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Pharmaceuticals in the Environment: A Brief Review

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Abstract: Pharmaceuticals are the complex molecules with different functionalities, diverse physicochemical properties. They are developed and used because of their specific biological activities. Biodegradation modifies the chemical structure of their active molecules resulting in a change in their physicochemical and pharmaceutical properties. Pharmaceuticals are generally focused considering them as therapeutics. Nevertheless, they indicate the negative impact that these chemical contaminants may have on living organisms, ecosystems and ultimately, public health. This study describes the different contamination sources as well as fate and both acute and chronic effects on non-target organisms. An overview of the sources of environmental contamination, environmental fate and ecotoxicology is outlined in this review.

Key Words: Pharmaceuticals; Surface water; Sewage treatment; Photosensitizers; Therapeutic.

1. Introduction

Pharmaceutically active compounds are complex molecules with different functionalities, physicochemical and biological properties. They are developed and used because of their more or less specific biological activity and are most notably characterised by their ionic nature. Their molecular weights range typically from 300 to 10000. Under environmental conditions molecules can be neutral, cationic, anionic, or zwitterionic. They also often have basic or acidic functionalities. Pharmaceuticals can be classified according to their effects, but also "crosswise" according to their chemical structure. Normally, pharmaceuticals and disinfectants are classified according to their therapeutic purpose (e.g. antibiotics, analgesics, antineoplastics, anti-inflammatory substances, antibiotics, antihistaminic agents, contrast media, etc.). Powerful hyphenated chromatographic-detection techniques enabling detection upto the ng/ L allowed researchers to quantify a large number of medicines components (i.e. drugs and excipients) in the environment, thus compelling the scientific community to consider this contamination type as a potential issue meriting concern [1–3]. They are conceived primarily to have particular physiological modes of action and frequently to resist to inactivation before exerting their intended therapeutic effect. However, these same properties are paradoxically responsible either for bioaccumulation and toxic effects in aquatic and terrestrial ecosystems [4,5]. In a different way from some conventional pollutants (such as pesticides, detergents, fuels, among others), medicines are continuously delivered at low levels which might give rise to toxicity even without high persistence rates [6–8].Wide dissemination at low concentrations mainly in the aquatic environment is evident today. Such concentrations have been detected in aquatic compartments such as influents and effluents from sewage treatment plants (STPs), surface waters (rivers, lakes, streams, estuaries, among others), seawater, groundwater and drinking water. The scientific community is in broad agreement with the possibility that adverse effects may arise from the presence of pharmaceuticals not only for human health but also for aquatic organisms. Several, almost negligible effects have been shown to occur from continuous exposure during the life cycle of aquatic vertebrates and invertebrates to sub-therapeutic drug concentrations. These effects slowly accumulate to manifest themselves into a final irreversible condition which is frequently only noticed several generations' later, affecting sustainability of aquatic organisms' populations. This paper presents an overview of the acquired knowledge regarding the sources, spreading conditions, occurrence and induced toxic effects on non-target organisms by drugs in the environment.

2. Discussion

2.1. Sources of environmental contamination

The most obvious pathway for environmental contamination of medicines is via the unaltered excretion in urine and faeces although other anthropogenic mechanisms should be assumed, namely:

a) Metabolism post-consumption
b) Diagnostic compounds
c) Household Disposal
d) Impacts due to anthropogenic activities
e) Effluents of pharmaceutical production facilities

At a higher level, existing geographical information on environmental contamination sources is sparse and limited. Countries and regions worldwide differ concerning the prevalence of diseases, waste treatment processes, cultural habits or economic constraints related to the pharmaceutical market. Nevertheless, it seems that urban regions are major sources of contamination due to the proximity of hospitals and STP facilities. Additionally, the contribution of rural regions where agriculture, animal husbandry and aquaculture represent important ways of life should be considered as important.

2.2. Environmental fate

The fate and behaviour of medicines in the environment still requires further elucidation. Drugs (used in human and/or in veterinary medicine) and their metabolites are spread into the environment in different ways, namely through STP effluents, heavy rain on agricultural land provokes (surface) water run-off, and occasionally, through untreated sewage (domestic wastes and flooding, among others). Some of them do reach surface waters (rivers, lakes and estuaries, among others) and eventually ground waters after resisting the intended biological degradation. However, in surface waters they may be degraded through different processes such as photolysis whose efficiency depends on factors such as intensity of solar irradiation, latitude, season of the year and presence of photosensitizers (e.g. nitrates, humic acids) [9,10]. In the case of drugs that have low volatility and high polarity distribution is mainly made by aqueous transport or even via food chain dispersion [11]. Usually, wastewaters are conducted to STPs, which play a key role in the entrance of pharmaceuticals in the environment. However, in some regions or even countries these kinds of facilities may not exist and the environmental problem is still worse. The evaluation of removal efficiency in STPs (by comparing influent and effluent contents) has been studied in detail, showing removal rates that can differ by up to 99% [12–14]. Depending both on the particular technology resorted to and the active substance properties they may undergo:

a) Degradation (mineralization) to low molecular weight compounds (e.g. CO_2 and water)
b) Entrapment by suspended solids
c) Discharge of the parent compound through chemical cleavage of the respective conjugate forms and
d) Conversion to a more hydrophilic, persistent form which will short-circuit the treatment process. Thus, in hospitals use of specific antibiotics, antineoplasic or diagnostic agents subsequently requires a sewage treatment process more embracing and directed to these kind of drugs, which are only used in hospitals and that must be different to the more specific procedure adopted at STPs receiving industrial discharges from drug manufactures. In both, the form and extension of the final contamination risk will also depend on geographical location of the STP facility. Low adsorption coefficients that make active substances remain in the aqueous phase, favour their mobility through the STP and into nearby surface waters [12]. However, one should be aware of the fact that if a particular pharmaceutical is not detected in a STP effluent, this does not imply that it has been fully removed. On some occasions, it may have been degraded and give rise to unsuspecting metabolites that will subsequently contaminate surface waters. Notwithstanding that some drugs and their metabolites show a stable nature, nowadays is still difficult to establish a complete contamination pattern in final receiving surface waters, due to the water dilution, the treatment and discharging processes [13].

2.3. Ecotoxicology

Continuous consumption of drugs even at sub-therapeutic concentrations represents a potential threat to public health although one should bear in mind that it is still impossible to evaluate the effects of exposure on human health [15,16]. In turn, many non-target organisms (which possess human- and animal-alike metabolic pathways, similar receptors or biomolecules) are therefore inadvertently exposed to active substances released into the environment [17]. A comprehensive manner to evaluate the toxicity effects on non-target organisms must include the development of specific tests embracing either acute effects (where mortality rates are often registered) or chronic effects (by means of exposure to different concentrations of a chemical compound over a prolonged period of time). In the latter, effects are measured through specific parameters such as growth index or reproduction
rates [11]. Unfortunately, studies on acute effects in organisms belonging to different trophic levels (i.e. algae, zooplankton and other invertebrates and fish) predominate relatively to chronic ones. Acute toxicity data is only valuable when accidental discharge of the drugs occurs, since the environmental concentrations usually reported for these compounds are low, typically in a factor of one thousand. Bioaccumulation and chronic toxicity tests are scarce probably due to the complex experimental work involved [17]. However, recent development of sensitive methods for identification and quantification of drugs enabled to devise their distribution patterns in several environmental samples, thus highlighting the more relevant therapeutic classes in terms of environmental contamination. These data is useful to set out the most appropriate active substances to be used in ecotoxicity tests. According to data present in literature, scientific community has mainly concerned their attention on therapeutic classes such as, non-steroidal anti-inflammatory drugs, blood lipid lowering agents, antibiotics and sex hormones. Within this context, some of the acute and chronic toxicity effects caused by drugs belonging to different therapeutic classes and mixtures of them in non-targets organisms deserve further analysis. Therefore, toxicity data will be related to the environmental concentrations, to establish the severity of the situation.

3. Conclusions

Today, the presence of pharmaceuticals in the environment is being reported worldwide. Furthermore, new data on the sources, fate and effects of pharmaceuticals in the environment, seems to indicate the possibility of a negative impact on different ecosystems and imply a threat to public health. For this assumption, data from acute and chronic ecotoxicity tests on species belonging to different trophic levels such as bacteria, algae, crustaceans and fish among others, is relevant to illustrate the several adverse effects that environmental exposure to measured concentrations of these contaminants can have. On literature, the principal toxicological endpoints/studies that are described are growth, survival, reproduction and immobilization of species, comparatively to transgenerational and population level studies that are still sparse. This demonstrates the lack of data relatively to long-term exposure of non-target organisms and principally how a continuous exposure, during several generations, may affect a whole population. In the near future, the evaluation of chronic toxicity effects should be set out as a priority for the scientific community since simultaneous exposure to pharmaceuticals, metabolites and transformation products of several therapeutic classes are unknown and whose probable effects on subsequent generations should be assumed. It is also important to assess the presence of pharmaceuticals and/or their metabolites and transformation products in several environmental compartments in different countries with a view to gaining reliable knowledge of the contamination levels. Only with further available information will be easier to improve existing legislation in order to protect humans, animals and ecosystems from the threat posed by the presence of pharmaceuticals in the environment.

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References

[1] K. Kummerer, Introduction: pharmaceuticals in the environment, in: K. Kummerer (Ed.), Pharmaceuticals in the Environment: Sources, Fate, Effects and Risks, Springer, Berlin, 2001, pp. 1–8.

[2] P. Pfluger, D.R. Dietrich, Effects on pharmaceuticals in the environment—an overview and principle considerations, in: K. Kummerer (Ed.), Pharmaceuticals in the Environment: Sources, Fate, Effects and Risks, Springer, Berlin, 2001, pp. 11–17.

[3] E. Zuccato, S. Castiglioni, R. Fanelli, G. Reitano, R. Bagnati, C. Chiabrando, F. Pomati, C. Rossetti, D. Calamari, Pharmaceuticals in the environment in Italy: causes, occurrence, effects and control, Environ. Sci. Pollut. Res. 13 (2006) 15–21.

[4] B. Halling-Sorensen, S. Nors Nielsen, P.F. Lanzky, F. Ingerslev, H.C. Holten Lutzhoft, S.E. Jorgensen, Occurrence, fate and effects of pharmaceutical substances in the environment—a review, Chemosphere 36 (1998) 357–393.

[5] J.L.C.M. Dorne, A.M.J. Ragas, G.K. Frampton, D.S. Spurgeon, D.F. Lewis, Trends in human risk assessment of pharmaceuticals, Anal. Bioanal. Chem. 387 (2007) 1167–1172.

[6] S.T. Glassmeyer, D.W. Kolpin, E.T. Furlong, M.J. Focazio, Environmental presence and persistence of pharmaceuticals: an overview, in: D.S. Aga (Ed.), Fate of Pharmaceuticals in the Environment and in Water Treatment Systems, CRC Press, Taylor and Francis, 2008, pp. 3–52.

[7] M.J. Gomez, M.J. Martinez Bueno, S. Lacorte, A.R. Fernandez-Alba, A. Aguera, Pilot survey monitoring pharmaceuticals and related compounds in a sewage treatment plant located on the Mediterranean coast, Chemosphere 66 (2007) 993–1002.

[8] A. Tauxe-Wuersch, L.F. De Alencastro, D. Grandjean, J. Tarradellas, Occurrence of several acidic drugs in sewage treatment plants in Switzerland and risk assessment, Water Res. 39 (2005) 1761–1772.

[9] M. Crane, C. Watts, T. Boucard, Chronic aquatic environmental risks from exposure to human pharmaceuticals, Sci. Total Environ. 367 (2006) 23–41.

[10] P.H. Roberts, K.V. Thomas, The occurrence of selected pharmaceuticals in wastewater effluent and surface waters of the lower Tyne catchment, Sci. Total Environ. 356 (2006) 143–153.

[11] T.A. Ternes, Occurrence of drugs in German sewage treatment plants and rivers, Water Res. 32 (1998) 3245–3260.

[12] N. Lindqvist, T. Tuhkanen, L. Kronberg, Occurrence of acidic pharmaceuticals in raw and treated sewages and in receiving waters, Water Res. 39 (2005) 2219–2228.

[13] D.L. Sedlak, K.E. Pinkston, Factors affecting the concentrations of pharmaceuticals released to the aquatic environment, Water Resour. Update 120 (2001) 56–64.

[14] M. Cirja, P. Ivashechkin, A. Schaffer, P.F.X. Corvini, Factors affecting the removal of organic micropollutants from wastewater in conventional treatment plants (CTP) and membrane bioreactors (MBR), Rev. Environ. Sci. Biotechnol. 7 (2008) 61–78.

[15] J.R. Vane, R.M. Botting, Mechanism of action of antiinflammatory drugs, Int. J. Tissue React. 20 (1998) 3–15.

[16] J. Zou, N.F. Neumann, J.W. Holland, M. Belosevic, C. Cunningham, C.J. Secombes, A.F. Rowley, Fish macrophages express a cyclo-oxygenase-2 homologue after activation, Biochem. J. 340 (1999) 153–159.

[17] R. Braund, B.M. Peake, L. Schieffelbien, Disposal practises for unused medications in New Zeland, Environ. Int. 35 (2009) 952–955.

Vitae

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