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Review

Status of pharmaceuticals in African water bodies: Occurrence, removal and analytical methods

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ABSTRACT

In this review paper, the milestones and challenges that have been achieved and experienced by African Environmental Scientists regarding the assessment of water pollution caused by the presence of pharmaceutical compounds in water bodies are highlighted. The identification and quantification of pharmaceuticals in the African water bodies is important to the general public at large due to the lack of information. The consumption of pharmaceuticals to promote human health is usually followed by excretion of these drugs via urine or fecal matter due to their slight transformation in the human metabolism. Therefore, large amounts of pharmaceuticals are being discharged continuously from wastewater treatment plants into African rivers due to inefficiency of employed sewage treatment processes. Large portions of African communities do not even have proper sanitation systems which results in direct contamination of water resources with human waste that contains pharmaceutical constituents among other pollutants. Therefore, this article provides the overview of the recent studies published, mostly from 2012 to 2016, that have focused on the occurrence of different classes of pharmaceuticals in African aqueous systems. Also, the current analytical methods that are being used in Africa for pharmaceutical quantification in environmental waters are highlighted. African Scientists have started to investigate the materials and remediation processes for the elimination of pharmaceuticals from water.

Contents

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1. Introduction

In recent years, many African Scientists embarked on the research based on quantitative analysis of pharmaceuticals in water bodies. Pharmaceuticals are compounds that are designed to prevent, cure, treat disease and improve health (Jelic et al., 2011). After intake of pharmaceutical drugs by the intendent consumer, they are subjected to metabolic reactions, such as hydroxylation, cleavage or glucuronation (Beausse, 2004). However, many pharmaceutical drugs are not completely degraded in the human body, therefore, they are normally excreted after slight transformation or in unchanged form (Debska et al., 2004).

Excreted drugs are transported into wastewater treatments plants (WWTPs) via sewage pipes. Globally, it has been scientifically demonstrated that most WWTPs are unable to remove pharmaceutical drugs completely during the sewage treatment process, which lead to the contamination of surface water (Sun et al., 2014; Gurke et al., 2015; Moreno-Gonzalez et al., 2015; Pereira et al., 2015). However, there are other factors that contribute to pharmaceutical contamination of water resources. For example, in many African communities there are areas whereby there is poor or no sanitation processes (Segura et al., 2015). Such areas do not have the sewage treatment facilities, therefore the human waste is directly disposed on the ground or surface water (Segura et al., 2015). In such areas during the rainy seasons, fecal matter is washed off from the ground into the rivers, thus contaminate the surface water and causes health danger to humans and aquatic species. Other sources of pharmaceuticals in the environment include direct discharge of untreated wastewaters to the environment through the leakage of septic tanks, landfill leachates, animal waste and treatment drugs, and the application of manure or WWTP sludge as fertilizer in agricultural fields (Paiga et al., 2016).

The groups of pharmaceuticals that are being detected in aqueous samples worldwide include non-steroidal anti-inflammatory drugs (NSAIDs), β-blockers, antibiotics, anti-epileptics, antiretroviral drugs (ARVs), steroid hormones and antipsychotics (K'oreje et al., 2012; Manickum and John, 2014; Matongo et al., 2015a, 2015b). The chemical structures of the most detected compounds that belongs to some of these groups are given in Table 1 with their physicochemical properties (Dahane et al., 2013; Fenet et al., 2012; Ngumba et al., 2016; Vymazal et al., 2015; Wood et al., 2015). Such properties indicate that pharmaceuticals could be more detected in water rather than solid matrices such as sediments and aquatic plants. Long-time exposure of some organisms to certain classes of these pharmaceutical groups may result in resistance, which is directly linked to public health (Segura et al., 2015). Hence, there is strong need to monitor the occurrence of pharmaceuticals in the environment.

To date, many research papers have indicated the widespread of pharmaceuticals in the environment. However, many of these scientific papers emerge from European based countries, while African countries are still lagging behind in terms of identifying and quantifying pharmaceuticals in environmental samples. Furthermore, the capability of sewage treatment processes for the removal of pharmaceutical constituents in Africa is not fully achievable. This is the area that has been well exploited in Europe over the years (Kasprzyk-Hordern et al., 2009a; Gros et al., 2010; Jelic et al., 2011; Garcia-Lor et al., 2012), whereas the removal efficiency of pharmaceuticals during the wastewater treatment process has been reported recently in few African based studies (Kermia et al., 2016; K'oreje et al., 2016; Zunngu et al., 2016).

Globally, several review articles that are based on the occurrence of pharmaceuticals in aquatic environment and sediments have been published (Beausse, 2004; Li, 2014; Santos et al., 2010; Savci, 2013). To the best of authors knowledge, none of these published reviews focused on the occurrence of pharmaceutical drugs in African environment. Some of African reviews that have been published focused more on endocrine disrupting chemicals with little information on environmental pollution caused by pharmaceutical drugs (Olujimi et al., 2010; Tijani et al., 2015). Therefore, this is the first review to demonstrate the milestones that have been reached by African Scientific community in the field of environmental analysis of pharmaceuticals. This review also gives an overview of the analytical methods that have been used by African researchers for evaluating pharmaceutical pollutants in the aquatic environment. Therefore, in the perspective of the African community, this study attempts to highlight the extent of water pollution on the continent by pharmaceutical compounds, the achievements in the study area by African researchers and the shortcomings with future research possibilities.

2. Data collection for literature review

The scope and the area of this study was Africa. Even though there are limited studies on pharmaceutical compounds in African water bodies, there were enough papers to prepare this review article. Regarding African studies, data from twenty-six articles was reviewed and compared to the global trends. The presented data were obtained after thoroughly searching different scientific journals from mostly three search engines: Web of Science, Scopus, and Google. The expanded keywords were Africa, pharmaceutical, water and each of 53 African countries. In the African context, the cited work was published from 2012 to 2016, however, some sampling for the presented data could have been performed in earlier years. There was not much information obtained relating to the occurrence of pharmaceutical residues in water bodies prior to these years. For simplicity and consistency, in most cases the concentration units reported in literature were converted from ng L^{-1} to μg L^{-1}.

3. Occurrence of pharmaceuticals in African water bodies

3.1. Non-steroidal anti-inflammatory drugs (NSAIDs)

Globally, NSAIDs are widely detected in the environment due to their availability over the counter that do not require any medical prescription which allows for self-medication (Manrique-Moreno et al., 2016). Maximum concentrations of pharmaceuticals detected in African wastewater and surface water are given in Figs. S1-S3. As presented in Table 2, naproxen, ibuprofen, diclofenac and ketoprofen are the most common drugs in African aqueous environment. Some of the reported quantities in African wastewater exceed the levels found in WWTPs located in well developed countries such as in Europe, this could be due to poor sanitation in African countries. For example, a maximum concentration of 221 μg L^{-1} for ibuprofen (Fig. S1 and Table 2) was reported in a WWTP influent located in South African Province of KwaZulu-Natal (Madikizela and Chimuka, 2016a). Further to this, the mean concentration of ibuprofen detected in the influent of Northern WWTP located in Gauteng Province of South Africa was 111.9 μg L^{-1} (Amdany et al., 2014). Whereas, the maximum concentrations in influent reported for ibuprofen in several European based studies were 22.8, 1.36 and 20.2 μg L^{-1} (Dahane et al., 2013; Gilart et al., 2013; Larsson et al., 2014). Therefore, ibuprofen is one of the most frequently detected NSAIDs in African wastewater and surface water. In Kenya, among other NSAIDs, ibuprofen had the highest concentration of approximately 30 μg L^{-1} in WWTP effluent (K'oreje et al., 2012). It is speculated that the inefficiency of sewage treatment facilities contributes to the pollution levels of the surface water. As a consequence, traces of ketoprofen, diclofenac,