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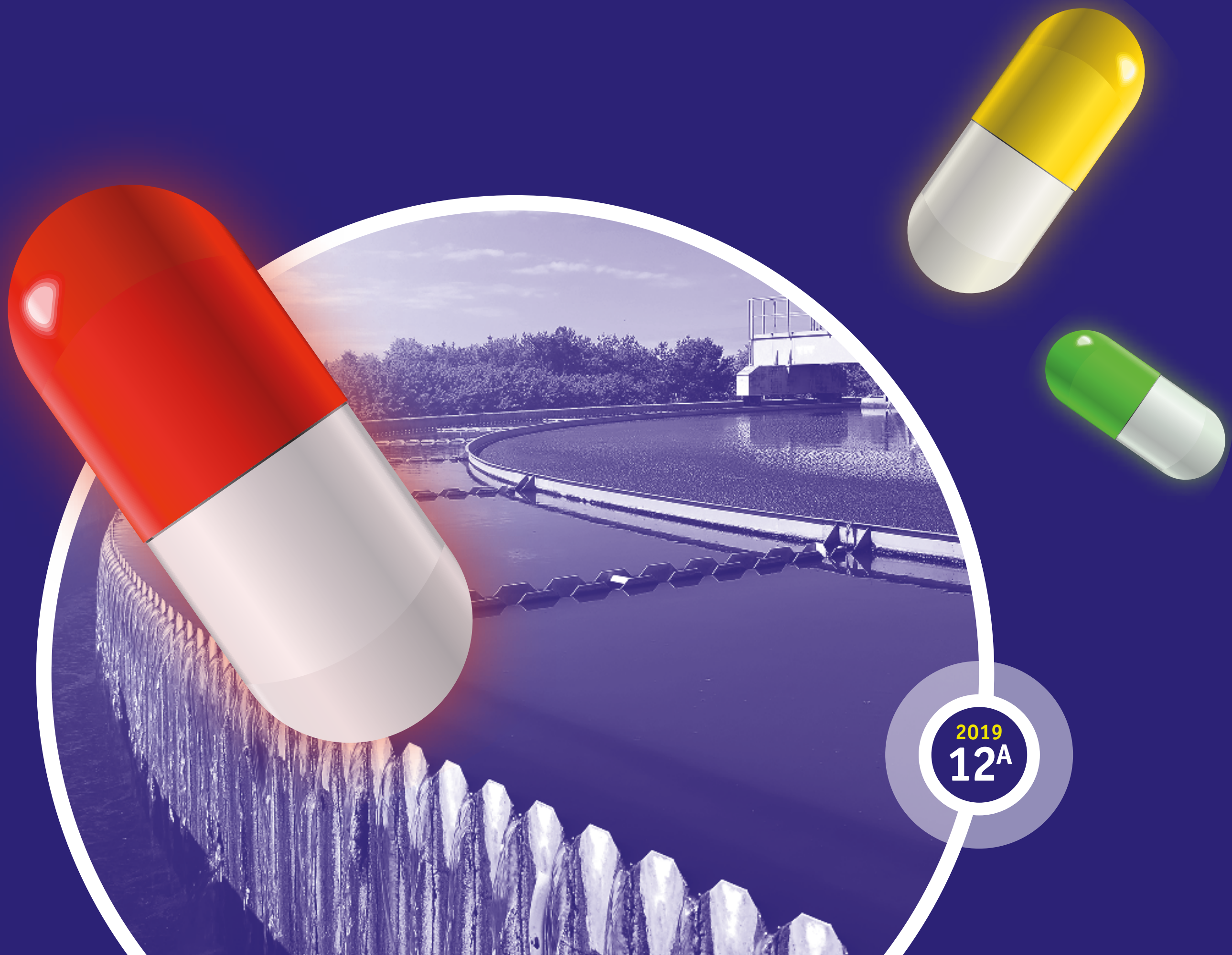
Ministry of Infrastructure
and Water Management

INNOVATION PROGRAM REMOVAL OF MICROPOLLUTANTS AT WWTPS



2019

12A

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FOREWORD

Collaboration speeds up the application of innovations in Dutch wastewater treatment practice.

This joint innovation program of the Regional Water Authorities, the Ministry of Infrastructure and Water Management and STOWA aims to further develop technologies and techniques for the removal of micropollutants, including medicine residues, from wastewater treatment plants (wwtps). These are technologies and techniques that are on the verge of breaking through, but are insufficiently proven to be directly applicable on a large scale in wwtps in the Netherlands. This will lead to a better understanding of operating mechanisms and dimensioning principles, thereby reducing the risks when putting technology into practice. The program thus accelerates the application of innovations in Dutch municipal wastewater treatment practice.

This innovation program fits in well with the contribution scheme 'demos zuivering medicijnenresten' ('demonstration installations removal of medicine residues') from the Ministry of Infrastructure and Water Management and the developments of the regional water authorities with regard to the introduction of additional treatment steps for wwtps in demonstration installations using existing available techniques for the removal of medicine residues.

An important aspect of this program is knowledge sharing. Under the motto of 'Learning by Implementation', knowledge and experience from this program and those from the parallel program with the demonstration installations are shared as it becomes available so that it can be applied as quickly as possible in the wastewater treatment practice of the regional water authorities.

In this innovation program, central government, regional water authorities, knowledge institutions, drinking water companies and businesses work together to remove medicine residues and a wide range of other micropollutants from wwtp wastewater and thereby further improve the water quality in the Netherlands.

This report provides an overview of the various research routes. Important points of attention in the research are the removal efficiency, the costs and sustainability aspects. The first results of the various feasibility studies are expected early 2020.

IR. JOOST BUNTSMA
Director STOWA

INTRODUCTION

Since 2016, the Ministry of Infrastructure and Water Management has been working with a large number of parties on the chain approach to 'Medicijnenresten *uit* Water' ('Medicine Residues *Removal* from Water') in order to reduce the emissions of medicine residues into surface water and their negative effects on the water environment and the production of good drinking water. The chain approach has mapped the route, brought the parties in health care and the water branch together, analysed which emission-reducing measures are possible and how effective these measures are. This has resulted in an Implementation Program 2018-2022, which describes the objectives and long-term activities in all areas of the chain; from source approach at the front, such as with medication use in the health care sector and by patients, and at the end by extensive removal of medicine residues and other micropollutants in a wastewater treatment plant (wwtp). The aim is to work together with all parties involved and, by means of learning by implementing, to always take those steps that have the greatest positive effect on water quality and drinking water production at socially acceptable costs. This has led to the 'Medicine Residues *Removal* from Water' approach being one of the four spearheads of the Green Deal Sustainable Health Care, which the Ministry of Health, Welfare and Sport has signed with approximately 130 parties in the health care sector. These measures at the front of the chain, however, remain necessary, but they will not be able to solve the problem since the vast majority of emissions from households end up in surface water via the wwtps.

In order to achieve a substantial reduction in emissions, additional removal of medicine residues through extensive treatment at a wwtp is essential. Other micropollutants can also be removed depending on the properties of the substance and the chosen treatment technique. In a national hotspot analysis 'Medicijnenresten in Oppervlaktewater (STOWA 2017-42)', the regional water authorities have identified the wwtps which have a relatively large influence and contribution to the concentrations of medicine residues in surface water (as a sum parameter), for both receiving waters and downstream waters and also inlet points for drinking water production. Following on from this, a further refinement took place by the regional water authorities by carrying out a further regional analysis of the results of this national hotspot analysis. For example, a further analysis was carried out for the River Meuse catchment area within the 'Schoon Maaswaterketen' ('Clean River Meuse Water Chain') partnership, whereby the regional water authorities have, among other things, assigned value to regional waters.

In Germany and Switzerland, the topic of medicine residues/micropollutants in surface water is also being addressed by policy makers and water managers. Much research is carried out into, among others, extensive treatment techniques and the knowledge/experience is shared with third parties in so-called 'Kompetenzzentra'. This research and practical applications at wwtps has shown that oxidation through the use of ozone and/or adsorptive techniques through the use of activated carbon can remove medicine residues and a wide spectrum of other micropollutants from wwtp wastewater efficiently and at socially acceptable costs. There are various forms of technology for this which will be developed further for (specific) applications in the treatment processes at wwtps. Until now, limited experience has been gained in the Netherlands with these extensive treatment techniques for municipal wastewater from wwtps[1]. Various techniques have been tested in a number of lab studies and pilots, such as i) powdered activated carbon dosing to activated sludge systems (PACAS), ii] ozone oxidation with sand filtration, iii] ion exchange and UV H_2O_2 oxidation, iv] ozone oxidation with ceramic membrane filtration, v] ozone oxidation with granular activated carbon filtration and vi] comparison of ozone with UV/H_2O_2 oxidation.

In addition, STOWA has listed the various extensive treatment techniques in an exploratory report (STOWA 2017-36). A distinction has been made here, among other things, in treatment techniques or combinations of techniques that are directly applicable within existing treatment practice for wwtps and some promising short-term (5-7 year period) applicable removal techniques for medicine residues from wwtp wastewater. This report looked not only at the effectiveness of the removal of medicine residues and the associated costs, but also at aspects such as sustainability, energy consumption, residual products, use of chemicals and bycatch of, for example, other micropollutants. Knowledge gaps, development of innovative concepts and optimization of extensive treatment techniques, which could be applicable in the short term, have all been given a place in the present innovation program 'Micropollutants *Removal* from Municipal Wastewater' from the Ministry of Infrastructure and Water Management and STOWA for the period 2019-2023. The focus of this program is on applied research into treatment techniques for the removal of micropollutants, including medicine residues, that can be applied within a period of 5-7 years in Dutch wwtps. In addition, the techniques must have added value compared to the existing available techniques, such as a better treatment efficiency, lower costs, more sustainable or a reduction of the ecotoxicological risks of the wwtp discharge into the aquatic environment. Project proposals vary from exploratory or feasibility studies to practical pilots at wwtps. This in contrast to the contribution scheme 'Zuivering Medicijnenresten' from the Ministry of Infrastructure and Water Management, in which regional water authorities are financially supported in both constructing and the actual commissioning of large-scale demonstration installations for extensive treatment techniques at wwtps for a minimum of ten years. In these demonstration installations, the effectiveness of the applied technology will be monitored on the basis of a few guide substances and the remaining ecotoxicological risks of the wwtp discharge. Research of a more fundamental scientific nature has been taken up in the University research program 'Contaminants of Emerging Concern in the Water Cycle', in which STW, STOWA, TKI Water Technology and KWR work together.

1 *In the drinking water sector there is ample experience with the application of processes for extensive removal of micropollutants; translating this experience is proving difficult without further research in lab studies and (large-scale) pilots because wwtp effluent has a different composition than the sources used for drinking water production such as groundwater and surface water.*

TARGET

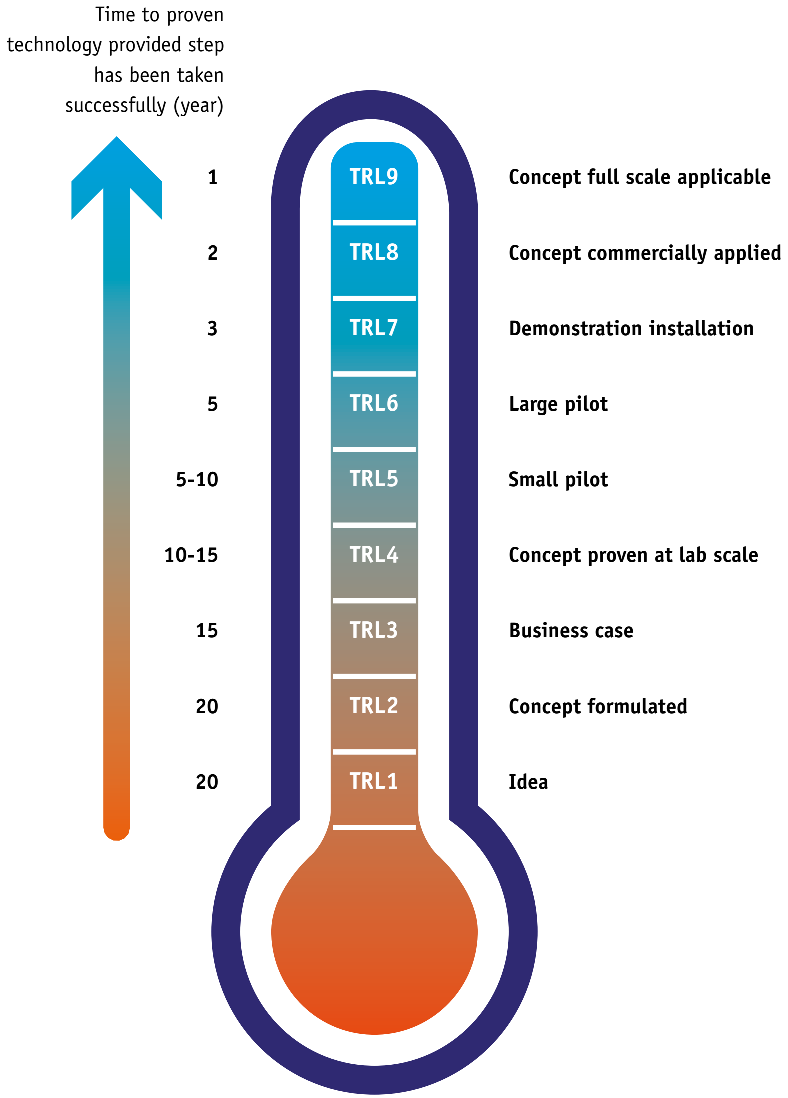
The aim of this program is to investigate technologies and techniques for the removal of micro-contaminants from wwtp wastewater, these are on the verge of breaking through but have not been sufficiently proven to be directly applicable on a large scale at wwtps in the Netherlands. This is because there are many uncertainties about the performance of the technology such as removal efficiencies, costs and CO_2 footprint. Similarly, it is not known whether the technique can be properly integrated into Dutch wwtps and what effects may occur in the operational management and treatment process of the wwtp. Along with that, it concerns the influence on the quality of the effluent (the permitted macro parameters such as organic matter, nitrogen, phosphate and discharge of suspended solids) also the influence on sludge composition and processing and necessary maintenance. This means that for the contribution from the Ministry of I and W for demos for (Zuivering Medicijnenresten), primarily projects will be submitted using techniques that, on the basis of full-scale results abroad, can be 'safely' implemented where it is expected to represent only a limited risk to the operation of wwtps in The Netherlands as well as having a proven removal efficiency of micropollutants.

This program aims to stimulate innovations. If an innovation is promising for practical application in the next 5-7 years, the regional water authorities that want to explore this technique or test it on a pilot scale will be financially supported by this program. This will lead to more insight into operating mechanisms and dimensioning principles, which reduces the risks of using the technology on a demonstration installation scale. The program thus accelerates the application of innovations in Dutch wastewater treatment.

An important aspect of this program is knowledge sharing. Much can be researched, but if the knowledge and experience is not actively shared, no new technologies will break through. Under the motto of 'Learning by Implementation', knowledge and expertise will be constantly shared in this program as soon as it becomes available, so that it can be applied as quickly as possible in wastewater treatment. To this end, a users' network will be set up, whereby the knowledge and experiences from the studies, both from this innovation program and from the demonstration installations, are brought together with the actual wastewater treatment practice.

Based on the (interim) results of this program (and the results from the demonstration installations), regional water authorities can make policy choices for the realization of more effective and efficient technologies than the current commercially available proven techniques that lead to a reduction of micropollutant discharges from wwtps and thus an improvement in water quality.

FIGURE 1 *Technology Readiness Levels*



DESCRIPTION OF ACTIVITIES

In this program, techniques will be researched that can provide a significant improvement over current proven techniques for the removal of micropollutants from wwtp wastewater in one of the following aspects:

- CO_2 footprint;
- Costs;
- Removal of micropollutants, including the guide substances[2] from the Ministry of I and W contribution scheme for demonstration installations;
- Reduction of ecotoxicological risks in the discharge of wwtp effluent into the aquatic environment.

In addition to the points mentioned above, it will be made clear what influence the application of technology has on the operation of the treatment process, the operational management and the maintenance of the wwtp. Robustness, complexity and aspects of working conditions and safety will be brought into focus.

This program centres on the removal of micropollutants and the effect of the discharge of these and other emerging substances from wastewater treatment plants into the aquatic environment. In addition, attention is paid to possible bycatch, such as an improvement in the removal of nitrogen, phosphate and microplastics, and a reduction in antimicrobial resistance and pathogens.

Priority themes

As a follow-up to the STOWA exploratory report, from which promising techniques have emerged for the removal of medicine residues from sewage, an inventory was made in 2018 of the knowledge needs of the regional water authorities. It was determined which techniques and technologies have potential and which have priority to be investigated because of policy strategies and on the request of experts at regional water authorities The focus here was on improving the CO_2 footprint, costs, removal efficiency of micropollutants and/or effect on the ecotoxicology of the wwtp effluent.

In addition to an improvement on the previous aspects, the following aspects have been assessed in this inventory:

- The technique/technology can be used in Dutch wastewater treatment.
- The technique/technology can be applied on a demonstration installation-scale within 5-7 years. This means that the TRL (Technology Readiness Level) of the technology/technology within 5-7 years, in 2025, must have a value of at least 7 (*see Figure 1*). In this innovation program, a demonstration installation-scale is understood to mean: a full-scale application for wwtps smaller than approximately 25,000, i.e. (inhabitant equivalents). For treatment plants larger than

2 *Benzotriazole, clarithromycin, carbamazepine, diclofenac, metoprolol, hydrochlorothiazide, mixture of 4- and 5-methylbenzotriazole, propranolol, sotalol, sulfamethoxazole, trimethoprim.*

approximately 25,000 i.e. at least one process stream equal to, or larger than, 25,000 i.e. must be adapted to meet this purpose.

This inventory has led to the following topics that will be addressed in this program in the short term:

1

EFFECTS OF THE USE OF OXIDATIVE TECHNIQUES AND IMPROVEMENT OF EFFECTIVENESS/EFFICIENCY

There is a range of oxidative techniques for converting micropollutants in wwtp wastewater into other less harmful substances. To date, ozonation of wwtp effluent in combination with sand filtration has been widely used abroad and therefore is a 'proven technique'. In addition to ozone, however, other technologies can also be applied, such as UV and hydrogen peroxide, whether or not in combination with ozone. The use of oxidative techniques can lead to so-called transformation products, which from an ecotoxicological point of view can be more harmful than the so-called parent substance which is present in sewage. An example of this is the conversion of bromide to persistent bromate by ozone. The mechanisms under which this takes place and to what extent this determines the choice of an oxidative technique are still insufficiently clear. Recent studies show that post-treatment sand filtration used abroad does not remove these transformation products which have formed. Foreign studies do not provide a definitive answer to the application of these techniques to Dutch sewage. In the pilot study the 'Zoetwaterfabriek' ('Fresh Water Factory') at the wwtp De Groote Lucht into the ozonation of wwtp effluent, no satisfactory answers were found either, due to the limited number of effective measurements. There is also no conclusive explanation for whether or not bromate is formed. This theme investigates the effects of using oxidative techniques such as ozone, UV and other oxidative techniques on the ecotoxicity of the treated wwtp effluent and whether the effectiveness and efficiency can be improved.

2

EFFECTS OF THE USE OF POWDERED ACTIVATED CARBON (PAC) AND IMPROVEMENT OF EFFECTIVENESS/EFFICIENCY

In Germany and Switzerland, PAC has already been used at more than 20 wwtps at full scale to extensively remove micropollutants from wastewater from wwtps. This technique is mainly used as a so-called 'post treatment': the PAC is dosed into newly built tanks or converted tanks, where it is mixed with wwtp effluent. The micropollutants adsorb to the PAC and are discharged in the separated PAC. Nowadays there are more initiatives to integrate PAC into the current processes of a wwtp. One of the applications has been tested at full scale at the Papendrecht wwtp in the so-called PACAS study, where PAC was dosed directly into the activated sludge system of the wwtp. Good results were achieved: the removal of micro-contaminants doubled and the ecotoxicity of the wwtp effluent was reduced by half. The effluent quality for macro parameters such as nitrogen, phosphate and organic matter did not deteriorate. This success opens up possibilities for dosing in other ways and locations in the treatment process. This theme focuses on improving the effectiveness and efficient application of PAC at wwtps. Naturally, attention is also paid to the effects on effluent quality and the operation of wwtps (including effects of

PAC on effluent and final sludge processing). PAC is a fossil product and the use of this at sewage treatment plants results in additional CO_2 emissions compared to the current treatment of sewage. Theme 4 investigates how this CO_2 footprint can be reduced by using more sustainable carbons or other adsorbents

3

EFFECTS OF THE USE OF GRANULAR ACTIVATED CARBON (GAC) AND IMPROVEMENT OF EFFECTIVENESS/ EFFICIENCY

Granular Activated Carbon, unlike Powdered Activated Carbon consists of granules. In a post-treatment filter, these granules ensure the adsorption of micro-contaminants the same as with PAC but also the growth of bacteria so that macro-contaminants such as phosphate and nitrogen can also be removed. In the Netherlands a full scale GAC filter has been built at the Horstermeer wwtp, which can simultaneously remove nutrients such as phosphate and nitrogen as well as micropollutants (the 1-STEP filter). The full-scale results show, however, that the retention time to remove micro-contaminants from the filter is very short and although radical nutrients are still being removed, the removal of micro-contaminants decreases considerably after 3 months. This makes the technology relatively expensive. However, there are new technologies on the market that ensure that GAC can be used more effectively. This technique is not widely used in Germany and Switzerland so far because of the higher costs, but it is unknown what the risks surrounding the possible formation of unknown transformation products (oxidative techniques, *see theme 1*) or discharge of carbon powder particles (powdered activated carbon dosage, see theme 2). Research into increasing the efficiency and effectiveness of this technique will therefore be further investigated in this theme.

4

EFFECTS OF THE USE OF MORE SUSTAINABLE ADSORBENTS AND IMPROVEMENT OF EFFECTIVENESS/ EFFICIENCY

Adsorption of micropollutants by activated carbon is now being used full-scale and extensively abroad. However, the activated carbon used is largely of fossil origin (coal). To date there have been some initiatives to develop so-called ‘sustainable carbon’ by the suppliers, but this is still very limited. To achieve breakthroughs in this theme, adsorbents are being tested with a lower CO_2 footprint than the current fossil carbon.

5

EFFECTS OF USING FILTRATION AND IMPROVING EFFECTIVENESS/EFFICIENCY

Nanofiltration of effluent appears promising for extensive removal of micro-contaminants from wwtp effluent (> 90%). However, the treatment of the separated fraction containing the micropollutants is still unclear. New concepts are currently being developed for this, which may perhaps be easily integrated into current wwtps as a post-treatment step. In addition, concepts for water factories are being developed aimed at the highest possible reuse of raw materials that are contained in sewage and/or reuse of the effluent produced. In these so-called ‘water factories’, filtration is used in combination with adsorption and oxidation. This combination of tech-

WWTP De Groote Lucht

niques is known from drinking water production. Treating sewage and effluent from wwtps appears to be difficult without further investigation in lab studies and (large-scale) pilots, because wwtp effluent has a completely different composition to the sources used for drinking water production such as groundwater and surface water. However, lab studies have shown that it is feasible to extensively remove up to more than 95-99% of micropollutants from effluent from wwtps. This requires combinations of techniques such as oxidation, coagulation, filtration and adsorption. Given the high removal efficiency of filtration techniques, it is interesting to see how these techniques can be integrated into existing wwtps.

From 2019 the above themes will be taken up in various projects in the program. These projects are shown in annex 1. In 2020, a new inventory will be made based on the knowledge requirements of the regional water authorities in order to recalibrate the themes.

Approach

The projects that fall under the various themes are worked out in project plans. This elaboration usually involves the process technologists of the wwtps of the regional water authorities. This guarantees the link between practice and research. A distinction will be made in the project plans between the feasibility phase and the follow-up phases. The submitting parties (regional water authorities often supported by market parties, drinking water companies and knowledge institutes) must demonstrate by means of a feasibility study that the technology to be tested provides added value compared to the current proven extensive treatment techniques PACAS, ozonation combined with a sand filter and Granular Active Carbon filtration, which will be used as a reference. The assessment of whether this is actually the case takes place on the basis of transparent and clearly formulated criteria in the field of CO_2 footprint, costs and removal efficiency of micropollutants submitted beforehand (*see Table 1*). In addition, it must be demonstrated that the technique can be integrated into Dutch wastewater treatment practice, achieve a 50% reduction in the ecotoxicity of wwtp effluent and achieve a TRL higher than or equal to 7 in 2025.

For a number of projects, it is known that suppliers have already conducted literature research, lab analyses and/or small pilots, whether or not in collaboration with regional water authorities. For these projects, a full feasibility study is not required, but will have to be substantiated that criteria are met.

The projects are divided into the following categories, for which different maximum contributions from central government apply:

- Exploration/feasibility study: € 25,000 - € 50,000;
- Exploration/feasibility study including lab study: max € 75,000;
- Simple pilot (testing one technique/technology): max € 250,000;
- Complex pilot, including the water factories (testing several techniques/technologies): max € 300,000.

The maximum amounts apply to the entire project, including the feasibility study phase. Projects are funded by businesses, regional water authorities and STOWA.

TABLE 1 *Quantitative criteria Innovation Program Removal of Micropollutants at wwtps*

	Unit	PACAS	Ozone+sand filter	GAC
CO_2 footprint	g CO_2/m^3 (1	116	119	325
Costs	€/m^3 (1	0.05	0.17	0.26
Removal efficiency guide substances Ministry of Infrastructure and Water Management	% (2	70-75%	80-85%	80-85%

(1 *Per m^3 treated wastewater*

(2 *Removal efficiency for at least 7 of the 11 guide substances benzotriazole, clarithromycin, carbamazepine, diclofenac, metoprolol, hydrochlorothiazide, a mixture of 4- and 5-methylbenzotriazole, propranolol, sotalol, sulfamethoxazole, trimethoprim in every 24-hour or 48-hour flow rate or time-proportional sample, taking into account the residence time of the water in the wwtp. These 11 guide substances are chosen to monitor the effectiveness of a treatment technique for additional removal of micropollutants from wwtp effluent and have no relationship with any environmental hazard.*

ORGANIZATION

The project plans were set up in detail and in a definite form at the beginning of 2019 and will deliver tangible intermediates at the end of 2019 (feasibility studies and substantiation that the predetermined criteria are met). At the beginning of 2020, project plans will be elaborated further for the follow-up phases based on the insights gained in the feasibility phase and feedback from the assessment.

Consultancy firms and other knowledge partners are involved in the implementation of the projects in order to bundle current knowledge as effectively as possible and to apply it in practice. Consortia consisting of consultancy firms, knowledge institutes and drinking water companies have already been formed for various projects.

KNOWLEDGE SHARING

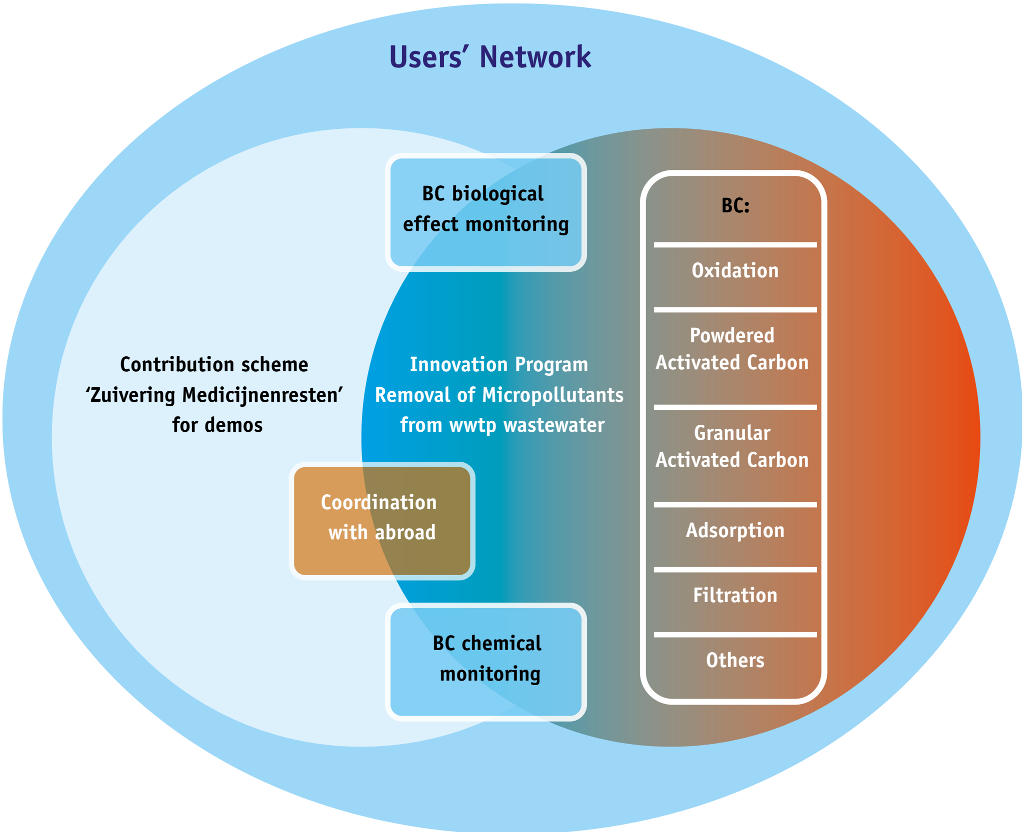
Knowledge sharing is essential in this program. In particular, timely knowledge sharing, so that water authorities can draw up and adjust a micro-contaminant removal strategy based on the latest results in time. The latter sometimes conflicts with preliminary results that are not suitable for publication, so that results sometimes only become available years after the research. To ensure that this runs smoothly, STOWA will set up a network organization (*Figure 2*). In addition to public knowledge sharing, this network will share information and knowledge in closed meetings and in confidence. Knowledge and experience from this program and the results that result from operating full-scale installations that fall under the 'Zuivering Medicijnenresten' contribution scheme for the demonstration installations are combined in this network.

The progress of the development of a robust sampling and analysis method for determining the treatment efficiency based on the guide substances and the development of an effect-oriented assessment of wwtp effluent on the basis of bioassays is also shared in the network via the relevant BCs (Advisory Committees).

Another point of attention within this program is the sharing of knowledge and coordination of results and experiences with our neighbouring countries. For each project, specific attention will be paid to this by including results from abroad in the feasibility phases and then, if it is decided to continue, coordinating results in the pilot phases. This coordination will be promoted and facilitated by establishing contacts with the various 'Kompetenz' centres in Germany and Switzerland and our water partners in Belgium, the United Kingdom and France.

Reference is made to *figure 3* for the organization.

FIGURE 2 *Users' network knowledge sharing with users active in the Innovation Program Removal of Micropollutants from wwtp wastewater. The Contribution scheme 'Zuivering Medicijnenresten' for demos, BC chemical monitoring, BC biological effect monitoring and coordination with abroad.*



EXPLANATION OF FIGURE 3

Advisory committees themes

An advisory committee (BC) is set up for each theme, with the participation of regional water authorities, drinking water companies and the business community, in order to ensure correct alignment with practice. The results are discussed in these BCs. The BC is responsible for a robust end product per phase. The BC gives advice for a go or no go for a follow-up phase to the advisory committee of this innovation program

Advisory Committee Innovation Program

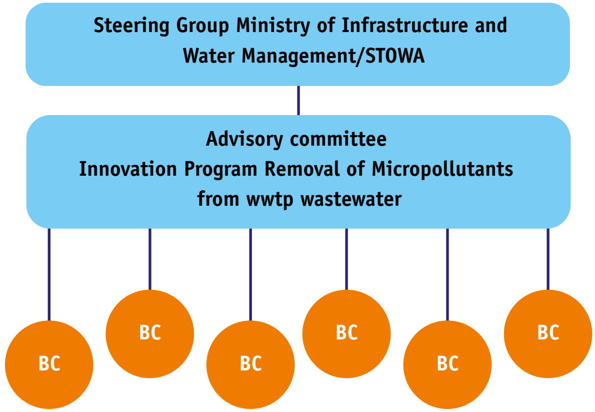
This committee consists of representatives from regional water authorities and central government, it oversees the overall quality assurance of the innovation program. Go/no go moments are submitted to this committee for decision. This committee advises the steering group on allocating funds from the innovation program.

Steering Group

The Ministry of Infrastructure and Water Management and STOWA discuss the results, progress and allocation of funds from the innovation program in this steering group. For this purpose, STOWA annually submits information on the progress and findings of the past year and the project plans for the coming year.

STOWA takes on the program secretariat and organizes knowledge sharing between projects and with the outside world. STOWA also makes its meeting centre available for all projects.

FIGURE 3 *Organization structure*

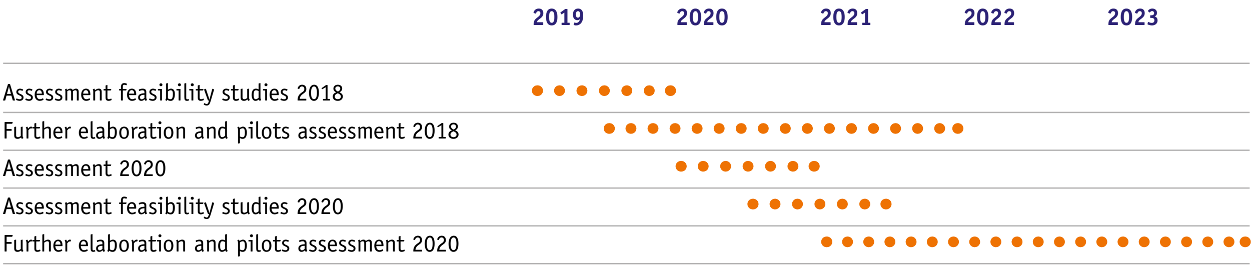


SCHEDULE

The end result of this program will be delivered in 2023.

As indicated on *page 8*, following the exploration of promising techniques for the removal of micro-pollutants from wwtp wastewater, an inventory was carried out under regional water authorities in 2018 on which the current program is based. A second inventory will be made in 2020. The schedule for the program is shown in *figure 4*.

FIGURE 4 *Planning*



APPENDIX 1: PROJECT OVERVIEW 2019

THEME OXIDATIVE TECHNIQUES

- Ultra sound technology to optimize energy consumption and costs of ozonation of wwtp effluent
- PAC4TOC: Reduction of organically bound carbon content, so that post-treatment technologies can be optimized in terms of costs and energy consumption
- Comparison of treatment oxidative techniques wwtp effluent: UV/H_2O_2 compared to ozone
- Decomposition products oxidative techniques including ozonation in relation to process settings and toxicity

THEME ADSORPTION ON POWDERED ACTIVATED CARBON

- PACAS Nereda: application of the PACAS process in Nereda treatment plants
- PACAS + Fe dosing: optimization of the PACAS process in the area of CO_2 footprint and costs by adding iron
- Removal of micropollutants, suspended solids and phosphate by a cloth filter with PAC
- Influence of the use of PAC on sludge fermentation, dewatering and final processing

THEME ADSORPTION ON GRANULAR ACTIVATED CARBON

- ARVIA: optimization of costs and CO_2 footprint of GAC filtration by combining adsorption with electrochemical and biological removal
- BAKF: optimization of GAC filtration by increasing biological removal and/or pre-treatment with membranes
- O3 STEP: optimization of costs and CO_2 footprint of GAC filtration through pre-switched ozonation in combination with nutrient removal

THEME OTHER ADSORBENTS

- Bio-activated carbon and Cellu2Carbon: lower the carbon footprint of PAC and GAC by using non-fossil sources and fine sieve methods for producing activated carbon
- Optimization of costs and CO_2 footprint for the removal of micropollutants through the use of cyclodextrin polymers
- Optimization of costs and CO_2 footprint for the removal of micropollutants through the use of zeolites in detergents
- Optimization removal of micro-contaminants in sand filters by other carrier material

THEME FILTRATION

- Extensive removal of micropollutants through ozonation of wwtp effluent in combination with ceramic microfiltration
- Extensive removal of micro-contaminants by Nano filtration of wwtp effluent and treatment of the brine with PAH or ozone
- Extensive removal of micropollutants through physical-chemical treatment and Nano filtration in combination with the recovery of raw materials
- Pharem: filtration of wwtp effluent in combination with enzymatic and biological removal

COLOPHON

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Disclaimer
This report is based on the most recent insights into this field of study. Nevertheless, when applied, the results must always be considered critically. The authors and STOWA cannot be held liable for any damage caused by the application of the ideas in this report.

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