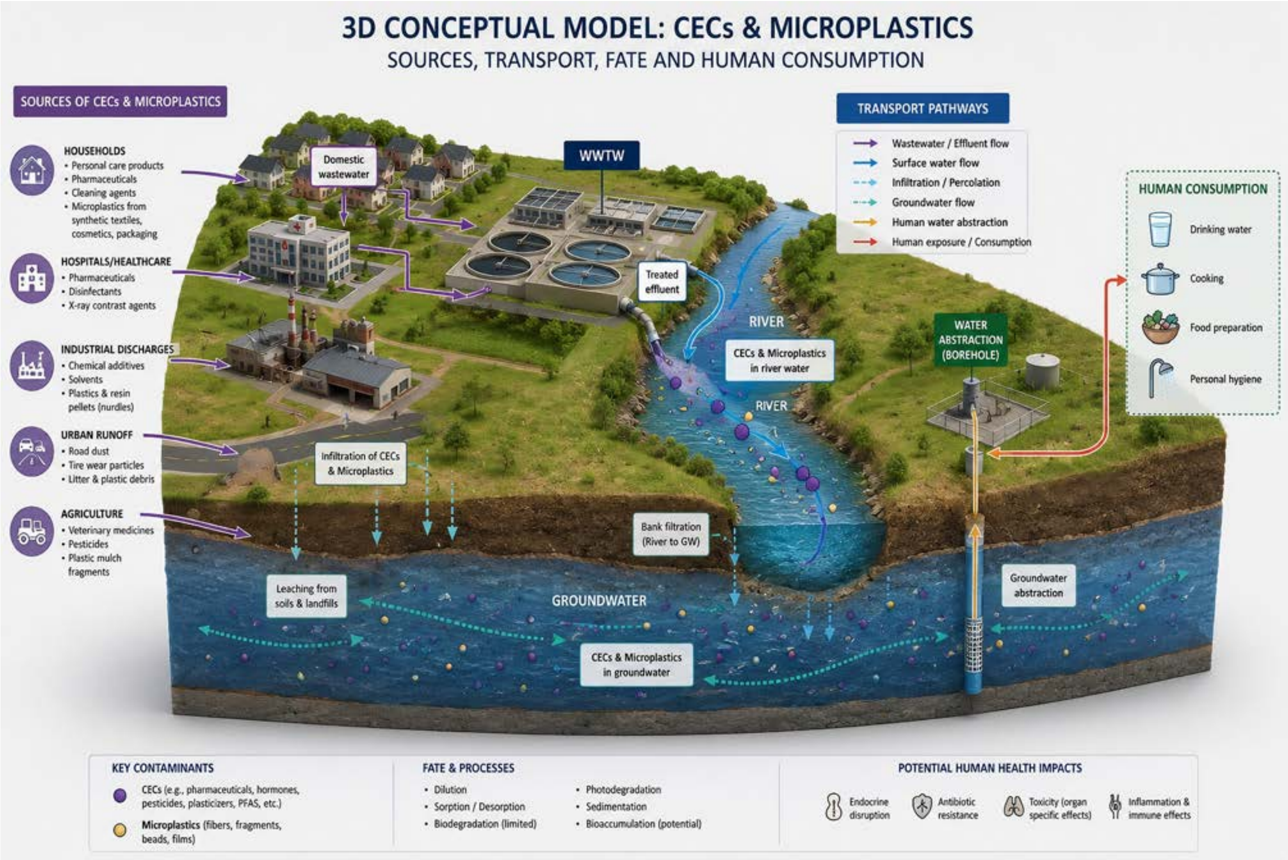
Although only a tiny portion of water molecules contain heavy oxygen and hydrogen isotopes, they have a unique atomic signature. This allowed the researchers to use isotopes to trace where groundwater came from and the processes it had undergone.

High-resolution mass spectrometry allowed the researchers to detect the tiny tell-tale differences in isotope concentrations. The results indicated all surface water and some groundwater samples had gone through evaporation.

Analysis revealed spikes in electrical conductivity and levels of chlorides and nitrates at the start of the wet season. Elevated nitrate levels are associated with fertilisers and human or animal waste, while increased chloride may also indicate wastewater, sewage, or other human activities. This suggested a first flush into aquifers of CECs accumulated in the dry season, in the soil and rock above the water table and on hard urban surfaces. Subsequent rains were observed to recharge aquifers, diluting contaminants.

Concentrations of nitrates and sulphates in populated areas south-west of Pinetown and Phoenix "strongly suggest sewage leakage and surface runoff as possible active contamination sources of groundwater". Isotopic evidence confirmed "surface waters can enter the aquifer quickly, bypassing the natural filtration capacity (of the soil and rock above), increasing the likelihood of CECs reaching the water table", the study found. "The aquifer is most vulnerable during the start of the wet season, where the mobilisation of pollutant loads creates a surge in contamination potential."

Plumes of salty water occurring with sewage indicators in urban areas served as a "strong proxy" for the presence of CECs, Photo supplied



How CECs and microplastics find their way into groundwater.

suggesting these contaminants "co-migrate with conventional pollutants".

The search for CECs involved targeted analysis of 17 selected contaminants, and non-targeted analysis, which took a drag-net approach. The 17 CECs included anti-inflammatories, like the ubiquitous ibuprofen; the antiepileptic carbamazepine; antibiotics like tetracycline; and lifestyle and industrial compounds like caffeine and bisphenol A (used in plastics goods and can linings).

Contaminant detection was found to be strongly seasonal, with water quality deteriorating as pollutants concentrated during low rainfall. In total, 207, 138 and 121 CECs were detected across all the sample sites during the end of the dry season, start of the wet, and end of the wet season, respectively.

Seven broad classes of CEC were detected: pharmaceuticals and personal care products (PPCPs); pesticides, herbicides and biocides; industrial chemicals and plasticizers; surfactants and polymers; fatty acids and amides; dyes and pigments; and microplastics.

Topping the list of CECs in Durban's groundwater were PPCPs, especially in urban and industrial areas like Pinetown and the South Durban Basin, where a cornucopia of ***muthi*** was detected. These included non-steroidal anti-inflammatory drugs; antibiotics; antidepressants; antidiabetics; anthelmintics; antiepileptic and anticonvulsants; antifungals; antipsychotics; antihistamines; anxiolytic and sedatives; cardiovascular drugs; and hormones and steroids.

The presence of antibiotics heightened growing concerns that these may raise antimicrobial resistance in aquatic food chains, "ultimately affecting the human population". Many PPCPs, or their remnants, pass through the body, enter the sewers, and reach wastewater treatment works, where processes have proved ineffective at removing some of them. They also ended up in municipal landfill sites, fortifying a noxious soup of nasties leaching into the groundwater. Older and decommissioned sites tended to be leakier than newer sites.

Groundwater samples from boreholes near landfills and rivers contained the highest contaminant levels. The lowest numbers of CECs were in samples from standalone boreholes used for drinking water. "Overall, the contaminant profile in landfill monitoring boreholes was characterised by high detection frequencies of analgesics, hormones and specific antibiotics, confirming landfills as point sources of PPCPs residues," the study reported.

Industrial chemicals and plasticizers (used to make plastics malleable, including triethyl phosphate and phthalates) were concentrated around landfills and manufacturing hubs, especially in Pinetown, Isipingo and Mobeni. Triethyl phosphate (a flame retardant and plasticizer) is slow to break down in the environment, lingering in aquatic and soil systems. It dissolves easily in water, so once released into the environment is transported with surface water or groundwater. It can then affect wider areas.

Phthalates are used in plastics and cosmetics. Like several other CECs detected in the study, they are endocrine disruptors – compounds that interfere with natural hormones in living organisms. They can throw body temperature, blood sugar, and fluid levels out of whack and fiddle with fertility. Pesticides and herbicides were detected in more diffuse patterns, most likely associated with farming and residential gardens. Surfactants, found in soaps and detergents and used in industry, were "pervasive… and served as sensitive proxies for greywater ingress and untreated sewage".

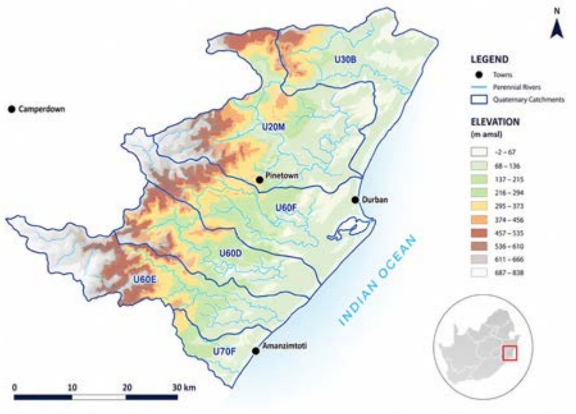
The study dedicated a chapter to microplastics, tiny pieces of plastic polymers, including tyre dust, shards and scrapings from carrier bags and packaging, and filaments from synthetic textiles. Filaments were found in all the groundwater and surface water sampled – especially in the wet season and in samples collected around townships, informal settlements and industrial areas.

Fibres were the most common microplastic shape detected, followed by fragments, films, and foams. Because fibres tend to be longer and skinnier than irregular shaped fragments, once liberated in the laundry they are good at slipping through the pores of aquifer material and more likely to survive the journey intact.

Ndlovu and Demlie were surprised by the volume and variety of microplastic they found in groundwater samples, having anticipated the soil above would do a better job trapping it. That said, the microplastic fragments were typically smaller than those found in surface waste, suggesting bigger fragments were being checked.

Examined under an electron microscope and with X-ray spectrometry, the microplastic samples revealed surfaces cracked and scratched from being bumped about and broken while travelling down rivers and through soil. The roughened surfaces of the fragments might "serve as hosts and habitats for other contaminants, such as heavy metals and microorganisms", making microplastics not only contaminants, but carriers.

For this study, 54 groundwater and 7 surface water samples were collected in three seasons across the greater Durban region. Groundwater levels, onsite physico-chemical parameters, borehole construction and location information were documented during the fieldwork. All samples were analysed for major ions and trace elements, environmental isotopes, microplastics, and CECs.



The study focused on the greater Durban area.

The authors felt that water authorities and the public were rightly anxious about the increasing presence in drinking water of microplastics – and other CECs. They warned that Durban's freshwater resources were being progressively transformed, "with significant implications for ecosystem integrity and human health".

The data demonstrated how certain contaminants could serve as tracers, helping to identify the source of pollution. The presence of carbamazepine and artificial sweeteners in groundwater, for example, pointed to wastewater ingress because of these contaminants' persistent usage and environmental stability. Saccharin and bisphenol A were associated with landfill-affected groundwater, although these compounds can originate from other sources.

The authors called for integrated water resource management and upgrades to waste and wastewater infrastructure and methodologies to raise treatment standards.
Greater scrutiny of industrial waste and wastewater was needed too. And water quality monitoring must be improved.

WRC research manager for the study, Dr Yazeed van Wyk, said the study's significance lies in showing where these contaminants occur, how they move through groundwater systems and the implications for future groundwater monitoring and management.

"The findings provide an important scientific basis for developing more proactive approaches to groundwater protection in South Africa."

But monitoring and mitigation measures won't happen on their own. Policy and regulations must first be rejigged and expanded to include targeted CECs. More research was needed too, including on how contaminants are transported through the ground; on groundwater in different hydrogeological settings in the country and beyond.

"This study must not stop here. It has to go into how this affects people," said Demlie, calling for multidisciplinary research on the health implications of CECs. The authors hope their study will lay the groundwork for this. On it rests not only the future of our groundwater, but perhaps of us all.