39th WEDC International Conference, Kumasi, Ghana, 2016

ENSURING AVAILABILITY AND SUSTAINABLE MANAGEMENT
OF WATER AND SANITATION FOR ALL

Drug disposal flow diagrams and sustainable water quality

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BRIEFING PAPER 2520

Pharmaceuticals and Personal Care Products (PPCPs) are present in water sources in various parts of the world. Strategies have been implemented to control their presence in water sources. Strategies, both potential and existing, must be ascertained to be able to tackle the challenge effectively. This paper examines the feasibility of drug disposal flow diagrams (DDFDs) to control the presence of PPCPs in water sources. Surveys and key informant interviews were conducted in 3 regions in Ghana to assess how community pharmacies, consumers and other participants in the pharmaceutical value chain dispose of unused medicines. The information so gathered was put together in a flow diagram. From the results, DDFDs can be used to control PPCPs in water sources: since 57% of PPCPs disposed of in the areas where they are generated and 29% are discharged untreated into receiving waters, focus on these areas will yield the best outcomes.

The environment and health

Living organisms, including humans, interact actively with their environment as they undertake their life-sustaining processes. Some of the significant interactions of human beings, and other living organisms, with the environment include taking up food and water from the environment, taking in oxygen-rich air and bringing out carbon-dioxide and releasing waste products into the environment – with the expectation that the environment will adequately handle such waste. A strong and dynamic environment will support the needs of the organism, ensuring a good quality of life. On the other hand, where the environment, as a result of insult inflicted from various quarters, cannot support the needs of that organism, the quality of life will be reduced.

A number of factors impact the ability of the environment to support life to an optimum level: massive population growth, climate change and human-made pollution (Royal Society of Chemistry, 2007). The factor of human-made pollution has to do with the human activities that have the effect of introducing pollutants into the environment whether or not the introduction is on purpose. This is directly linked with the population growth, as increased numbers of humans will directly increase the activities that introduce pollutants into the environment. When pollutants enter the environment, they affect both the quality and quantity of resources that are available for consumption. The quality is affected by the mere presence of pollutants, whereas the quantity is affected because the polluted resources are no longer available for use for the intended purpose. Pollution may be as a result of both clearly negative practices such as poor sanitation as well as intrinsically positive practices such as the use of pharmaceuticals and other chemicals to improve the quality of life of the members of the community.

Water pollution

The phenomenon of water pollution means that for billions of people in developing countries not having access to clean water or safe sanitation is real (The World Bank, 1992). The implication is that water supply is limited and water that is available may be of dubious quality (UNDP, 1994). This affects the health status of the populations in question contributing to diarrhoeal diseases, water-borne diseases, worm infestations and millions of cases of preventable deaths; fish stocks are declining and the cost of providing water to communities and households have increased (The World Bank, 1992). Water related diseases make up the largest cause of human illness and death.

Pollution of water resources by pharmaceuticals and personal care products (PPCPs) occur in a number of ways. PPCPs are used in everyday life for the treatment and management of health conditions, as with medicines, or for the purposes of improving quality of life, as with shampoos and insecticides. PPCPs may be introduced into surface water as a result of discharge from waste water treatment plants (WWTPs). These are, generally, not designed to effectively remove PPCPs. WWTPs may be fed by discharge from industry or various institutional facilities where PPCPs may be added to liquid waste and treated. From homes, PPCPs may be present in septage as a result of elimination after consumption of medicines. Sullage from households will deliver any PPCPs, which may be present from washing or bathing, directly into receiving waters. Any PPCPs used for agricultural purposes will be delivered directly into the soil and receiving waters as a result of elimination after consumption by animals, direct administration into soil and water or reapplication of contaminated manure. PPCPs may also enter water sources as a result of disposal of unused, unwanted or expired medicines. Figure 1 is a schematic of the movement of PPCPs from production to water sources.

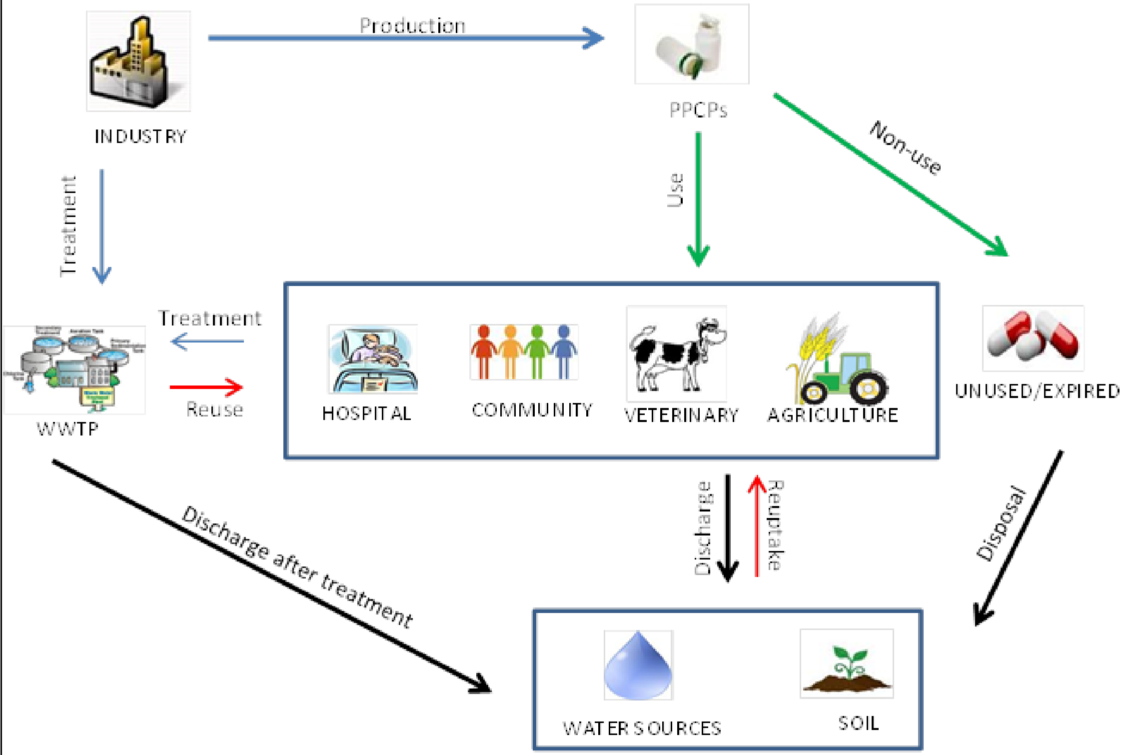

Figure 1. PPCPs – from production to water sources

Source: Esseku, 2014

Endocrine disruption and pharmaceutical and personal care products

Endocrine Disrupting Compounds (EDCs) have been identified as contaminants of water sources and other environmental media. EDCs are said to be exogenous substances or mixtures that alter function(s) of the endocrine system and consequently cause adverse health effects in an intact organism, or its progeny, or (sub)population (International Programme on Chemical Safety, 2002). They interfere with the endocrine system of humans and other animals and therefore, pose a threat to living organisms. This is because they may alter physiological function and reproductive capability of the exposed organisms. EDCs have been found to feminise male fish (Christiansen, et. al., 2002) and reduce phallus sizes and survival and reproductive capacity of male alligators (Guillette, et. al., 1996b).

PPCPs have been identified as endocrine disrupting in nature. This raises concerns for products even when they are present in water sources in sub-therapeutic doses. The concerns stem from the fact that although consuming water with subtherapeutic doses of PPCPs may not produces effects similar to those that may be observed in wrong self-medication, the ingested PPCPs may have effects at the endocrine and physiological level. PPCPs form an integral part of life. Medicines may be used for the prevention, diagnosis, management or treatment of diseases or to alleviate sysmptoms of disease conditions. Soaps and shampoos are essential for personal hygiene while air freshners and insecticide preparations may be used to make life more comfortable. After use of PPCPs, they may be excreted, washed off or otherwise disposed of into, primarily, water sources.

Effective implementation of strategies

Some interventions have been implemented in various parts of the world aimed at reducing the quantities of PPCPs in environmental media as well as curbing the effects of their presence and persistence in those environmental media. Take back schemes and events (Daughton and Ruhoy, 2010) are designed to receive from consumers any unwanted, unused and expired PPCPs they have in their possession. This ensures that the products are not disposed of indiscriminately. Environmental management plans (Holm, et. al. 2013) are designed to make organisations that are introducing new products responsible for mitigating the environmental impact of the product being introduced.

The ubiquitous nature of the use of PPCPs means that even where steps have not been taken to quantify PPCPs in water sources, there is the need to introduce and implement effective strategies with the aim of reducing the quantities which may be present or reduce their impact. In resource constrained countries, such strategies have to be ascertained to be cost effective to ensure efficient use of resources. In order to ensure such cost effectiveness, the strategies implemented should utilise a holistic approach and take into consideration assessment of the context within which the strategies are to be implemented. Such contextual assessment requires effective tools and should also be reproducible and sustainable.

Methodology

In undertaking this work, surveys and key informant interviews were the main tools utilised in gathering information. Key informants were interviewed on disposal practices used by consumers in general, and pharmaceutical manufacturers, wholesalers and distributors in particular. This diagram is a pictorial representation of the disposal practices of various levels of the value chain involved in PPCPs. The informants targeted in this study were officials from the Environmental Health and Sanitation Directorate (EHSD), the Food and Drugs Authority (FDA) and the Environmental Protection Agency (EPA). The interviews utilised semi-structured interview guides to allow for comment, explanation and discussion as may be necessary.

A survey was conducted among community pharmacies and another among consumers. For community pharmacies, 30 pharmacies in two regions in Ghana were surveyed on information concerning how they deal with their expired medicines which require disposal. One hundred and twenty (120) consumers in the Greater Accra, Ashanti and Northern regions of Ghana were also interviewed with regards to how the deal with their unwanted, unused and expired medicines. In both surveys, informed consent was obtained from all participants.

The information gathered from the key interviews and the surveys were used to develop a matrix indicating the practices at various levels and how these practices affect the presence and persistence of PPCPs in the environment. The matrix shows a quantification of the contributions of various participants in the value chain. The matrix was used to construct a model Drug Disposal Flow Diagram (DDFD) which gives a pictorial representation of how safely, or otherwise, PPCPs are disposed of and where they end up in the environment.

The drug disposal flow diagram (DDFD)

This diagram is a pictorial representation of the disposal practices of various levels of the value chain involved in PPCPs. The primary focus of the DDFD is the method of disposal used by all these participants. The diagram does not assess the production or distribution methods used for PPCPs.

In creating the model DDFD, a design identifying the various components of the value chain was prepared from the information gathered during from the surveys and key informant interviews. The information was further used to quantify the various contributions of the different participants to the presence in the water sources and the quantifications used to develop a matrix. The matrix sets out the percentages contributed by the different processes to different types of contamination. The information from the matrix is used to prepare the diagram.

Design

In designing the diagram, the various participants at the different levels of the value chain are identified. These identified levels are responsible for the different processes of the value chain in the relevant industries. For the model DDFD which is presented here, the different processes are put together as the process chain. Figure 2 shows the process chain developed for the model DDFD.

Figure 1. Process chain for DDFD

Source: Esseku, 2015

Generation within the process chain deals with the source from which the PPCPs enter the environmental media. For the purposes of the model DDFD, the sources of generation identified are industry, hospital, community pharmacy, household and animal consumption. The collection aspect of the process chain deals with quantities that are collected for treatment or disposal. The assessment is with regard to the quantities that are safely collected, transported and treated or reused. Based on the information gathered from the study, percentages are estimated are either being safely or unsafely collected, transported and treated.

Matrix development

The matrix is developed to ascertain the total percentages of PPCPs that are safely handled during generation, collection, transportation, disposal or treatment. To this end, each of the points at which any of the processes takes place are identified and assigned a percentage value in correlation with the information gathered. As the target of all production of PPCPs is consumption, the total percentage assigned to human consumption and agricultural and veterinary use is 90%. It is estimated, from the information gathered, that human consumption will be significantly higher and is therefore assigned 55%, with animal consumption being assigned 10% and hospital and other institutional use taking 25%. Industry is assigned 8% and community pharmacy, 2%.

According to the FDA (Amedzro, 2015), all manufacturing concerns dispose of their sold and semi-solid products under the supervision of the FDA. This is considered as making up the bulk of the products that will require disposal. However, only two of the thirty-six PPCP manufacturing concerns have effluent treatment plants to treat discharge from various manufacturing processes (Amedzro, 2015). Thus over 90% of these manufacturing concerns discharge their washings off and other discharges directly into receiving waters without any treatment. These facilities have means of collecting these liquid discharges although they are not treated. With respect to collection, therefore, industry is assigned 100% as being safely collected.

This method is followed for each of the contributors of the products for disposal. This information is used to complete the matrix and generate information on what percentages are safely handled at the different process levels and what percentages are not safely handled. Table 1 shows the matrix developed for the model DDFD.

Table 1. DDFD Matrix

Type of System	Input	of which safely collected	not safely collected	of which safely delivered	not safely delivered	of which safely treated	not safely treated	Safe : 4%
Industry	8%	100%	0%	100%	0%	20%	80%	
		8.00%	0.00%	8.00%	0.00%	1.60%	6.40%	**2%**
Hospital	25%	25%	75%	75%	25%	20%	80%	
		6.25%	18.75%	4.69%	1.56%	0.94%	3.75%	**1%**
Community Pharmacy	2%	10%	90%	100%	0%	20%	80%	
		0.20%	1.80%	0.20%	0.00%	0.04%	0.16%	**0%**
Household	55%	50%	50%	70%	30%	5%	95%	
		27.50%	27.50%	19.25%	8.25%	0.96%	18.29%	**1%**
Animal Consumption	10%	10%	90%	100%	0%	20%	80%	
		1.00%	9%	1.00%	0.00%	0.20%	0.80%	**0%**
Unsafe: 96%		**57%**		**10%**		**29%**		
		Local area & drainage		Drainage system		Receiving waters		

Source: Esseku 2015

Model DDFD

The DDFD for a particular country or region is designed by putting the information from the matrix into a pictorial format. This format allows the situational analyses to be displayed for easy understanding. In the model DDFD, medicine-filled arrows were utilised to show the deposit of pharmaceuticals into environmental media by the various ineffective methods used. This culminates in a red figure indicating the percentage of pharmaceuticals deposited in the environment without attenuation. To portray the appropriate methods of collection, treatment, disposal and reuptake or reuse, the green arrows are used to show that those methods are environmentally friendly. These arrows point to green figures indicating the value percentage of pharmaceuticals disposed of properly.

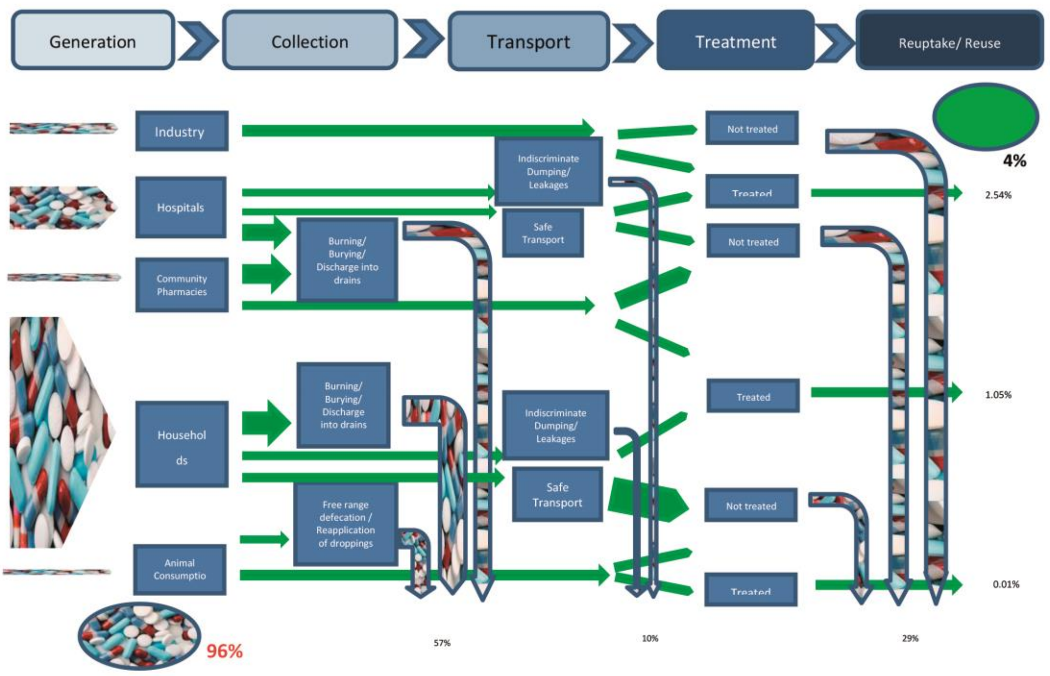

Figure 3. Model DDFD

Source: Esseku, 2015

The results indicated that DDFDs are a feasible tool for controlling pharmaceutical waste in Ghana. The tool highlights areas that require focused intervention to achieve maximum impact. For example, since 57% of waste is disposed of unsafely in the local areas where they are generated and 29% is discharged untreated into receiving waters, focus on these areas will yield the best outcomes.

Conclusions and recommendations

The presence of PPCPs in the environment results in different kinds of effects. Water sources are polluted resulting in less volumes of water available for consumption. Water quality is also affected as a result of the presence of PPCPs in water sources. PPCPs also affect the survival and reproductive capabilities of some organisms making them less likely to survive and reproduce in their native environment. The reuse of water in agricultural settings also mean that PPCPs present in water sources may end up being consumed inadvertently by humans and other organisms that are higher up in the food chain. These humans and other organisms will, therefore become susceptible to the endocrine disrupting effects of these PPCPs. The DDFD provides a pictorial representation of where the PPCPs end up when the existing disposal practices are used. It therefore offers a tool for deal with the presence and effects of PPCPs in environmental media.

The model DDFD demonstrates that 57% of PPCPs are disposed of unsafely in the local areas where they are generated and 29% is discharged untreated into receiving waters with a further 10% being deposited in drainage systems. The 57% could be dealt with by education and the introduction of take back schemes which will receive unused, unwanted and expired PPCPs from consumers. The 29% can be dealt with by use of WWTPs that are designed to remove PPCPs during treatment.

This information may be incorporated into policies for effective strategies for the disposal of PPCPs. The DDFD incorporates the context and outcomes for the methods of disposal currently in place. It provides relevant information for policy formulation and the implementation of effective strategies. Such strategies will be relevant in the implementation of EPV in practice. Further, DDFDs are adaptable and can be used in multiple settings including in resource constrained countries like Ghana where its feasibility has been demonstrated as it identifies areas for focused interventions. The DDFD provides policy makers with information on which areas to target and assess the impact of implemented strategies.

Acknowledgements

This work is part of research conducted by the author for the purpose of an MPhil Pharmacology degree from the Kwame Nkrumah University of Science and Technology.

The author would like to extend thanks to Professor A. N. O. Dodoo and Professor E. Woode as well as the Pharmacology Department, KNUST

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