Project title

Occurrence of pharmaceutical residues in wastewater and surface water and their impact on aquatic organisms during the Covid-19 pandemic in Sri Lanka

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4. Research report

4.1 Purpose

The global COVID-19 pandemic has significantly influenced the consumption and disposal of pharmaceuticals and personal care products (PPCPs), potentially leading to adverse effects on aquatic environments. This study aims to collect and analyze waste and surface water samples from Sri Lanka to assess the presence of selected PPCPs during the COVID-19 period. Building upon prior environmental monitoring of PPCPs conducted before the pandemic (2016-2018), this research involves a comparative analysis of pre-pandemic and pandemic-era data to evaluate potential environmental consequences. The primary objectives of the study are:

1. To examine the presence and distribution of PPCPs in various aquatic environments.
2. To assess the potential ecological impacts of PPCPs on vulnerable aquatic species.

4.2 Materials and Methods

4.2.1 Sample collection:

In 2022, during the surge of the Omicron variant of COVID-19, a total of 100 samples were collected across six time points: January, February, April, July, and December of 2022, as well as December 2023. These samples were obtained from diverse sources, including eight hospitals (H1 to H8), four surface water sampling sites [lake (KL), canal (KMC: Kandy mid canal), and river (MR-before and MR-after the WWTP discharge into the Mahaweli River)], and a wastewater treatment plant (WWTP, inlet and outlet) in the Kandy area, Sri Lanka (Figure 1).

Hospital water samples were categorized based on the presence of COVID-19 patients:

Covid+++: Samples specifically from COVID-19 patients.

Covid ++: Samples primarily from COVID-19 patients, possibly mixed with non-COVID-19 patients.

No recorded COVID-19 patients were present in hospitals H-4 and H-5 during the study period. From the fourth sampling event (July 2022) onward, there was no specific prioritization of COVID-19 patients in sample selection, due to patients were treated based on their medical conditions without differentiation based on COVID-19 status.

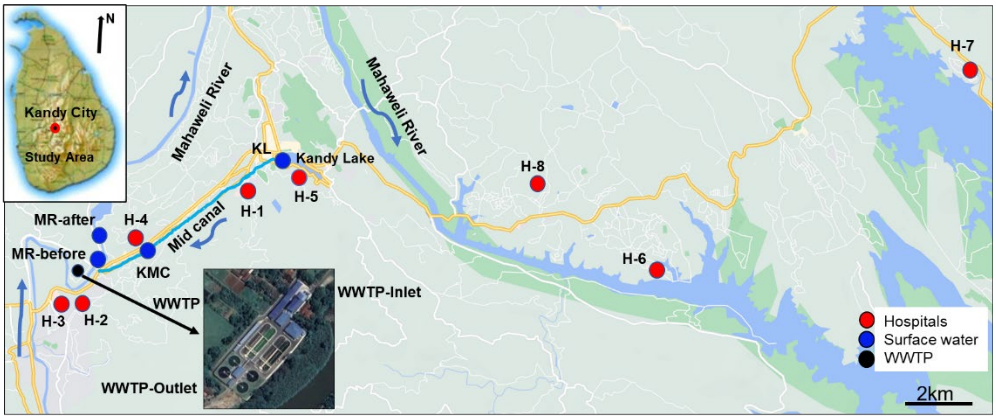

Figure 1: Sample locations

H-1: Largest Hospital [samples were collected from four sites (H-1-1, H-1-2, H-1-3 Covid++, H-1-4],

H-8: COVID-19 Intermediate Care Center [samples were collected from two sites (H-8-1, H-8-2 Covid +++]

4.2.2 Target compounds, extraction and detection:

In this study, 15 selected pharmaceuticals, including 14 antibiotics and one mostly used analgesic/antipyretic agent, were targeted for quantitative analysis in water samples (sulfapyridine, sulfamethoxazole, trimethoprim, clindamycin, clarithromycin, azithromycin, vancomycin, levofloxacin, ciprofloxacin, doxycycline, fluconazole, metronidazole, cefuroxime, piperacillin, acetaminophen). The analytical method employed modifications of previous procedures (Guruge et al., 2019; Tanoue et al., 2015). Briefly, samples were filtered using glass-fiber filters to remove suspended solids. A 20 mL aliquot was acidified with formic acid, spiked with internal standards, and processed through Oasis HLB and MCX cartridges after preconditioning. Target compounds were eluted, combined, evaporated, and diluted for LC–MS/MS analysis. To prevent adsorption, polypropylene and polyethylene containers were used, and acetonitrile replaced methanol for beta-lactam analysis.

4.3 Results

4.3.1 Drug usage pattern in hospitals:

According to epidemiological data on drug usage in the Kandy district, information gathered from the Regional Medical Supply Department (RMSD) in the Kandy district indicates a priority usage of certain drugs. The penicillin family drugs, specifically amoxicillin and co-amoxiclav, were identified as the most frequently used. In the category of cephalosporins, cefalexin and cefuroxime were prioritized as 1^{st} and 2^{nd}-generation options, respectively. Doxycycline emerged as the primary tetracycline drug. Among macrolides, clarithromycin, erythromycin, and azithromycin were the most utilized, while co-trimoxazole (a mixture of sulfamethoxazole and trimethoprim) was the preferred choice for sulfonamides. Ciprofloxacin stood out as the predominant fluoroquinolone. In the realm of antiparasitic and antifungal drugs, metronidazole were given priority while acetaminophen was received high priority drug for analgesic and antipyretic agents. At the COVID-19 Intermediate Care Center (H-8), patients were predominantly administered azithromycin, amoxicillin and ciprofloxacin antibiotics. Additionally, azithromycin was consistently used for treating all COVID-19 patients in other hospitals, suggesting its potential as a drug-marker for tracing COVID-19 related drugs in wastewater and surface waters.

4.3.2 Target compounds detected in the samples

In general, most of the target compounds were detected in major hospitals such as H-1, H-2, H-3, H-7, and the WWTP inlet. The highest concentration recorded was 1,370,000 ng/L of acetaminophen in H-1, where the sample was collected at the onset of COVID-19, primarily from wastewater originating from COVID-19 patients' wards (Figure 1b). Acetaminophen concentrations were several orders of magnitude higher than other detected compounds in most samples, suggesting its widespread use as an analgesic/ antipyretic agent. Among the detected compounds, metronidazole (791,000 ng/L), clarithromycin (372,200 ng/L), and ciprofloxacin (69,500 ng/L) were found at the highest concentrations, primarily in COVID-19-related wastewater.

When comparing COVID and non-COVID samples, azithromycin, levofloxacin, ciprofloxacin, doxycycline, and metronidazole were detected at higher concentrations—several-fold greater—in the COVID ward samples from H-1 (Figure 2a, 2b). Similarly, in the COVID ward of H-8, clarithromycin, azithromycin, and ciprofloxacin showed elevated levels compared to non-patient wastewater samples (Figure 3a, 3b), reflecting their preferential use for COVID-19 patients in both facilities. Clarithromycin and ciprofloxacin concentrations in hospital wastewater increased during the COVID-19 period compared to pre-COVID levels (2016–2018). However, in most cases, drug concentrations in wastewater during 2022–2023 did not show a distinct COVID-related accumulation pattern, likely due to mixing with effluents from other patient wards.

Most of the target compounds were not detected in lake water (KL). However, their concentrations increased severalfold in the downstream mid-canal (KMC), particularly for metronidazole and acetaminophen (data not shown). Notably, beta-lactams such as cefuroxime and piperacillin were occasionally detected for the first time in surface waters, suggesting potential direct discharge of untreated household wastewater into the river and mid-canal. The WWTP demonstrated effective removal of most target compounds, particularly macrolides and fluoroquinolones (Figure 4a, 4b). However, in December 2023, its performance was notably less effective for many compounds, likely due to heavy rainfall, which may have caused system malfunction just before the sampling dates. Temporal data from 2016 to 2023 indicate that following the construction of a WWTP to treat hospital wastewater, pharmaceutical concentrations in KMC have significantly decreased.

The estimated hazard quotient (HQ) based on predicted antimicrobial resistance data for metronidazole in the WWTP outlet exceeded 1, indicating a potential risk for enhancing the selection and maintenance of antimicrobial resistance in neighboring aquatic environment. However, in the receiving river waters, both upstream and downstream of the discharge point, HQ values remained below 1, suggesting that the predicted ecological risk in these waters is minimal.

Conclusion

This study highlights how a pandemic situation can impact drug contaminations in hospital wastewater, WWTP treated water and receiving surface water. To gain a more comprehensive understanding of the effects of antimicrobials on surface and wastewater, continuous monitoring is essential. Future studies should also focus on tracking the presence of resistant bacteria and genes in the studied areas to assess the broader environmental and public health implications.

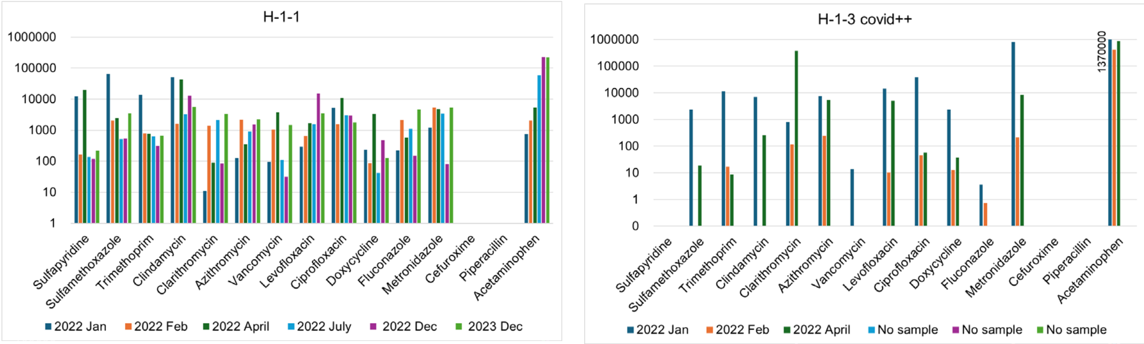

Figure 2. Concentrations (ng/L) of pharmaceuticals in Hospital-1. a: H-1-1: (non-Covid-19 patients) and b: H-1-3++ (with Covid-19 patients)

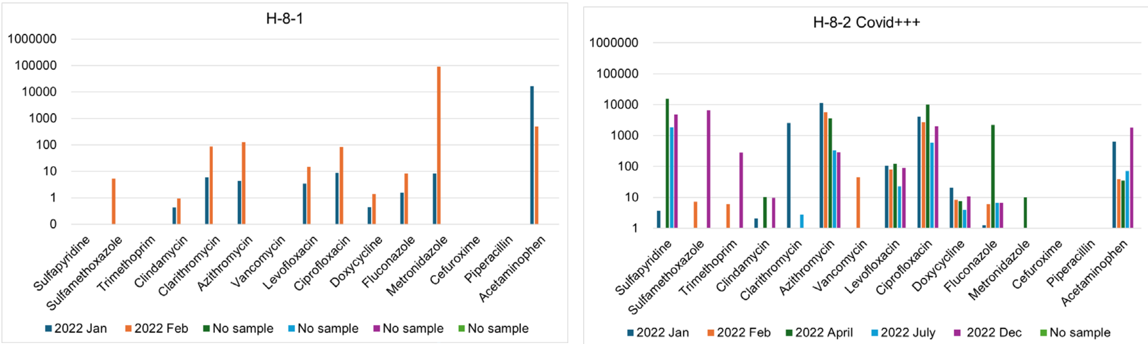

Figure 3. Concentrations (ng/L) of pharmaceuticals in Hospital-8. a: H-8-1 (wash/kitchen/bathing wastewater from staff) and b: H-8-2 Covid+++ (**Only Covid-19 patients**)

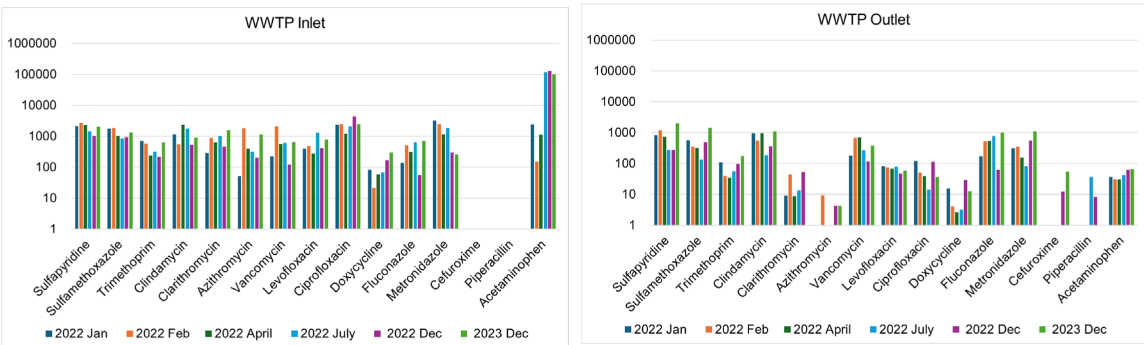

Figure 3. Concentrations (ng/L) of pharmaceuticals in the WWTP. a: WWTP inlet (before treatment) and b: WWTP outlet (after treatment)