pills
Pharmaceutical Input and Elimination from Local Sources

Pharmaceutical residues in the aquatic system – a challenge for the future

Insights and activities of the European cooperation project PILLS

A European partnership project of:

Emschergenossenschaft (DE), Waterschap Groot Salland (NL), Centre de Recherche Public Henri Tudor (LU), Eawag (CH), Glasgow Caledonian University (UK) and Université de Limoges (FR)

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
NWE
INTERREG IVB

PILLS – "Pharmaceutical Input and Elimination from Local Sources" is a project in the context of the INTERREG IV B programme of Northwest Europe.

Lead Partner of the project is the Emschergenossenschaft, a German water board. The PILLS partners are the Waterschap Groot Salland (NL), the Centre de Recherche Public Henri Tudor (LU), the Eawag (CH), the Glasgow Caledonian University (GB) and the Université de Limoges (FR).

The PILLS-partnership works together from 2007 until 2012. Its budget comprises approx. 8 million Euro; 50% is co-financed by the European Regional Development Fund.

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

Contents

Background

We cannot imagine our society without them: highly active modern pharmaceuticals. They help to prevent or cure diseases. Large quantities of various pharmaceutically active substances are manufactured today for the protection of humans and animals.

As a result of improved medical care, rising life expectancy and the progressive industrialisation of agriculture, an increasing amount of medicinal products are consumed. These products are, however, in many cases not completely absorbed and metabolised by the patient but partially excreted again. Thus traces of the products reach the water cycle.

It is not only the growing use of medicinal products that has led to an increased awareness of this topic however: Thanks to enormous advances in chemical analysis technologies, many pharmaceutical residues can now be determined in water at extremely low concentrations, often many times lower than was possible several years ago. As a result, concentrations can now often be detected in the nanogram per litre range. This means that, for example, a lump of sugar dissolved in a reservoir with a holding capacity of about 2,700 million litres of water (approx. 19 Mio. filled bath tubes), results in sugar traces that can be measured by modern analysis methods.

The concentrations of pharmaceutical residues, which are detected in the water, are very low and according to the current state of knowledge are not harmful to humans. However, it is unclear what effects these residues have on the water habitat – for example on micro organisms. The

Concentrations of active substances in waters and the significance to humans

An example of a pharmaceutical active substance that can be detected in waters is Diclofenac. Diclofenac is a pain killer and an anti-inflammatory; the dosage of the active substance, in one tablet, range from 25 mg up to 750 mg. Measurements show that not all of the active substance is absorbed by the body, and that – in many cases – more than half of the administered dose is excreted and released into the wastewater.

In different studies, residues of Diclofenac were detected at levels up to 1 µg per litre in surface waters. In order to consume the quantity of even a (low-dose) tablet of 25 mg, a person would have to drink 25,000 litres of this untreated water at a time. Nevertheless, the consequences for the water habitat are of serious concern.

question: "What implications do these pharmaceuticals have in turn for the food chain, for biodiversity and thus for the entire ecosystem?" is now frequently posed. Studies show, for example, that there is a link between water-bound traces of hormonally effective substances – such as female hormones contained in contraceptive pills – and the shift in the sex ratio of some fish species where males are becoming "feminised", in that they produce less sperm and instead start to produce eggs. In the long term these type of effects may lead to smaller population sizes, which may have corresponding implications for the entire food chain.

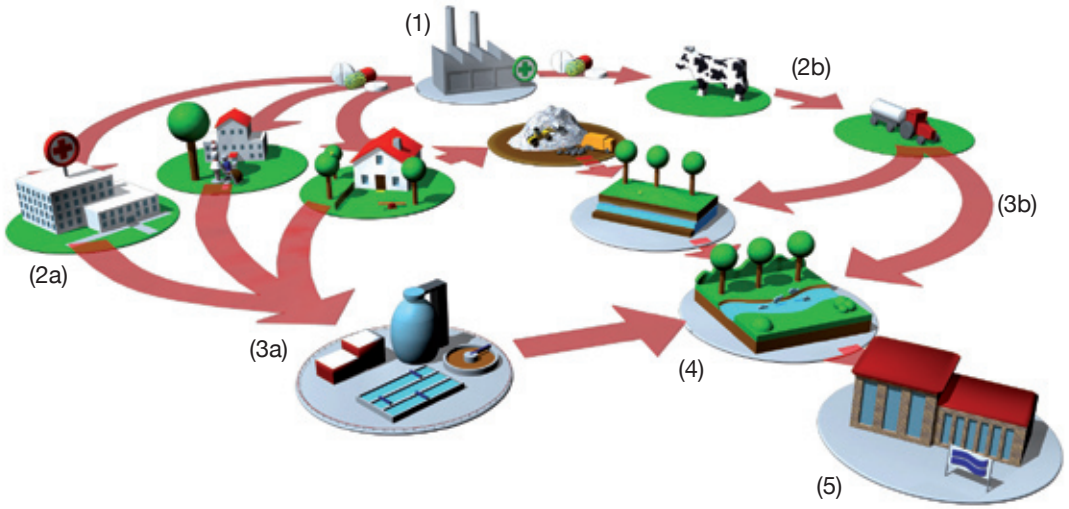
The life-cycle of pharmaceuticals

Pharmaceutical residues reach the water system by various paths and in order to identify these, the entire life-cycle of pharmaceutical substances needs to be considered (see figure on page 6).

This life-cycle starts with the development and production of pharmaceuticals (1). Here, during the manufacturing process, wastewater may be contaminated by pharmaceuticals. Although this wastewater is pre-treated, it is possible that residues are emitted into the water system.

After production, the pharmaceuticals are used in human (2a) or veterinary (2b) medicine. In the case of human medication (2a), active substances may not be completely absorbed by the body; they are partially excreted unchanged and reach the central wastewater treatment plants (3a). However, modern wastewater treatment methods are not able to completely eliminate all these substances, since they are primarily optimised for the removal of biodegradable substances and nutrients such as phosphorus and nitrogen. Therefore, these residues may pass through the treatment plants and reach surface waters such as rivers and lakes. Further emissions can result from leaks in the sewers, as a result of emergency sewage overflows during heavy rainfall, or come from the sewage sludge when used in agriculture. The consequence of these

The life-cycle of pharmaceuticals



Source: PILLS project

emissions is that pharmaceutical residues – even in very low concentrations – can be detected in surface waters (4) or in water for drinking water production (5).

Pharmaceutical residues resulting from veterinary use get into the ground and surface water (4), mainly through the deposition of liquid manure on arable land (3b).

Micropollutants

"Micropollutants" refers to organic substances or metals that are found in the lowest concentrations (traces) in the water system. In general, synthetic chemicals are meant, but natural and geogenic substances (e.g. estradiol) are often included.

These substances are characterised as "pollutants" if their presence is liable to cause pollution. "Hazardous substances" refers to substances that are toxic (poisonous), persistent (low biodegradability) and liable to bioaccumulate (concentrate within the organism) or to other substances which give rise to an equivalent level of concern.

At first sight, it might therefore be reasonable to avoid pharmaceutical residues altogether in order to protect our water-system. However, not producing and not taking medication does not represent a realistic or desirable scenario. Another option is to take technical measures to clean the burdened water. But a complete elimination of all micropollutants is for practical and economic reasons not reasonable. In this respect life completely without pharmaceutical residues in our industrial society is not achievable.

A very promising approach to minimise the pharmaceutical residues in the water cycle appears to be one that involves all stakeholders across the entire life-cycle of pharmaceutical substances. Only if all involved parties – from industrial producers to human or veterinary medicine users to wastewater management companies and drinking water suppliers – take precautions in their respective fields, can the burden on water systems be effectively reduced.

Objectives and management structure

Six partners from Northwest Europe – two water boards from Germany and the Netherlands, two research institutions from Switzerland and Luxembourg and two universities from Scotland and France – have joined forces to work together. The different partners each have specific knowledge that they bring to the PILLS project.

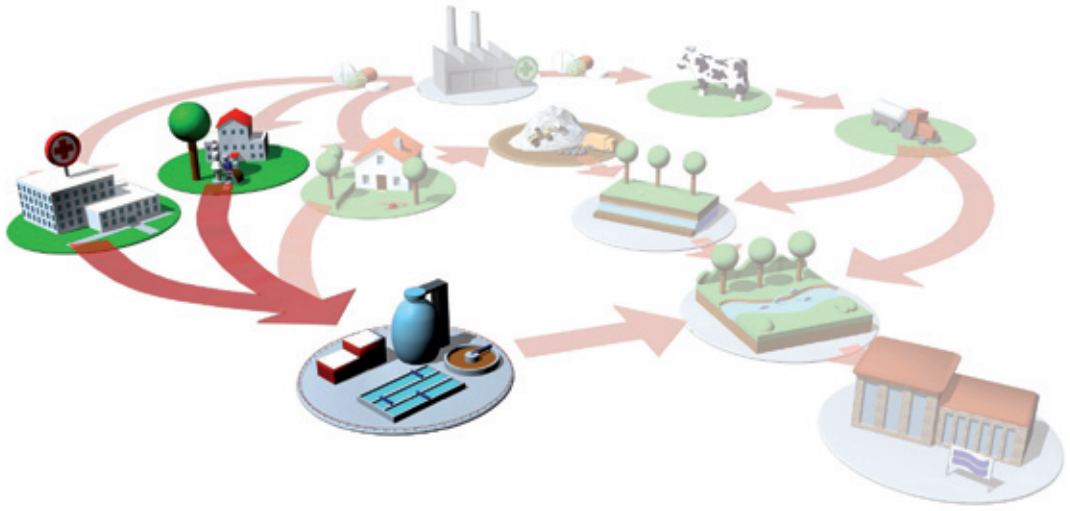
The PILLS partners focus on the path of human pharmaceuticals and specifically on wastewater treatment. Since the concentration of pharmaceutical residues at point sources (such as hospitals or nursing homes) is considered to be comparatively high, they test new wastewater treatment technologies at these points and hope to

Point sources

Although the total load of pharmaceutical residues detected in municipal wastewater is higher, the PILLS partners refer to point sources as local emitters that register high concentrations of pharmaceutical residues in their wastewater. When this wastewater reaches the sewage system it is mixed with municipal wastewater, having comparably lower concentration of micropollutants.

The partners of the PILLS project are investigating whether they can eliminate pharmaceutical residues in a more targeted and cost-effective manner by treating wastewater decentralized, directly at these point sources.

The PILLS focus



Source: PILLS project

find the optimum conditions here for the removal of the residues.

The partners wish to find out which treatment methods are best suited to reduce pharmaceutical residues and antibiotic resistant bacteria in wastewater. In this context they would like to gain more knowledge about the question whether and under which circumstances local treatment, for example at hospitals, is reasonable. Finally, they would like to increase awareness of this problem across Europe.

In order to achieve the objectives the project partners have devised the following project components:

- The analysis of the wastewater that is contaminated with pharmaceutical residues as well as a characterisation of the wastewater flows is in the centre of this working step.

  Work package 1: Characterisation of the pharmaceutically burdened wastewater

- Technologies for the treatment of pharmaceutically burdened wastewater are further developed and tested in practice by the construction of four pilot plants. To this end each partner cooperates with a hospital in their region.

  Work package 2: Design, construction and operation of wastewater treatment plants which includes advanced treatment technologies.

- The efficiency, the cost-benefit ratio and the ecological balance (made using a life-cycle assessment methodology) of the advanced treatment technologies is investigated. This research will provide information on the question, whether and when the local treatment of wastewater may represent a valuable approach for the reduction of pharmaceutical residues.

Work package 3: Assessment of different advanced treatment technologies

- Various communication measures enable an exchange of information in the scientific and political field. Furthermore, the topic is brought to the attention of the broader public to make them aware of the issues.

Work package 4: Communication of the issues and of the results of the project.

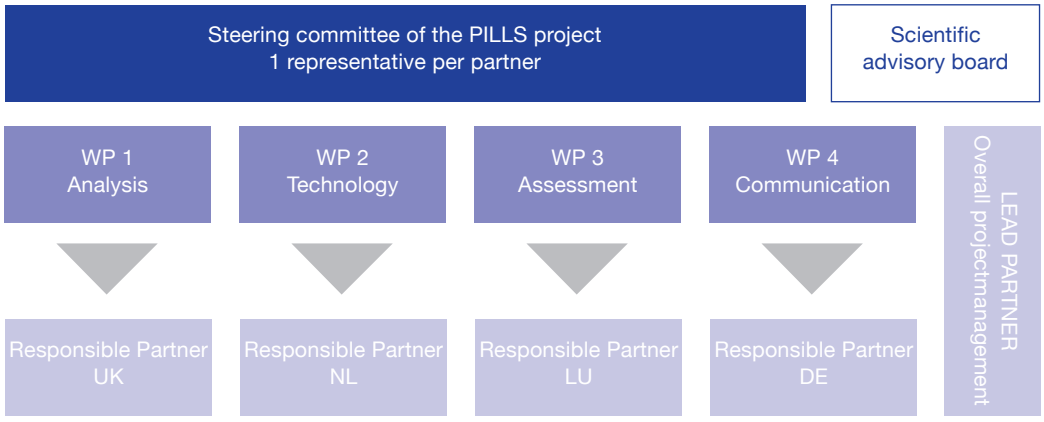
Different partners are responsible for the implementation and quality control of the work packages. A steering committee is in charge of the overall control of the project with regards to the content. For each partner there is one representative in this committee. The steering committee is advised by a scientific advisory board, which is associated with the project for its duration.

The members of the scientific board come from science, industry and administration. It is asked to provide critical feed-back related to the project results and provide information sources as well as ideas based on their individual key-expertise. Furthermore the scientific board aims at integrating the projects´ findings into discussions at European level.

»The PILLS project facilitates an international discussion on pharmaceutical micropollutants being found in the aquatic system. The research into technologies to minimise this pollution is one possible solution amongst others which need to be considered. And with the project we gain findings that are highly relevant not just for Germany but also for the European policy. Communicating our results together shows that Europe – at least at project level – is very capable of speaking with one voice.«

Dr Jochen Stemplewski, chief executive officer Emschergenossenschaft, Germany

The PILLS management structure



Source: PILLS project

Characterisation of (treated) wastewater

In Europe there are estimated to be more than 100,000 chemical substances in circulation and, of these, more than 3,000 approved active substances are medicinal products. Against this vast array of chemicals it is important that the partnership identifies the substances which all partners of the different countries should be analysing in a targeted manner within the scope of the project in order to obtain a comparable database.

Chemical analyses

For the selection of the most important pharmaceutical substances to be analysed, the following three criteria have priority:

- Which active substances are used (in high concentrations) in hospitals and are also found in the aquatic system?
- Which active substances have known ecotoxicological effects and may therefore represent the greatest risk to the environment?
- What active substances are not eliminated in the conventional treatment process and must be removed using advanced treatment methods?

On the basis of literature data, and their own measurements, the partners identify substances they considered as important. It appears that in different countries, the same active substances are found repeatedly. Although the concentrations vary from region to region, some pharmaceuticals with a high consumption rate in some partner hospitals are not used at all in others.

Based on the above considerations, the partnership selected eight substance

groups of active substances for this project: analgesics, anesthetics, cytostatics, antibacterials, X-ray contrast media, anticonvulsants, lipid regulators and betablockers (see appendix for more details).

To ensure that the measurements between the various countries are indeed comparable, the partners also compare the analytical methods of the various laboratories and – whenever necessary – agree on cooperations whereby the laboratories assist each other and carry out measurements for the partners from other countries.

Eco-toxicological tests

For the assessment of the quality of wastewater containing a mixture of pharmaceuticals eco-toxicological tests (biotests or bioassays) are carried out in addition to the chemical analyses. These tests help to characterise the ecotoxicity of water before and after treatment. General effect based, in-vitro tests (bioluminescent bacteria test and algae photosynthesis test), have been selected for this purpose as common tests for the partnership.

Eco-toxicological tests

Eco-toxicological tests investigate toxic effects of substances to an ecosystem. Eco-toxicological tests are conducted with representative environmental species (single cells or multicellular organisms) determining the biological activity of substances to these organisms.

The test systems can be differenitated into in-vivo and in-vitro tests. In-vivo (Latin: within the living) tests are those that usually apply multicellular organism for testing. In contrast in-vitro (Latin: within the glass) tests are performed with single cells or even subcellular systems (e.g. enzymes) in a highly standardized environment, such as a test tube or a petri dish.

»The Netherlands have a special role in the system of the European river landscape. We are situated virtually at the end of the Rhine, Meuse and Scheldt rivers, and the water is already burdened several times over with pollutants from other countries before it reaches us. For us, however, the water quality of these rivers plays an extraordinary role since our two largest drinking water reservoirs are fed from the Rhine and the Meuse. The European cooperation on the topic of water quality – that examines the entire river course even before it reaches the Netherlands – is extremely important to us. Ultimately we are going to be drinking this water later on.«

Jan Oggel, member of the board
Waterschap Groot Salland,
The Netherlands

Analyses of antibiotic resistant bacteria and microbiological tests

Another aspect of growing concern are antibiotic resistant bacteria that are likely to be found in wastewater containing antibiotics. The partnership is aware of this issue and therefore they are investigating the appearance of antibiotic resistant bacteria in the wastewater to find an answer to the question to what extent a hospital is a source for antibiotic resistance or not. Furthermore, they assess if the advanced treatment techniques are useful in order to reduce the propagation of antibiotic resistance.

Further microbiological tests (e.g. determination of *E. coli*) are carried out in order to investigate the hygienic quality of the treated water.

Advanced wastewater treatment at local sources

Four partners of the project from the Netherlands, Germany, Luxembourg and Switzerland are each building a pilot plant in cooperation with a local hospital. While the Waterschap Groot Salland in the Netherlands and the Emschergenossenschaft in Germany are building full-scale wastewater treatment plants, which treat virtually the entire hospital wastewater, the partners from Switzerland and Luxembourg are installing smaller pilot-scale wastewater treatment plants treating partial flows of the hospital wastewater to support the design and operation of full-scale plants.

The pilot plants are characterised by a combination of technologies, which has the objective of eliminating the largely persistent residues of medicinal products in addition to the biodegradable substances and nutrients. For this reason conventional

Conventional wastewater treatment plants (conventional activated sludge system)

Source: PILLS project

wastewater treatment processes are applied in the PILLS plants which are complemented by advanced techniques.

In the mechanical pre-treatment unit (1), the water flows initially through a screen or a drum sieve, where coarse impurities are retained. The smaller the openings in the screen, the fewer particles which remain are ultimately included in the wastewater. The water is then discharged to a tank, where coarse, settleable impurities such as sand sink to the bottom and are removed from the wastewater. The biological treatment unit (2) copies the processes of self-purification of surface waters. In this section the nutrients nitrogen and phosphate as well as well biodegradable organic substances are eliminated. In the final clarification (3) the water is clarified from sludge particles. The excess sludge is generally discharged together with the sludge of the pre-clarification tank for further sludge treatment and disposal.

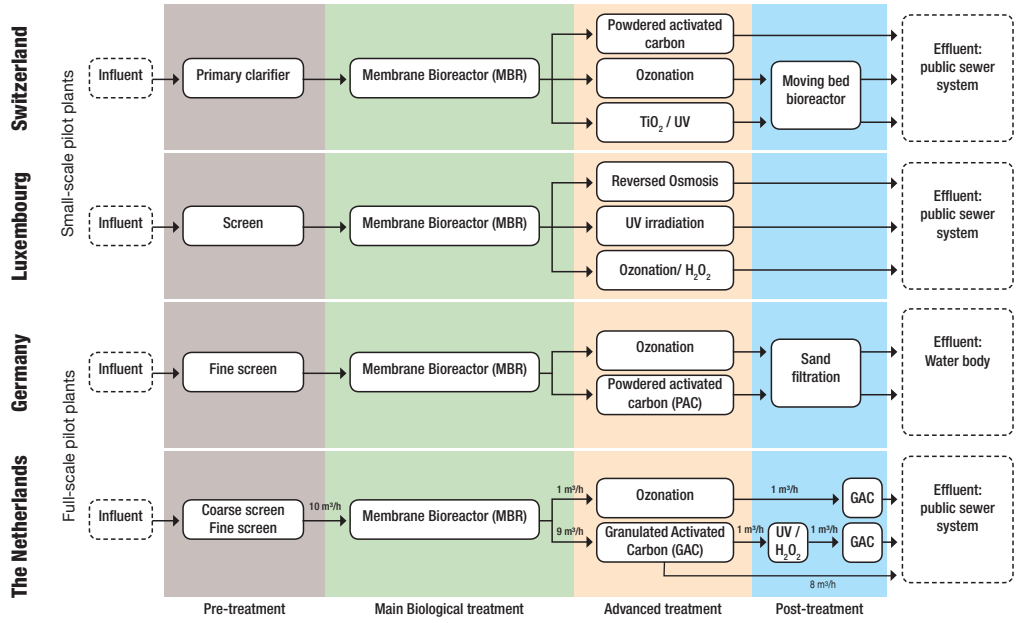
The PILLS pilot plants combine the biological treatment unit and the final clarification of the conventional treatment plants in a so-

called Membrane Bioreactor (MBR) before the advanced treatment steps are applied.

Advanced wastewater treatment

The elimination of pharmaceutical residues is possible only with advanced technologies using chemical and physical processes like filtration through dense membranes (e.g. reverse osmosis), adsorption onto activated carbon or advanced oxidation processes.

The PILLS pilot plants



Source: PILLS project

»We think you cannot always discuss about care of the environment without actively supporting it. The problems of pharmaceutical residues in the food chain are a common knowledge. With our cooperation I hope to support the development of economical methods for the elimination of pharmaceutical residues in wastewater. This would also mean a further step in the effort to reduce multiresistent pathogens.«

Andreas Eggmann, Kantonsspital Baden AG (partner hospital), Switzerland

Post-treatment is sometimes necessary, as ozone and UV treatment may generate toxic by-products, which have to be removed as well. When using adsorption with powdered activated carbon (PAC), a final separation step is necessary in order to purify the treated water from the activated carbon. When using granulated activate carbon (GAC), this treatment step is not necessary.

Small-scale pilot plants

With two small-scale pilot plants installed in Switzerland (Baden) and Luxembourg (Esch-sur-Alzette) several processes and operational settings can be tested.

The two pilot plants purify a partial flow which comes from the hospital wards where the concentrations of pharmaceuticals are particularly high. The average inflow to the plants is around 1-3 m^3 per day.

The treated wastewater of both pilot plants is discharged into the public sewage system – which is connected to a municipal wastewater treatment plant.

Full-scale pilot plants

Two full-scale plants, one in in Gelsenkirchen (Germany) and one in Zwolle (The Netherlands) are designed for permanent operation. The aim is to investigate what challenges confront full-scale application of advanced processes in practice and how efficient such large plants are in their purification performance. This is important because, to date, there has been very few full-scale trials on wastewater treatment plants on advanced elimination processes. In this respect there is a lack of experience on practical operation to assess the advantages and disadvantages as well as the associated costs and the by-products produced by these processes.

The pilot plant in Gelsenkirchen treats the relevant wastewater loaded with medicinal products, which represents about 80% of the entire wastewater produced by the hospital. The wastewater treatment plant in the Netherlands treats the entire wastewater flow of the local hospital. Both pilot plants have an average inflow to the plant of about 200m^3 per day.

In the Netherlands the purified water ultimately flows into the public sewage system. In Germany authorisation was obtained to directly discharge the treated wastewater into a river.

Assessing the approaches

Different assessment methods evaluating the individual advanced treatment techniques of the pilot plants are:

Efficiency of the plants

The respective plant configurations and advanced treatment processes are compared with regards to their purification efficiency. This research will show which method is best suited in the respective situation to eliminate specific pharmaceuticals. Furthermore, their efficiency regarding the reduction of ecotoxicological effects and of antibiotic resistance bacteria is investigated.

Cost assessment

In addition to the efficiency, the costs incurred from the construction and operation of the plants are of particular significance. For this reason the plants are subjected to a cost assessment in which both the overall costs and the costs of the different further treatment processes are compared. The annual investment costs and operational costs are determined for this purpose. In this way, a cost-benefit analysis is possible.

Life-cycle assessment

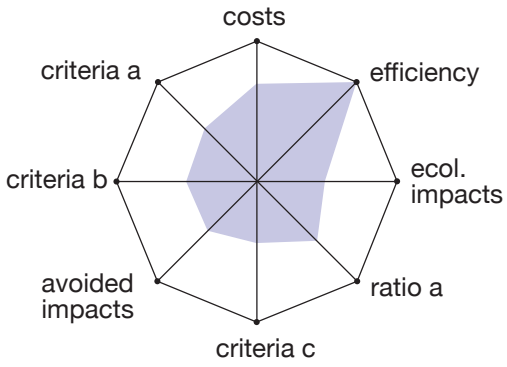
A life-cycle assessment methodology normally considers the three steps of the life-cycle: the construction, the operation phase and the dismantling. In this particular case, because this life-cycle assessment aims at comparing scenarios having similar infrastructures, the first and the last phases of the life-cycle can be neglected. Only the indirect pollutant emissions due to the

operation of the plant, i.e. those generated by energy and raw materials consumption and production, are considered. The environmental impact is calculated for many impact categories (global warming potential, acute and chronic ecotoxicity in water, carcinogenic effects and others) to broaden the possibility of comparison.

Multi-criteria analysis

In the multi-criteria analysis the above-described analysis results are examined and assessed in an integrated manner. For example, the cost-benefit ratio, the ratio between the induced and avoided ecological impacts and the overall efficiency of the reduction of antibiotic resistance bacteria may be an integral part of the analysis. Furthermore, other important technical and social criteria for decision-makers are considered.

Example of a multi-criteria analysis



Source: PILLS project

»In Scotland we are examining this issue from another perspective: one current disposal route of sewage sludge is via application to arable land. In 2007, approximately 50% of all the sewage sludge in Scotland was disposed of using this approach. However, if the sludge were to contain residues of pharmaceuticals and other micropollutants, there is the possibility they may enter groundwater. Therefore we welcome the European initiative on this topic and hope to gain new findings through this for water protection in Scotland.«

Andrew Rawlins, Scottish Environment Protection Agency, SEPA, Great Britain

Further actions for a sustainable reduction

It is apparent that there is still a lot more research needed for a comprehensive assessment within this field. However, experts agree that for precautionary reasons, action is already necessary now. They also agree on the fact that that substances with a potential eco-toxicological risk are to be avoided as far as possible, or reduced to the extent that they have no effect. In this context, the benefits (quality of life) and damage (risk to humans and the environment) need to be taken into account.

According to the precautionary principle – a significant principle of the European environment and health policy – the objective should be to reduce the entry of pharmaceutical residues into surface water to a level at which they are harmless, taking into consideration ecological, economic and social issues. To achieve

Environmental Quality Standards

As long as pharmaceutical products are produced and taken as long we will find pharmaceutical residues in our environment. As a total elimination of all micropollutants is practically and economically not reasonable, all measures for the reduction of these residues aim at achieving a concentration below the known environmental quality standards or the actual detection limit.

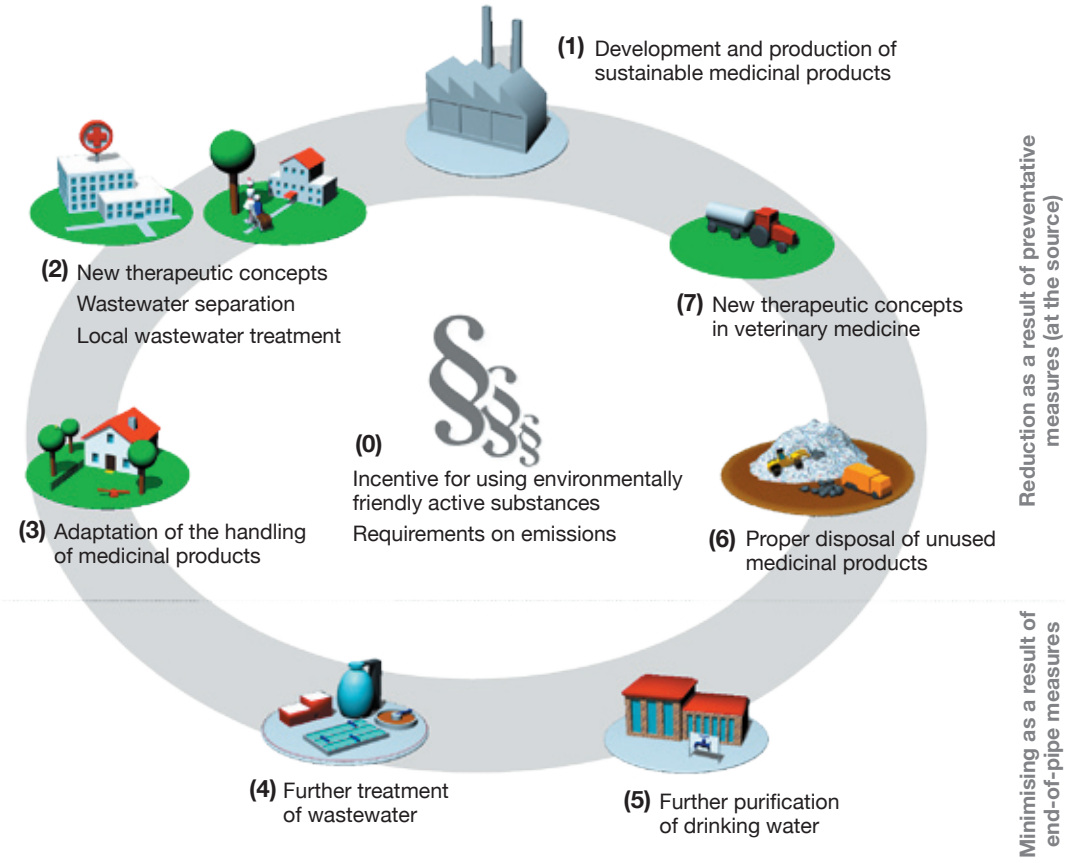
But this does not mean that in the future – with further advances in chemical analysis technology – it will be possible to analyse them. It is therefore also a scientific task to find out which concentration of the relevant substances is harmless to humans and environment.

this objective, greater efforts to identify the environmental relevance of the substances concerned are necessary, so that it can be defined to what extent the substance can be classified as “harmless”.

In the further course of the PILLS project, it will show to what extent advanced wastewater treatment methods can contribute to eliminating pharmaceutical residues without causing increased “ecological costs” in another area. At present this cannot be evaluated – further investigation and above all, further trials are still necessary in this area. Additional experience in small-scale and full-scale plants is required to be able to assess this approach comprehensively. The PILLS project supplies a building block for this.

It is, however, undisputed, that wastewater treatment is not able to reduce the burden to the environment sustainably. Once these micropollutants have reached the wastewater, their complete elimination is

Measures to reduce pharmaceutical substances in the aquatic environment



Source: PILLS project

hardly reasonable – even if, in many cases, a low enough concentration is achieved so that their appearance is below the detection limit, or they have no (measurable) effects. This is the reason why an integrative strategy is necessary, that takes into account the entire life-cycle of the substances examined, from the production, to the points of use, to the disposal.

Possible measures to minimise pharmaceutical residues at the source:

- Legislative body (0): The creation of incentives which promote the use of more environmentally friendly substances in the manufacture of medicinal products. Establishing a framework for the emissions of pharmaceutical substances.
- Pharmaceutical industry (1): Taking into consideration the possible environmental effects of individual active substances already in their development and performing targeted research in this field.
- Health professionals (2): Further training for health professionals concerning the long-term change of prescription practice so that overall, fewer or – where possible – "more environmentally friendly" medication is used.
- Private households (3): A change in how individuals deal with medicines

»Luxembourg is situated on the water divide between the Meuse and the Rhine and apart from the Moselle River only has small mountain streams. In our country there is a long tradition of cross-border cooperation on water protection since we are very aware that the challenges of water supply and distribution do not stop at borders. Therefore, Luxembourg actively participates in several working groups on the level of international river basins such as the working group on micropollutants of the International Commission for the Protection of the Rhine. In this context, the cooperation in a European initiative such as the PILLS project is important for us as European collaboration on this topic is indispensable. We hope to obtain new findings through this that may be of benefit for the development of our own national water protection strategy.«

Dr André Weidenhaupt, Administration de la gestion de l'eau, Luxembourg

- Agriculture (7): A more environmentally friendly use of medication in animal husbandry and in veterinary medicine, to minimise the emission of pharmaceutical residues via manure.

End-of-pipe measures to minimise pharmaceutical residues:

- Medical centres, hospitals and nursing homes – so-called point sources (2): Wastewater separation and local treatment of the wastewater where high concentrations of pharmaceutical residues are encountered.
- Wastewater management companies (4) and drinking water providers (5): Advanced wastewater treatment and improved drinking water purification to eliminate residues.

Individual measures to protect the environment

There are measures that each individual can adopt in order to help with the protection of our water system without reducing their quality of life.

Correctly dispose of medicinal products

In principle medication, whether in tablet form or as a liquid, must NOT be disposed of via the toilet or the sink! Medicines disposed of in this way will reach the municipal wastewater treatment plants, which are generally not equipped to eliminate them. In many regions, disposal of residual waste bins takes place by incineration, where the combustion process removes persistent substances. If this is the case, medication can be put in the residual waste. If the disposal route of the residual waste is not known, leftover medicines should be handed back to the pharmacies, who will ensure that these are disposed of appropriately.

Purchase medicinal products with awareness

Medicinal products cannot be returned and have only a limited shelf-life. In many cases unused drugs have to be disposed of, since they have not been completely used or have already expired. To prevent this, consideration should be given before purchasing, as to what quantity of the medication is actually needed and in the case of doubt, a smaller pack size should be purchased.

In some cases, several preparations containing different active substances are avail-

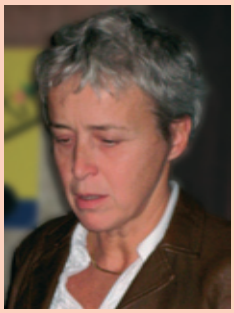
able for the treatment of an illness. In this case, consultation with a doctor or pharmacist is sensible, because if both active substances can be used to treat the illness with equal effects, a decision in favour of the more "environmentally friendly" substance can be made.

Store medicinal products correctly and safely

Medication should be stored correctly – which means dry, protected from light and if appropriate, in a cool place – as well as safely, so that unauthorised people and in particular children, cannot access these products. This avoids incorrectly stored or opened preparations having to be disposed of, even though they have not been used.

Take medicinal products with awareness

Often, we are so used to taking medication – although they have not actually been prescripted by a doctor – that we no longer ask ourselves if taking it is necessary. A conscious decision for or against the use of a medicine can lead to the reduction in the consumption of medication. But attention: all medication which has been prescribed by a doctor should be taken for the period being indicated!



«Pharmaceutical residues in the water system is an issue of interest for decision makers in France: A 5-year action plan to reduce pharmaceuticals in waters will be published by the end of 2010 in France. Research will be enhanced in the assessment of environmental and health risks in relation with the presence of residues. At the same time we implement preventive measures in order to decrease the pollutant releases at the source. Refering to these objectives the PILLS project has come at the right time – so we can compare our national findings with those of European partners and evaluate them in a larger context.»

Chantal Gatignol, Ministère de la Santé et des Sports, France

Technical data of the plants

	Full-scale plants		Small-scale plants	
	Emschergenossenschaft	**Waterschap Groot Salland**	**Eawag**	**Centre de Recherche Public Henri Tudor**
Average inflow per day	200 m^3	200 m^3	1.2 m^3	1 – 3 m^3
Design flow per hour	25 m^3	10 m^3	0.125 m^3	0.125 m^3
Mechanical pre-treatment	Yes	Yes	Yes	Yes
Coarse screening	2 mm	6 mm	4 mm	2 mm
Fine screening	-	0.5 mm	-	-
Biological treatment	200 m^3 membrane bioreactor	200 m^3 membrane bioreactor	Membrane bioreactor	Membrane bioreactor
Hydraulic retention period	> 6 hours	> 6 hours	20 hours	
Sludge concentration per litre	10 – 12 g	8 – 12 g	2 g	
Advanced treatment	Yes	Yes	Yes	Yes
Filtration	-	-	-	Reversed osmosis
Adsorption	Powdered activated carbon	Granulated activated carbon	Powdered activated carbon	-
Chemical oxidation	Ozone	Ozone	Ozone	Ozone
			Photocatalysis	Ultraviolet radiation/ hydrogen peroxide
Post-treatment	Yes	Yes	Yes	No
	Sand filtration	Granulated activated carbon	Moving bed bioreactor	
		Ultraviolet radiation / hydrogen peroxide		
Exhaust air treatment	Yes	Yes	Yes	No
	Sound protection hoods	filtration	Granular activated carbon	
	Supply and discharge air links	UV radiation		
	Encapsulation and solid construction	Catalytic oxidation		
	Discharged air treatment plant (e.g. photoionisation)	Ionisation		
Discharge of the treated water	Water body	Public sewage network	Public sewage network	Public sewage network
Duration of the installation	Permanent from 2011	Permanent from the end of 2010	1 year (April 2009 – March 2010)	1 year (April 2010 – March 2011)

Substances that are measured by all partners of the PILLS project

Type of medication	Specific active substance
Analgesics / anti-inflammatories	Diclofenac Naproxen
Anesthetics	Lidocaine
Cytostatics	Cyclophosphamide Ifosfamide
Antibacterials	Amoxicillin Ciprofloxacin Clarithromycin Erythromycin Sulfamethoxazole
metabolite of antibacterial	Acetyl-sulfamethoxazole
X-ray contrast media	Diatrizoate Iopamidol Iopromide
Anticonvulsants / tranquillisers	Carbamazepine
Lipid regulators	Bezafibrate
Betablockers / anti-hypertensives	Atenolol

Tests being used for the characterisation of wastewater

Microbiological tests	General effect based tests
E. Coli	Bioluminescent bacteria test
Intestinal enterococci	Algae photosynthesis test
Antibiotic resistance	

Publisher:
Emschergenossenschaft
on behalf of the PILLS project
Kronprinzenstraße 24
45128 Essen
Germany

Editors:
The PILLS partnership
Responsible: Eva Böhling
Emschergenossenschaft
Kronprinzenstraße 24
45128 Essen
Germany

Layout:
konzept:gelb
Büro für Gebrauchsgrafik
www.konzeptgelb.de

Published in November 2010

Photo credits
Page 4: Frog jumping in the water © Waterschap Groot Salland; **Page 5:** Waterfall © Emschergenossenschaft; **Page 7:** PILLS partner discussion round © Emschergenossenschaft 2008; **Page 8:** PILLS partners © Emschergenossenschaft 2008; **Page 9:** Dr Jochen Stemplewski © Emschergenossenschaft; **Page 10:** Laboratory technician analyzing samples © Emschergenossenschaft; **Page 11:** Jan Oggel © Emschergenossenschaft; **Page 12:** Advanced wastewater Treatment at the Waterschap Groot Salland © Waterschap Groot Salland 2010; **Page 13:** Advanced wastewater Treatment at the Centre de Recherche Public Henri Tudor © Centre de Recherche Public Henri Tudor 2010; **Page 14:** Andreas Eggmann © Andreas Eggmann; Advanced wastewater Treatment at the Centre de Recherche Public Henri Tudor © Centre de Recherche Public Henri Tudor 2010; **Page 15:** PILLS partners' Working Group © Emschergenossenschaft 2010; **Page 16:** Andrew Rawlins © Andrew Rawlins; Results are discussed in the laboratory of Eawag © Eawag, Annual Report 2009; **Page 17:** Water course © Emschergenossenschaft; **Page 18:** Wastewater treatment plant of Emschergenossenschaft © Emschergenossenschaft; **Page 19:** Dr André Weidenhaupt © Administration de la gestion de l'eau, Luxembourg; Different Pharmaceutical Products © Emschergenossenschaft; **Page 20:** Water jet © Emschergenossenschaft; **Page 21:** Chantal Gatignol © Emschergenossenschaft 2010

Lead Partner
Emschergenossenschaft
Eva Böhling, Kirsten Adamczak
Kronprinzenstraße 24
45128 Essen, Germany
Phone: 0049 - 201 104 2606 / 2679
E-mail: boehling.eva@eglv.de /
adamczak.kirsten@eglv.de

Germany
Emschergenossenschaft
Dr Issa Nafo
Kronprinzenstraße 24
45128 Essen
Phone: 0049 - 201 104 2779
E-mail: nafo.issa@eglv.de

The Netherlands
Waterschap Groot Salland
Dr ir. Herman Evenblij
Dr. Van Thienenweg 1
8025 AL Zwolle
Phone: 0031 - 38 455 7431
E-mail: hevenblij@wgs.nl

Luxembourg
CRP Henri Tudor
Dr Alex Cornelissen
Schlassgoart 66, rue de Luxembourg
4002 Esch-sur-Alzette
Phone: 00352 - 545580 519
E-mail: alex.cornelissen@tudor.lu

Switzerland
Eawag
Dr Christa McArdell
Ueberlandstraße 133
8600 Duebendorf
Phone: 0041 - 44 823 54 83
E-mail: christa.mcardell@eawag.ch

United Kingdom / Scotland
Glasgow Caledonian University
Dr Ole Pahl
Cowcaddens Road
Glasgow G4 0BA
Phone: 0044 - 141 331 3572
E-mail: O.Pahl@gcal.ac.uk

France
Université de Limoges
Prof. Dr Christophe Dagot
33, rue François Mitterand
87032 Limoges
Phone: 0033 - 555 423 697
E-mail: dagot@ensil.unilim.fr

Scientific Board

Mark Heggie (Scottish Environment Protection Agency, United Kingdom)

Dr Florian Keil (prev.: Institute for Social-Ecological Research ISOE GmbH, Germany)

Dr Thomas Schwartz (Karlsruhe Institute of Technology, Germany)

Dr Steger-Hartmann (Bayer Schering Pharma AG, Germany)

Prof. Dr Pim de Voogt (IBED, University of Amsterdam, The Netherlands)

Dr Luc Zwank (Administration de la Gestion de l'Eau, Luxembourg)