



Patterns of Prevalence, Seasonality, and Treatment Efficiencies of Endocrine Disruptive Chemicals, Pharmaceuticals, and Personal Care Products in the Wastewaters of the Himalayan City of Dehradun, India

Manish Kumar^{1,2}, Rahul Silori², Durga Madhab Mahapatra^{2,3}, and Jurgen Mahlknecht¹

¹Technologico de Monterrey, Campus Monterrey, Monterrey, Mexico

²Sustainability Cluster, School of Advanced Engineering, UPES, Dehradun, India

³Department of Biological and Ecological Engineering, Oregon State University, USA

The present communication investigated the dynamics (prevalence, seasonality, and removal) of endocrine disruptive chemicals (EDCs) and seven target pharmaceuticals and personal care products (PPCPs) in the Himalayan city of Dehradun in Uttarakhand province of India. Two municipal and two academic institutions WWTPs were selected for wastewater (WW) sampling in the city during spring, summer, and monsoon seasons. The result showed Diclofenac and Caffeine occurrence in all influent samples of the WWTPs indicative of considerable intake in the city. During the study, Caffeine and Acetaminophen concentrations were consistently higher in the sampled WW influents. The total PPCPs concentration in the WWTPs ranged from 1K to 74K ngL⁻¹ and 22 to 64K ngL⁻¹ in influent and effluents, respectively. Seasonal variations in influent wastewater samples indicated high mean PPCP levels during spring, followed by monsoon and summer seasons. Caffeine showed the highest PPCP concentration (71K ngL⁻¹) during monsoon and while Ciprofloxacin concentration was high (16K ngL⁻¹) during the spring season. The study also revealed high correlation between Acetaminophen with Diclofenac ($r=+0.77$) and Ketoprofen ($r=+0.62$). In addition, Diclofenac was firmly linked with Ketoprofen ($r=+0.89$), whereas Ciprofloxacin was strongly linked with Carbamazepine ($r=+0.65$).

While the estrone showed concentrations at µgL⁻¹ levels in influent concerning ngL⁻¹ levels of triclosan (TCS). The highest global concentration of ~124 µgL⁻¹ is recorded for the estrone during our monitoring period. The tests for Normality showed a non-normal data distribution ($p>0.05$) for all WW PPCPs samples except for Caffeine influents. PPCP concentration showed a high statistically significant variation between the influent and effluent samples ($p<<<0.001$), indicating highly decisive evidence for unequal means. The PPCPs treatment rates in the WWTPs ranged from ~69 -100%. In terms of total PPCPs, average removal efficiencies of WWTPs were recorded in the range of 41.66-71.40%. The maximum removal was recorded for Acetaminophen and Ketoprofen, while increased concentrations in the effluents (negative removals) were witnessed for Ciprofloxacin, Carbamazepine, and Caffeine in the WWTPs. The WWTPs have been found to contribute to existing PPCP loads and are channelized toward the disposal sites, posing a severe

threat to biodiversity, human health, and the ecological integrity of the region and its downstream. We critically highlighted the limitation of the WWTPs in the treatment, degradation, and assimilation of EDCs leading to several environmental & human health-based threats to one health in the region. This study is vital for setting up baseline data and setting a platform for future research surveillance and control of emerging contaminants (ECs) in ecologically sensitive hilly landscapes.