Forensic Sci Rev 35:79–105
July 2023

Analysis of Drugs in Wastewater: Forensic Science Perspective

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TABLE OF CONTENTS

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REFERENCE: Mwenesongole E: Analysis of drugs in wastewater: Forensic science perspective; *Forensic Sci Rev* 35:79; 2023.

ABSTRACT: Drug usage data in a community has traditionally been obtained through population surveys, records from law enforcement activities related to drug-related crime, drug treatment centers, prison data, and hospital records. Wastewater-based epidemiology has gained traction in the last 10 years as a formidable complimentary tool to monitor, track, and estimate community consumption of both illicit and therapeutic drugs within a community. In wastewater-based epidemiology, targeted biomarkers (parent drug and/or metabolite) of illicit and therapeutic drugs are quantified in wastewater and back-calculated to community consumption. In conjunction with more traditional methods of obtaining drug usage data, information from wastewater-based epidemiology has been used to detect the types and amounts of drugs being used within a community. One of the main advantages of wastewater-based epidemiology is the near-real-time data obtained from it, which assists with the quick adaptation of both harm reduction and supply mitigation strategies. Wastewater-based epidemiology has also seen an increase in forensic application through the detection of production facilities within a community, determining the synthesis route of certain illicit drugs like methamphetamine, and enantiomeric profiling to distinguish between illicit and therapeutic use of drugs. This review summarizes the main focus areas and applications of wastewater-based epidemiology from a forensic perspective.

KEYWORDS: Drugs, forensic, wastewater-based epidemiology.

INTRODUCTION

Compounds of Environmental Concern in Water

While agrochemical, petrochemical, industrial, and pharmaceutical compounds have their uses, their by-products from manufacture and their degradation products have been found in various bodies of water. This has led to increased public concern and scientific interest about their effects on the environment and human and aquatic life [45,107].

Polycyclic aromatic hydrocarbons, polychlorinated biphenyls, industrial chemicals, metals, pesticides, endocrine-disrupting compounds (EDCs), and microplastics are widely acknowledged as water pollutants [2,36,37,43,48,124]. EDCs, in particular, have been linked to the disruption of sexual development and reproductive function in aquatic organisms [45], while microplastics have been linked to intestinal damage of aquatic organisms [124].

Another category of water pollutants that has attracted scientific interest is pharmaceutical and personal care products (PPCPs) [12,86,87,92]. PPCPs include consumer products, veterinary and human pharmaceutical compounds, and illicit drugs [71]. PPCPs have been referred to by various names, including emerging organic contaminants [49], emerging contaminants [92], contaminants of emerging concern [98], and micropollutants [115].

Of particular interest to this review are pharmaceutically active compounds (PhACs) comprising drugs manufactured for both illicit and therapeutic use, with a particular emphasis on illicit drugs. PhACs as environmental contaminants gained widespread scientific interest with the advancement of more sensitive analytical techniques and have undergone increased investigation as water pollutants since the early 2000s [56,94]. As a result, PhACs have been detected in wastewater influent and effluent, surface water as well as tap water [81,89,98,101,107].

Wastewater Management

Globally, wastewater treatment processes are monitored by different agencies that provide water quality standards that need to be met by a wastewater treatment plant (WWTP) before it can discharge treated effluent into surface and/or ground water [64,115]. For example, the US Environmental Protection Agency (EPA) has a list of priority pollutants that are required to be monitored in wastewater effluent [36–38]. From these, various states develop their guidelines for monitoring wastewater effluent as well as effluent from various manufacturing industries. The Effluent Guidelines developed by the EPA set regulatory standards for wastewater discharge according to the industry and technology relevant to that industry to maximize reduction of priority pollutants [38].

The United Nations Environment Programme report on Good Practices for Regulating Wastewater Treatment summarizes successful case studies for regulating wastewater treatment and management in six economically diverse countries; Argentina, Austria, Finland, Jordan, Singapore, and South Africa [114]. The United Nations

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Ellen Mwenesongole worked for seven years as a Senior Scientist at Procter & Gamble (South Africa and UK) before obtaining an M.S. degree in forensic science from the University of Strathclyde (Glasgow, UK), an MSc in Chemistry from the University of Pretoria (Pretoria, South Africa), and a Ph.D. degree in forensic science from Anglia Ruskin University (Cambridge, UK).

In between her studies, Dr. Mwenesongole worked in toxicology, pharmaceutical, and doping control laboratories. Since obtaining her Ph.D. degree, Dr. Mwenesongole has led the development of undergraduate and postgraduate forensic science programs in both South Africa and Botswana and she is currently an Associate Professor in Forensic Science at the University of Alabama at Birmingham. Her main research interests are in chemical profiling of illicit drugs as well as the detection of drugs of abuse from wastewater. Dr. Mwenesongole also conducts research in wildlife forensics with emphasis on characterizing the morphological features of animal hair to aid in species identification in matters related to wildlife crime such as poaching.