POLICY BRIEF

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Environmental Occurrence of Contaminants of Emerging Concern in Kenya

Status and Management Options for Athi River Basin

Maurice O. Okoth
Kenneth O. K'oreje
Samuel T. Lutta
Kristof Demeestere

University of Eldoret
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Introduction

HIGHLIGHTS

The study was carried out between 2020 and 2022. Twenty two locations at River Athi and its tributaries, as well as two WWTPs, were sampled during three sampling campaigns covering dry and wet seasons.

- 86 Contaminants of Emerging Concern were included in the analytical target list.
- 31 pharmaceuticals, 6 personal care products and 20 pesticides were detected and quantified. Areas influenced by informal settlements and industrial activities are the most polluted.
- High risk of development of antibiotic resistant bacteria strains are driven by metronidazole, sulfamethoxazole and trimethoprim.
- Need for policy and operational interventions to arrest CECs pollution not only in the River Athi basin but also nationally.
- The results were presented to a large group of stakeholders for awareness creation and feedback which has been integrated in this policy brief.

This policy brief is based on a study by the University of Eldoret, Kenya, and Ghent University, Belgium, which focused on pollution of River Athi and its tributaries by Contaminants of Emerging Concern (CECs). The policy brief summarizes the study, its findings and recommendations with respect to pollution control interventions.

Kenya is a water scarce country, a situation that has been compounded by widespread pollution of surface water and ground water. The water resources have been polluted by both conventional pollutants and CECs.

The latter group comprises an array of largely unregulated trace organic compounds such as pharmaceuticals (PhACs), personal care products (PCPs), flame retardants and new generation pesticides among others, which have increasingly raised environmental and public health concern in the recent decades. CECs are often poorly removed by conventional waste water treatment techniques, and behave as (pseudo-) persistent contaminants in the environment, thus, posing environmental and human health risks. Sources of CECs into the water resources are mainly domestic and industrial waste water discharges, leachates from solid waste dumpsites, and agricultural applications (Figure 1). However, the status of and risks posed by CECs in the Kenyan environment remain largely unknown.

Kenyan urban rivers have particularly borne the brant of pollution because of poor waste management practices, ever increasing population, and poor urban planning. For example, River Athi was at some point declared as unsuitable for human consumption by the National Environment Management Authority (NEMA).

The Athi River – the second longest river in Kenya, with an estimated catchment area of 58,639 km^2 – drains major urban areas such as the Nairobi metropolitan and significant agricultural areas which predisposes it to CECs pollution. Therefore, this study aims to document – for one of the first times – the status, risks and management options for CECs in the River Athi basin, focusing on 24 sampling sites (Figure 2).

Figure 1:
Some sources of pollution in River Athi basin: (a) broken manhole discharge of wastewater into River Ngong (Kibera), (b) Kariobangi wastewater treatment plant effluent discharged into River Nairobi (Korogocho), and (c) solid waste disposal in River Mathare (Gomongo). Photo: K'oreje (2020).

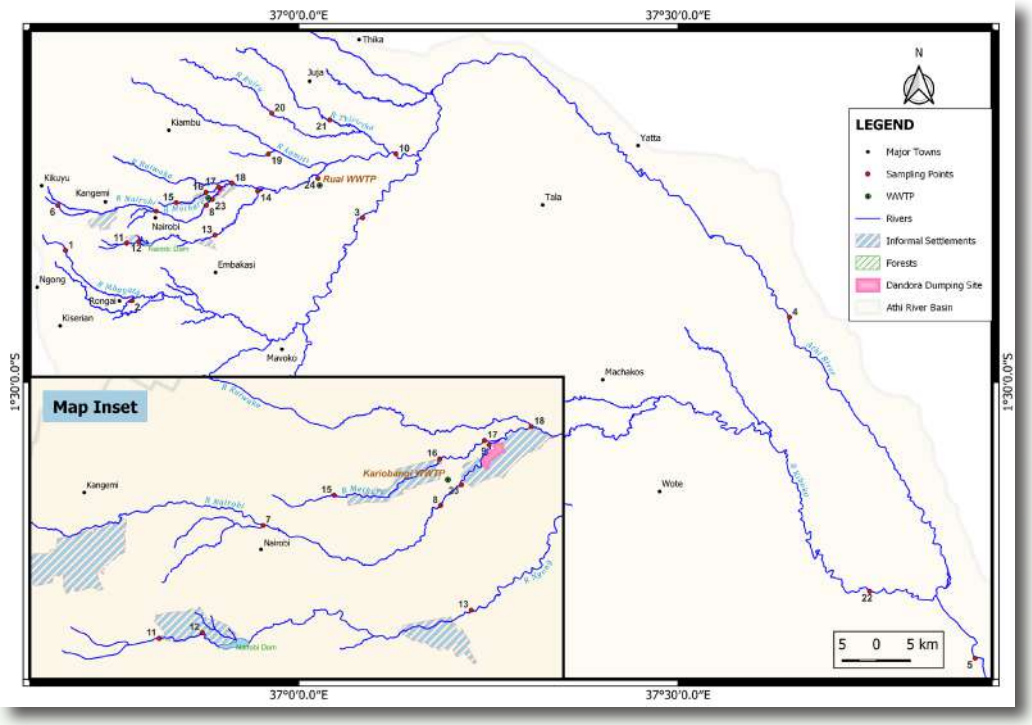

Figure 2 :
Map of the upper and middle River Athi catchment area, indicating the 24 sampling locations for this study. The sampling was carried out during three campaigns between 2020 and 2022. In this study, locations 1 to 5 are considered to form the main River Athi (Mbagathi/ Athi) whereas the others are its tributaries. Sampling point 23 and 24 represent the effluent of the WWTP of Kariobangi and Dandora wastewater treatment plants, respectively.

The burden of organic matter in River Athi basin

The level of organic matter in the River Athi basin – as indicated by the Biochemical Oxygen Demand (BOD) – varies spatially within the sub-basins (Figure 3).

Overall, the BOD ranges from 1 to 650 mg L^{-1}. Notably, the three sub-catchments – i.e. River Ngong, River Nairobi and River Mathare – which are characterized by informal settlements and industrial activities recorded up to twenty times the maximum BOD concentration that is legally allowed (30 mg L^{-1}) for effluent discharged into water resources.

Contextually, the BOD level at most sections of the three sub-catchments are within the range of what is found in untreated domestic wastewater, an indication of direct discharge of raw sewage into the rivers. Indeed, during field work, raw wastewater discharges could be observed from pit latrines constructed on the riparian areas and from broken sewers or sewer overflows (e.g. Fig. 1a).

The high organic load does not only render the river water unsuitable for domestic and even agricultural use, but also poses high risk to ecosystem sustainability. Notably, on average, the BOD concentration in the studied WWTP effluents is up to three times higher than the regulatory maximum limit. This suggests poor performance of the systems, hence a significant source of pollution in the area.

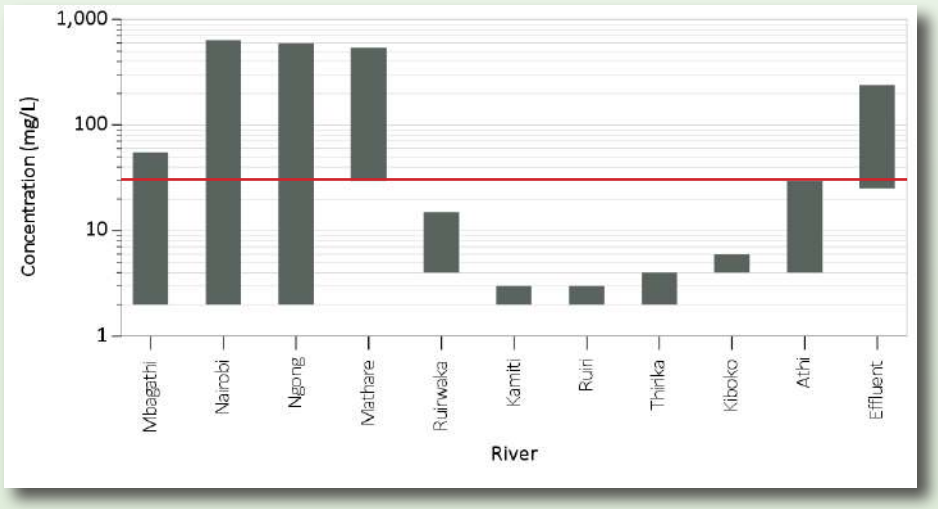

Figure 3:
Range of BOD concentrations within the River Athi basin. The red line indicates the allowable maximum BOD level for effluent discharged into water resources.

Occurrence and distribution of CECs in River Athi basin

Overall, a total of 57 CECs (31 pharmaceuticals, 6 personal care products and 20 pesticides) have been detected in the basin. Among the three CECs classes, pharmaceutical residues recorded the highest concentrations (Figure 4), which is attributable to the high pharmaceutical consumption in the region.

Within the group of the pharmaceuticals, antibiotics (e.g. metronidazole, trimethoprim, sulfamethoxazole and sulfadoxine), analgesics (e.g. paracetamol, ibuprofen and diclofenac) and antiretroviral drugs (e.g. lamuvidine, nevirapine and zidovudine) are the most frequently detected compounds (i.e. in > 50% of samples) at the highest concentrations (up to 140 µg L^{-1}).

Methyl paraben, N,N-diethyl-meta-toluamide (DEET) and oxybenzone dominated (i.e. in > 60% of samples) the category of the personal care products. The herbicides atrazine and diuron and the insecticides acetamiprid and imidacloprid are among the most ubiquitous pesticides (i.e. detected in > 60% of samples) in the basin.

Similar to the BOD trend, the highest concentrations of CECs were recorded at areas which are located within (e.g. River Ngong at Kibera, River Mathare at Gomongo) or receive water from informal settlements and industrial activities (e.g. pharmaceutical factories) (Figure 5). However, the concentration reduces significantly downstream, especially between River Nairobi at Juja farm and River Athi at Kiaoni, owing to the reduced pollutant input and self-epuration of the river system. As such, small-scale pollution interventions in the upstream sub-catchments could lead to a significant reduction in pollution load and concentrations downstream.

Notably, at some locations in the rivers, the CECs concentrations were higher than in the WWTP effluents, again an indication of direct discharge of raw wastewater into the rivers.

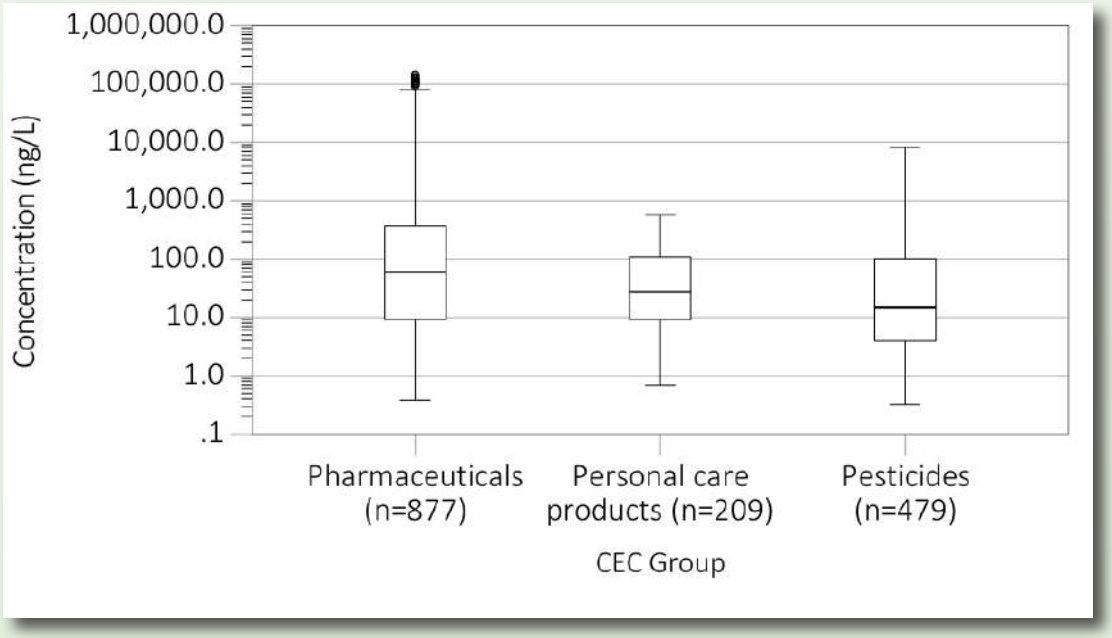

Figure 4: *Distribution of concentrations for various CECs groups within the River Athi basin. "n" represents the number of datapoints included in each box plot measured for the individual CECs at each of the sampling sites during the three sampling campaigns.*

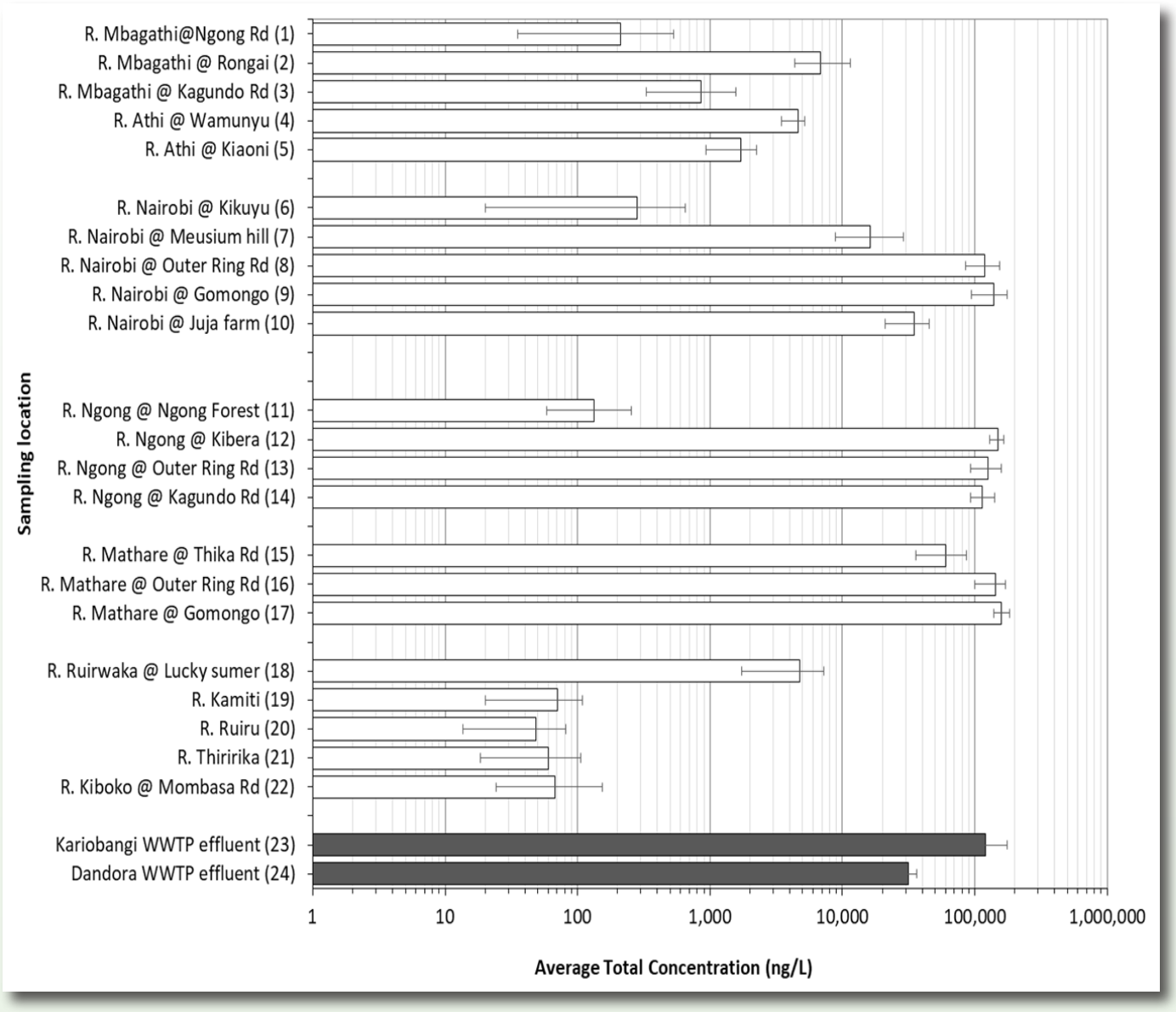

Figure 5:

CECs occurrence within the River Athi basin. The bars indicate the average total concentration of CECs measured at each of the 24 sites during the three sampling campaigns. The error bars represent the minimum and maximum total measured CECs concentration. The numbers within brackets refer to the sampling site codes (see Figure 2).

The danger of CECs in the basin

Possible development of bacterial strains that are resistant to antibiotics because of environmental occurrence of pharmaceutical residues is a major public health concern.

In the River Athi basin, 60% of the sampled river sites and both WWTP effluents show a high risk of resistant bacteria strain development (Figure 6).

The high risk is particularly driven by metronidazole, sulfamethoxazole and trimethoprim. Although the risk appears to be the highest upstream, especially within River Nairobi, Mathare and Ngong, it should be noted that resistant strains developed upstream are likely to be transported downstream where the exposure risk could even be much higher because the water is consumed untreated.

For example, at Kiaoni, the river water is drawn for domestic use while some community dwellers were observed drinking the water directly from the river.

Therefore, the resistant strains could easily be transferred to the water user communities in the basin, thus posing challenges for the management of bacterial infections.

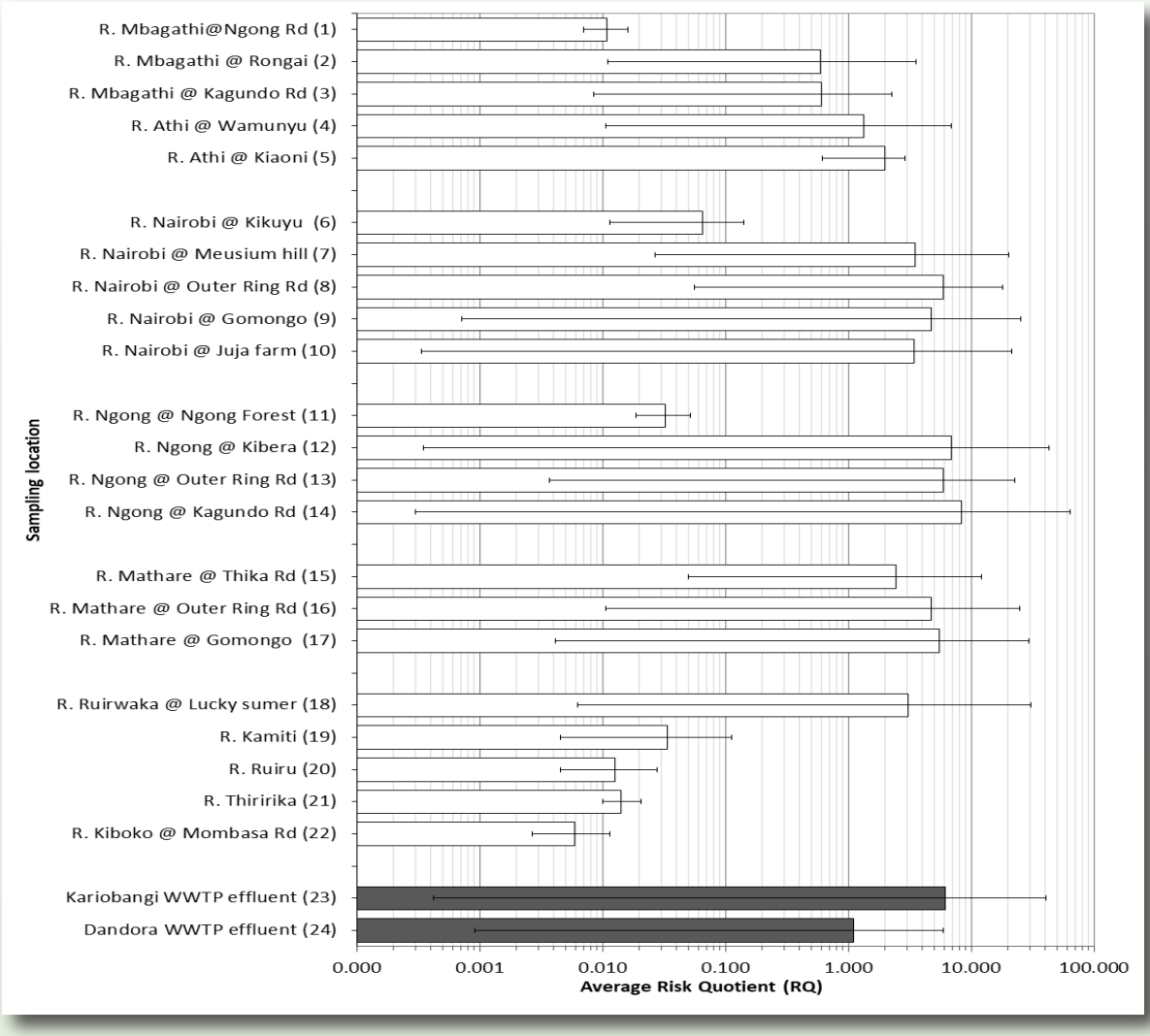

Figure 6:

Risk level for the development of antibiotic resistant bacterial strains at each of the 24 sampled sites. The risk level is determined by the Risk Quotient (RQ). When RQ is below 0.1, no risk is posed while values between 0.1 and 1 represent medium risk, and values above 1 imply high risk. The bars represent the average RQ for the antibiotics measured at each sampling site. The error bars represent the minimum and maximum RQ. The numbers within brackets refer to the sampling site codes (see Figure 2).

Conclusion

This study has comprehensively documented the status of organic matter (BOD) and CECs in the River Athi basin, underlining occurrence patterns and critical areas of concern.

Pharmaceuticals (antibiotics, pain relievers, antiretrovirals, psychiatrics, anti-asmatics, hypertensive and cardiovascular drugs), personal care products (preservatives, sunscreens and biocides) and pesticides (herbicides and insecticides) are ubiquitously present in the basin, at concentrations up to 140 µg L^{-1}, and pose a risk for the development of antibiotic resistant bacterial strains. Beside broken sewers, sewer overflows and WWTP effluents, informal settlements and industrial activities are major contributors of CECs in the basin owing to their inadequate sanitation facilities. Additionally, leachate from solid waste dump sites could be an important source.

These results have been presented to a group of water sector (including government agencies and research institutions) stakeholders during a workshop organized at the end of August 2022 in Nairobi.

The stakeholders provided feedback and recommendations on areas of further research, gaps and possible strategies to address the challenges of CECs. The suggestions and feedback are included in the list of proposed policy and regulatory intervention measures presented below.

Policy and regulatory intervention measures

1. Enhance awareness creation strategies on the risks and management of CECs.
2. Promote good agricultural practices and integrated pest management.
3. Strengthen the policy framework for effective and efficient management of non-consumed chemicals.
4. Develop a policy strategy to enhance analytical capacity and research for CECs including the establishment of a national environmental laboratory to serve as a Centre of Excellence for advanced environmental analysis.
5. Develop a policy and enhance regulatory enforcement strategies to guide prioritization of CECs and to implement regular monitoring for adequate compliance and risk assessment.
6. Develop toxicity threshold values for specific CECs geared towards ecological and human health protection.
7. Develop policies that promote eco-urban planning and upscale river riparian protection intervention measures.
8. Formulate a multi-sectoral strategy for the restoration of not only River Athi but also other urban rivers nationally.
9. Improve sewerage infrastructure and sanitation including adequate maintenance, especially in informal settlements.
10. Develop a policy framework to stimulate the development and enhance the adoption of affordable point-of-use drinking water and sanitation technologies in areas underserved by piped water and sewerage systems.

Correspondence:
University of Eldoret, **Prof. Maurice O. Okoth**, (okothmdo@uoeld.ac.ke)
Water Resources Authority, **Dr. Kenneth O. K'oreje**, (k.koreje@gmail.com)
University of Eldoret, **Prof. Samuel T. Lutta**, (stlutta@uoeld.ac.ke)
Ghent University, **Prof. Kristof Demeestere**, (kristof.demeestere@UGent.be)