Pharmaceutical Residues in Freshwater Hazards and Policy Responses
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Hazards and Policy Responses

“A combination of promoting hygiene practices to reduce the incidence of infection and disease, encouraging sustainable pharmaceutical design and production, spreading awareness of responsible pharmaceutical use and disposal, and improving environmental monitoring and risk assessment of pharmaceuticals, are critical steps to achieving the dual sustainable development goals of improving health and protecting the environment.”

Rodolfo Lacy
Director of the Environment Directorate, OECD
The OECD (2019) report *Pharmaceutical Residues in Freshwater: Hazards and Policy Responses* calls for a better understanding of the effects of pharmaceutical residues in the environment, greater international collaboration and accountability distribution, and policy actions to prevent and remedy emerging concerns. Laboratory and field tests show traces of oral contraceptives causing the feminisation of fish and amphibians, and residues of psychiatric drugs altering fish behaviour. Antimicrobial resistance, linked to the overuse of antibiotics, has rapidly escalated into a global health crisis.

Unless adequate measures are taken to manage the risks, pharmaceutical residues will increasingly be released into the environment as ageing populations, advances in healthcare, and intensification of meat and fish production spur the demand for pharmaceuticals worldwide. The report outlines a collective, life-cycle approach to managing pharmaceuticals in the environment. A policy mix of source-directed, use-orientated and end-of-pipe measures, involving several policy sectors, can help to improve health and protect the environment.
Pharmaceuticals are an important element of medical and veterinary practice, and their beneficial effects on human and animal health, food production and economic welfare are widely acknowledged. However, an area where we lack a common understanding is what happens when these pharmaceuticals are constantly discharged into the environment, through pharmaceutical manufacturing, consumption and excretion, and improper disposal of unused or expired products.

Pharmaceuticals in the environment are a challenge to manage for the following reasons:

- Pharmaceuticals are designed to interact with a living system and produce a pharmacological response at low doses, which makes them of environmental concern even at low concentrations. When exposed to non-target organisms in the environment, unintentional harmful impacts may occur.

- Pharmaceuticals are designed to be stable in order to reach and interact with target molecules. This means that either they are very slow to degrade or their constant use leads to continuous release into the environment at rates exceeding degradation rates.

### Number of pharmaceuticals detected in surface water, groundwater, tap water, and/or drinking water

- **0 or no data**
- **1-3**
- **4-10**
- **11-30**
- **31-100**
- **101-200**

Source: (aus der Beek et al., 2016).
Conventional wastewater treatment plants are not designed to, nor do they fully, remove pharmaceuticals from wastewater. Furthermore, veterinary pharmaceuticals used in agriculture and aquaculture can enter water bodies directly or via surface runoff (diffuse pollution).

For most wildlife, exposure to pharmaceuticals in the environment could be long-term, potentially occurring via multiple exposure routes, and involving mixtures of substances.

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2000

**ACTIVE PHARMACEUTICAL INGREDIENTS**

About 2,000 active pharmaceutical ingredients are being administered worldwide in prescription medicines, over-the-counter therapeutic drugs and veterinary drugs (Burns et al., 2018).

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**30-90%**

**ORAL DOSES EXCRETED AS ACTIVE SUBSTANCES**

Pharmaceuticals administrated to humans or animals are excreted via urine and faeces, with 30 to 90% of oral doses generally excreted as active substances (BIO Intelligence Service, 2013).

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**HIGH ENVIRONMENTAL CONCENTRATIONS OF PHARMACEUTICALS DETECTED**

Extremely high pharmaceutical concentrations (in the order of mg/l), have been detected in industrial effluents and recipient streams in China, India, Israel, Korea and the USA (Larsson, 2014).
Sources and trends of pharmaceuticals in the environment

Pharmaceuticals are present in the environment as a consequence of pharmaceutical production and formulation, patient use, use in food production and improper disposal of unused or expired products (Figure 1).

The presence of pharmaceuticals in freshwater and terrestrial ecosystems can result in the uptake of pharmaceuticals into wildlife, and have the potential to bioaccumulate. Humans can subsequently be exposed through drinking water, and ingestion of pharmaceutical residues in plant crops, fish, dairy products and meat.

The concentrations and impacts of pharmaceuticals in the environment depend on a combination of variables, including their use and the toxicity, degradation, persistence and mobility properties of the pharmaceutical; source and timing of pollution; wastewater treatment plant technology, operation and removal efficiency; agriculture and veterinary practices; and the sensitivity of the receiving environment and exposure history (Figure 2).

Figure 1. Major pathways of release of human and veterinary pharmaceuticals into the environment
Pharmaceuticals in the environment are expected to rise with an increase in pharmaceutical consumption. The use of pharmaceuticals will increase as:

- populations age and life-spans increase;
- economies grow - particularly in emerging economies - and with it, an increasing ability and expectation to treat ageing-related and chronic diseases;
- clinical practices evolve - recommendations of earlier treatment, higher dosages or prolonged treatment;
- livestock and aquaculture practices are intensified;
- new pharmaceuticals are engineered;
- climate change exacerbates existing diseases. Non-communicable diseases (e.g. cardiovascular disease and mental illness) and respiratory, water-borne, vector-borne and food-borne toxicants and infections are expected to become more common as climate change intensifies.

**Figure 2. A typology for pharmaceuticals in the environment**

<table>
<thead>
<tr>
<th>Sources</th>
<th>Pathways</th>
<th>Concentration patterns</th>
<th>Pharmaceutical properties</th>
<th>Receiving environment type (sinks)</th>
<th>Concentration, context-dependent factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmaceutical manufacturing plants</td>
<td>• Point source (WWTP discharge)</td>
<td>• Continuous (e.g. WWTPs)</td>
<td>• Persistence</td>
<td>• Rivers</td>
<td>• Medical, agriculture and veterinary practices</td>
</tr>
<tr>
<td>WWTPs</td>
<td>• Diffuse source (i.e. agricultural runoff, leaching of septic tanks to groundwater).</td>
<td>• Seasonal (linked with farming practices and with seasonal influenza and allergies, water flow and temperature)</td>
<td>• Solubility</td>
<td>• Lakes</td>
<td>• Illicit drug use</td>
</tr>
<tr>
<td>Municipal WWTPs</td>
<td>• Intermittent (linked with rainfall events, stormwater overflow, irrigation patterns and pandemics).</td>
<td>• Bioaccumulation</td>
<td>• Metabolites</td>
<td>• Groundwater</td>
<td>• Consumption rates</td>
</tr>
<tr>
<td>Hospitals</td>
<td></td>
<td>• Toxicity</td>
<td>• Transformation products</td>
<td>• Soil</td>
<td>• Pharmaceutical properties</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td>• Individual effects</td>
<td>• Additive effects</td>
<td>• Sediment</td>
<td>• Disposal and waste management practices</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td>• Population effects</td>
<td>• Mixture effects</td>
<td>Coastal zones</td>
<td>• WWTP technology, operation and removal efficiency</td>
</tr>
<tr>
<td>(particularly intensive livestock farming)</td>
<td></td>
<td></td>
<td></td>
<td>Oceans</td>
<td>• Receiving environment type</td>
</tr>
<tr>
<td>Aquaculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Climate</td>
</tr>
<tr>
<td>Septic tanks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Drainage characteristics</td>
</tr>
<tr>
<td>Waste management facilities (landfills)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Water flow variations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Sunlight, temperature</td>
</tr>
</tbody>
</table>

*Note: WWTPs: wastewater treatment plants.*

**Projected increase in antibiotics administered to livestock animals in feed: 67% worldwide by 2030 (from 2015 levels) (Van Boeckel et al., 2015). Much of this increase will come in emerging economies.**

**In Germany, pharmaceutical usage is projected to increase by 43-67% by the year 2045 (from a baseline of 2015). An ageing population is thought to be the main driver (Civity, 2017).**
Impacts of pharmaceuticals in the environment on human and freshwater ecosystem health

The presence of pharmaceuticals in the environment has raised concerns among drinking water regulators, governments, water suppliers and the public. Certain pharmaceuticals have been proven in laboratory experiments to cause unintended, undesired adverse effects on aquatic organisms, including mortality, as well as changes to physiology, behaviour and reproduction. Of greatest concern are: hormones, antibiotics, analgesics, antidepressants and anticancer pharmaceuticals used for human health; and hormones, antibiotics and parasiticides used as veterinary pharmaceuticals.

For example, active substances in oral contraceptives have caused the feminisation of fish and amphibians; psychiatric drugs, such as fluoxetine have altered fish behaviour making them less risk-averse and vulnerable to predators, and the over-use and discharge of antibiotics to water bodies exacerbates the problem of antimicrobial resistance. A summary of ecosystem health impacts of pharmaceuticals in the environment are presented in Table 1.

The impacts of other pharmaceuticals in the environment are less well-known; the vast majority of pharmaceuticals have not been evaluated for their long-term toxicity, occurrence or fate in the environment, and it is therefore difficult to generalise the risk they may give rise to.

In real life, substances are not isolated in the environment; instead they occur mixed together and in combination with other contaminants. There is growing evidence that mixtures of pharmaceuticals possess a joint toxicity greater (i.e. additive effects) than individual toxicities.

Table 1. Examples of measured effects of certain pharmaceutical residues on aquatic organisms in laboratory studies

<table>
<thead>
<tr>
<th>Therapeutic group</th>
<th>Examples of Pharmaceutical</th>
<th>Impact and effected organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analgesics</td>
<td>Diclofenac, Ibuprofen</td>
<td>Organ damage, reduced hatching success (fish)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Genotoxicity, neurotoxicity and oxidative stress (mollusk)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disruption with hormones (frog)</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>-</td>
<td>Reduced growth (environmental bacteria, algae and aquatic plants)</td>
</tr>
<tr>
<td>Anti-cancer</td>
<td>Cyclophosphamide¹, Mitomycin C, Fluorouracil</td>
<td>Genotoxicity</td>
</tr>
<tr>
<td>Antidiabetics</td>
<td>Metformin</td>
<td>Potential endocrine-disrupting effects (fish)</td>
</tr>
<tr>
<td>Anti-convulsants</td>
<td>Carbamazepine, Phenytoin, valproic acid</td>
<td>Reproduction toxicity (invertebrates), development delay (fish)</td>
</tr>
<tr>
<td>Antifungals</td>
<td>Ketoconazole, Clotrimazole</td>
<td>Reduced growth (algae, fish), reduced algae community growth</td>
</tr>
<tr>
<td></td>
<td>Triclosan</td>
<td></td>
</tr>
<tr>
<td>Antihistamines</td>
<td>Hydroxyzine, Fexofenadine, Diphenhydramine</td>
<td>Behaviour changes, growth and feeding rate (fish)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Behaviour changes and reproduction toxicity (invertebrates)</td>
</tr>
<tr>
<td>Antiparasitics</td>
<td>Ivermectin</td>
<td>Growth and reduced reproduction (invertebrates)</td>
</tr>
<tr>
<td>Beta blockers</td>
<td>Propranolol</td>
<td>Reproduction behaviour (fish), reproduction toxicity (invertebrates)</td>
</tr>
<tr>
<td>Endocrine disrupting pharmaceuticals</td>
<td>E2, EE2, Levonorgestrel</td>
<td>Disruption with hormones causing reproduction toxicity (fish, frogs)</td>
</tr>
<tr>
<td>Psychiatric drugs</td>
<td>Fluoxetine, Sertraline, Oxazepam, Citalopram, Chlorpromazine</td>
<td>Behaviour changes - feeding, boldness, activity, sociality (fish)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disruption with hormones (fish)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Behaviour changes - swimming and cryptic (invertebrates)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reproduction toxicity and disruption with hormones (invertebrates)</td>
</tr>
</tbody>
</table>

Note: ¹ Transformation of Cyclophosphamide and Ifosfamide; E2: 17β-estradiol (natural steroidal oestrogen); EE2: 17α-ethinylestradiol (synthetic oestrogen).
Antimicrobial resistance (AMR) is a global health crisis with the potential for enormous health, food security and economic consequences. AMR is the ability of a microbe to resist the effects of medication that could once successfully destroy or inhibit the microbe.

Drug resistant infections already cause an estimated 700,000 deaths each year globally. If no action is taken, this is projected to increase to 10 million per year by 2050 – that is more than the number of people dying from cancer. A continued rise in AMR is projected to lead to a reduction of 2-3.5% in GDP globally, with a cumulative cost of up to USD 100 trillion.

The mis- and over-use of antibiotics is an important contributing factor of AMR; up to 50% of the antibiotics prescribed for human use are considered unnecessary. The number is even greater in the agriculture and aquaculture sectors, where they are mainly administered as a growth promoter and as a substitute for good hygiene. The environment becomes a reservoir for resistant genes, as well as an arena for the development and spread of resistance to pathogens.

Sources: (IACG, 2018), (OECD, 2018), (Review on Antimicrobial Resistance, 2015).
There are several mitigation options for water quality improvement in the pharmaceutical life cycle, including improvements in the design, authorisation, production, use, solid waste and wastewater treatment. A focus on preventive options early in the pharmaceutical life cycle, may deliver the most long-term, cost-effective and large-scale benefits.

A selection of key mitigation policy options across the pharmaceutical life cycle are presented in Table 2. France, Germany, the Netherlands, Sweden and the United Kingdom have started a multi-sector dialogue to tackle the problem. At the EU level, a “Strategic Approach to Pharmaceuticals in the Environment” identifies actions for stakeholders throughout the pharmaceutical life cycle with an emphasis on sharing good practices, on cooperating at international level, and on improving understanding of the risks.
Table 2. Selection of key mitigation policy options across the pharmaceutical life cycle

<table>
<thead>
<tr>
<th>Step in pharmaceutical life cycle</th>
<th>Relevant stakeholders</th>
<th>Mitigation options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Industry</td>
<td>Innovation in green pharmacy, biological therapies, personalised or precision medicines.</td>
</tr>
<tr>
<td>Authorisation</td>
<td>Government, Industry</td>
<td>Legislation and standardised methodology for environmental risk assessment and incorporation into pharmaceutical authorisation process. More stringent conditions for putting a pharmaceutical on the market that is of high-risk to the environment (e.g. increased risk intervention and mitigation options, eco-labelling, prescription only, post-approval monitoring).</td>
</tr>
<tr>
<td>Production</td>
<td>Industry, Government, Intergovernmental Organisations</td>
<td>Green public procurement with environmental criteria. Environmental criteria for Good Manufacturing Practices, effluent discharge limits and disclosure of pharmaceutical wastewater discharge from supply chains.</td>
</tr>
<tr>
<td>Consumption (professional use)</td>
<td>Agriculture, Health sector, Government</td>
<td>Emission prevention through disease prevention and sustainable use: • improved human and animal health and well-being • improved diagnostics, avoided prescriptions • improved hygiene standards in health facilities, stable management and livestock handling • personalised medicines, vaccinations, targeted delivery mechanisms • prescription of environmentally-friendly pharmaceutical alternatives¹ • restrictions or bans of unnecessary high-risk pharmaceuticals (e.g. veterinary use of antibiotics for preventative measures and hormones as growth promoters in livestock)</td>
</tr>
<tr>
<td>Consumption (over-the-counter purchases/ self-prescription)</td>
<td>Health sector, Industry, Consumers</td>
<td>Eco-labelling on pharmaceutical products to improve consumer choice selection and awareness</td>
</tr>
<tr>
<td>Collection and disposal</td>
<td>Solid waste utilities, Industry</td>
<td>Education campaigns to avoid disposal of pharmaceuticals via sink or toilet • Public pharmaceutical collection schemes for unused drugs • Extended producers responsibility schemes • Improved manure management by passive storage or anaerobic fermentation in biogas plants</td>
</tr>
<tr>
<td>Wastewater treatment</td>
<td>Wastewater utilities</td>
<td>Upgrade of wastewater treatment plants</td>
</tr>
<tr>
<td>Drinking water treatment</td>
<td>Drinking water utilities</td>
<td>Upgrade of drinking water treatment plants • Water safety planning</td>
</tr>
</tbody>
</table>

Note: ¹ Requires that a substitute pharmaceutical is available with lower environmental risk. An alternative assessment would be required to confirm this, in order to prevent pollution-swapping.

The removal of pharmaceuticals is limited by wastewater treatment plant upgrades

Upgrading wastewater treatment with new technologies will not solely solve the problem of pharmaceuticals in water. They are limited by their removal efficiencies, high capital investment and operation costs and increased energy consumption. They do not capture diffuse sources of pharmaceutical pollution (e.g. from agriculture and aquaculture).
Germany has developed an environmental checklist for veterinarians and farmers with the aim of reducing the use and release of veterinary pharmaceuticals to the environment.

The United States has national regulations on the disposal of hazardous pharmaceutical waste in the health sector.

In the United Kingdom, the poultry industry has successfully reduced unnecessary antibiotic use – whilst increasing meat production – with a voluntary antibiotic stewardship programme.

Germany has developed an environmental checklist for veterinarians and farmers with the aim of reducing the use and release of veterinary pharmaceuticals to the environment.
Sweden has a ‘Wise List’ of recommended pharmaceuticals for the treatment of common diseases that takes into account environmental impacts when comparing medications that are equally safe and equally suitable for the medical purpose.

The Swedish government has proposed a revised public procurement system in which pollution control during manufacturing is considered when pharmaceutical companies compete to obtain product subsidies for state healthcare.

Switzerland has a nationwide tax to fund the upgrade of 100 wastewater treatment plants with new technologies to reduce pharmaceuticals in water bodies.

Korea uses suspect and non-target screening to identify and prioritise pharmaceuticals for water quality monitoring.

Australia has a national pharmaceutical collection and disposal programme, with retail pharmacies commonly acting as collection sites.
The OECD recommends government’s take a collective, life cycle approach to managing pharmaceuticals in the environment. This means: i) designing and implementing a policy mix of source-directed, use-orientated and end-of-pipe measures; ii) targeting stakeholders throughout the life cycle of pharmaceuticals; and iii) using a combination of voluntary, economic and regulatory instruments. A national pharmaceutical strategy and action plan to manage environmental risks should be developed in collaboration with relevant government departments, local authorities and other stakeholders, and be supported by a strategic financing strategy to ensure effective implementation.

Policies that cost-effectively manage pharmaceuticals for the protection of water quality and freshwater ecosystems rest on five strategies:

1. **Improvement of knowledge, understanding and reporting** on the occurrence, fate, toxicity, and human health and ecological risks of pharmaceutical residues in water bodies in order to lay the ground for future pollution reduction measures.

### OECD recommendations on improving knowledge, understanding and reporting

- Identify potential environmental risks of existing and new active pharmaceutical ingredients through intelligent and targeted assessment strategies. Reduce unknowns on relationships between pharmaceuticals, and human and environmental health. The relative risk of active pharmaceutical ingredients should also be compared with other pollutants (e.g. heavy metals, persistent organic pollutants and other contaminants of emerging concern) to achieve improvements in water quality and ecosystems in the most cost effective way.
- Encourage the uptake of new monitoring methods, modelling and decision-support tools to better understand and predict the risks. Prioritise substances and water bodies of highest concern.
- Increase access to data and information, and institutional coordination, to reduce knowledge gaps.
- Adopt precautionary measures when scientific evidence is uncertain, and when the possible consequences of not acting are high.
- Factor in financing needs and measures to recover policy transaction costs, as well as the capacity of government officials and stakeholders to implement policies.
- Educate and engage with the public to manage perceived and actual risks, and improve awareness and understanding.
2. Source-directed approaches to impose, incentivise or encourage measures in order to prevent the release of pharmaceuticals into water bodies. They are primarily targeted towards pharmaceutical companies and manufacturing facilities.

OECD recommendations on source-directed approaches. Pharmaceutical life cycle stages: design, marketing authorisation, manufacturing, post-authorisation

- Develop clear and shared environmental criteria (and performance indicators) for sustainable ‘green’ procurement of pharmaceuticals.
- Consider expansion of the regulatory framework for good manufacturing practice to include mandatory environmental criteria.
- Develop drinking water safety plans, monitoring programmes of pharmaceuticals and incidence reporting to identify and prevent contamination, and adapt policy to new science.
- Ensure Environmental Risk Assessment (ERA) robustness, consistency and transparency. Establish a centralised database with independent regulatory oversight to share ERAs of pharmaceuticals and prevent duplication efforts.
- Consider environmental risks in the risk-benefit authorisation of human pharmaceuticals in order to manage and mitigate risks.
- Provide incentive structures to advance green pharmacy, and personalised and precision medicines. A return on public investments in new pharmaceuticals should be considered when assessing support for the private sector in pharmaceutical development.
- Address any potential economic impacts to avoid loss of pharmaceuticals or supply chain interruptions, and to limit increased costs to healthcare providers against static budgets.
- Establish new business models for pharmaceuticals that balance access needs, appropriate use and adequate return. This is particularly important for new antibiotics and tackling AMR; current business models link profit (sales) with volume (consumption).
3. **Use-orientated approaches** to impose, incentivise or encourage reductions in the inappropriate and excessive consumption of pharmaceuticals. They are designed to inform and change the behaviours and practices of physicians, veterinarians, pharmacists, patients and farmers.

**OECD recommendations on use-orientated approaches. Pharmaceutical life cycle stages: prescription and use**

- Reduce the incidence of infection and disease. Improved access to safe water supply, sanitation and hygiene is particularly important. Other important measures include improved stable and livestock handling, practitioner training, education campaigns and vaccinations.

- Reduce unnecessary use and release of pharmaceuticals. Improve diagnostics and delay prescription of pharmaceuticals when they are not immediately required. If not already in place, consider bans or restrictions on antibiotics for preventative use, and hormones as growth promoters, in the livestock and aquaculture sectors.

- Optimise the use of pharmaceuticals with effective diagnosis, dosing, personalised medicines and targeted delivery systems.

- Reduce self-prescription of pharmaceuticals with high-risk (e.g. antibiotics and pharmaceuticals that target the endocrine system) and illegal sales of pharmaceuticals.

- Promote best practices on the storage and use of livestock manure and slurry from livestock treated with pharmaceuticals.
4. **End-of-pipe measures** – as a compliment to strategies 1-3 – that impose, incentivise or encourage improved waste and wastewater treatment to remove pharmaceutical residues after their use or release into the aquatic environment.

**OECD recommendations on end-of-pipe measures. Pharmaceutical life cycle stages: collection and disposal, and wastewater treatment and reuse**

- End-of-pipe measures should only be used in complementary to source-directed and use-orientated measures. An over-emphasis on upgrading wastewater treatment plant (WWTP) infrastructure is not a sustainable, optimal use of limited resources.
- Ensure value-for-money in investments in WWTP upgrades through evaluation and prioritisation, including achieving economies of scale. Consider potential trade-offs (e.g. incomplete removal of pharmaceutical residues to varying degrees; generation of potentially toxic transformation products and sludge; increased energy, chemicals and carbon emissions).
- Factor in financing needs and cost-recovery mechanisms for capital, and operation and maintenance costs of WWTP upgrades, including potential affordability issues with sanitation tariffs.
- Ensure appropriate collection and disposal of waste pharmaceuticals. Educate and engage with health professionals, veterinarians, consumers and farmers to raise awareness about inappropriate disposal of unused medications. Consider extended producer responsibility schemes to recover costs.
- Promote best practices on the use and disposal of biosolids (which may include toxic transformation products) following wastewater treatment.

5. **Collaboration and a life cycle approach**, combining the four strategies above and involving several policy sectors. Action on pharmaceuticals in the environment is much more likely to be extended and sustained if it is mainstreamed into broader health, agricultural and environmental policies and projects.
References


Civity (2017), Pharmaceutical usage in the context of demographic change: The significance of growing medication consumption in Germany for raw water resources, Civity Management Consultants.


IACG (2018), Antimicrobial resistance: Invest in innovation and research, and boost research and development and access. IACG discussion paper, UN Interagency Coordination Group on Antimicrobial Resistance.


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Unless adequate measures are taken to manage the risks, pharmaceutical residues will increasingly be released into the environment as ageing populations, advances in healthcare, and intensification of meat and fish production spur the demand for pharmaceuticals worldwide. The report outlines a collective, life-cycle approach to managing pharmaceuticals in the environment. A policy mix of source-directed, use-orientated and end-of-pipe measures, involving several policy sectors, can help to improve health and protect the environment.

For more information:

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