NEPTUNE

New sustainable concepts and processes for optimization and upgrading municipal wastewater and sludge treatment

Contract-No. 036845

A Specific Targeted Research Project

under the Thematic Priority 'Global Change and Ecosystems'

2nd Periodic Activity Report - Publishable Executive Summary

CONTENTS

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1 Publishable executive summary

1.1 Strategic objective

The scope of sewage treatment is changing: Up to date municipal wastewater treatment plants (WWTP) were seen as an end-of-pipe treatment just before discharge, having the aim to avoid eutrophication and hygienic health hazard in surface water. Due to the global demographic trends as well as new legislations (e.g. the Water Framework Directive, WFD) increased focus is put on quantity and quality of effluents: more and more seen as interface between sanitation and environment, **WWTP are delivering resources to the environment and for human activities** (recharge drinking water reservoirs, recycling of nutrient, efficient energy use). This focus shift has implications on the quality goals for WWTP products:

Existing focus:	New focus:
● nutrient removal	● nutrient recycling
● pathogens removal	● micropollutants and ecotoxicity removal
● energy optimization	● energy production
● sludge disposal	● reuse of sludge and of its resources

NEPTUNE will approach these tasks by focusing on **technology solutions** allowing to meet present and future standards via **upgrading of existing municipal infrastructure** (new control strategies with online sensors; effluent upgrading with oxidation, activated carbon or wetland treatment; safe sludge processing and reuse) as well as via **new techniques** (fuel cell applications; new oxidation processes; production of polymer and phosphate from sludge). By including pathogens and ecotoxicity aspects into life cycle assessment studies (LCA), the project is helping to improve the **comparability of various technical options** and propose a suitability ranking.

WWTP are the major pollutant point source for surface water, and consequently impact on the new focus legislated by the WFD. The emerging interest on organic (eco-)toxic compounds requires characterizing treated effluent and treatment technologies concerning ecotoxicologic aspects and micropollutants. NEPTUNE is contributing to this discussion by **ecotoxicity assessment** and micropollutant fate studies.

By directly **involving European players of the water management sector**, the generated know-how is expected to contribute to the export oriented knowledge based EU eco-industry. Further NEPTUNE will contribute to **sustainable growth** in the EU by helping to remove the barriers faced by new environmentally friendly integrated solutions, a) by covering knowledge gaps of new solutions and b) by evidencing pros and cons of technologic alternatives through direct comparison.

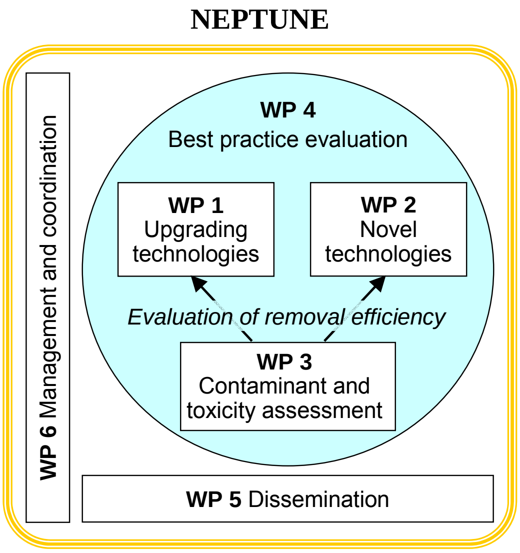

Fig. 1.1: General project structure as subdivision into workpackages (WP).

The project is structured into two technical workpackages (WP1 and WP2; Fig. 1.1) focusing on optimizing of existing technologies and forward-looking processes. Some key technologies studied in WP1 and WP2 are looked at for their micropollutant and pathogen removal capability (WP3) and compared for holistic impact with Life Cycle Assessment tools (WP4). Workpackages 5 and 6 support the project scope by disseminating the work done respectively by taking care of management and coordination. A summary of the detailed topics approached is given in Fig. 1.2.

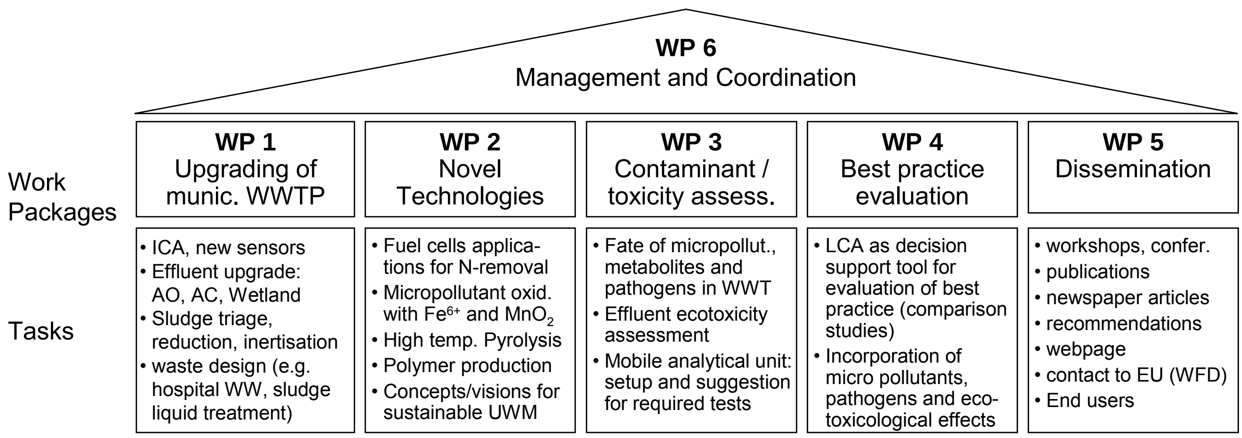

Fig. 1.2: General project structure as subdivision into workpackages (WP).

1.2 List of partners

Partic. Role[1]	Partic. no.	Participant name	Participant short name	Country	Date enter project[2]	Date exit project[2]
CO	1	Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz	Eawag	Switzerland	Month 1	Month 36
CR	2	Bundesanstalt für Gewässerkunde	BfG	Germany	Month 1	Month 36
CR	3	Laboratory of Microbial Ecology and Technolgy, University of Gent	LabMET	Belgium	Month 1	Month 36
CR	4	Consiglio Nazionale delle Richerche (CNR)	IRSA	Italy	Month 1	Month 36
CR	5	University of Frankfurt	UniFra	Germany	Month 1	Month 36
CR	6	Technical University of Denmark	DTU	Denmark	Month 1	Month 36
CR	7	National Institute of Research and Development for Isotopic and Molecular Technology	INCDTIM	Romania	Month 1	Month 36
CR	8	Aquafin NV	Aquafin	Belgium	Month 1	Month 36
CR	9	Deutsche Projekt Union	DPU	Germany	Month 1	Month 36
CR	10	Institute for Product Development	IPU	Denmark	Month 1	Month 36
CR	11	SILUET B	SILUET B	Bulgaria	Month 1	Month 36
CR	12	Pyromex PLC	Pyromex	Greit Britain	Month 1	Month 36
CR	13	Gebrüder Hunziker AG	Hunziker	Switzerland	Month 1	Month 36
CR	14	SCAN Messtechnik GmbH	S::can	Austria	Month 1	Month 36
CR	15	CAMBI A/S	CAMBI	Norway	Month 1	Month 36
CR	16	AnoxKaldnes	Anox	Sweden	Month 1	Month 36
CR	17	Université Laval	model*EAU*	Canada	Month 1	Month 36
CR	18	Advanced Wastewater Management Center, The University of Queenland	AWMC	Australia	Month 1	Month 36

[1]: CO = Coordinator; CR = Contractor.
[2]: Month 1: start of project, Month 36: end of project (request for 5 months prolongation pending)

The project is coordinated by the Engineering Department of the Swiss Federal Institute of Aquatic Science and Technology. The coordinators contact details are:

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Neptune FP6 Project

1.3 Work performed: second year

The major goal for the second project year was to operate pilot and full scale plants designed and built in the first project year, as well as to perform experiments on the laboratory set ups. The results obtained were used for the first LCA studies within the WP4.

Fig. 1.3 Sludge thermal hydrolysis plant

The following **full scale demonstration** plants have been operated:

- the zeolite addition experiments were carried out on an overloaded WWTP in Bulgaria to check for enhancement of the process efficiency as well as for improved micropollutants removal;
- nitritation/anammox SBR is in stable operation on three full scale plants (five reactors in total, with two reactors started up in the first project year);
- full scale ozonation plant with post-sandfiltration (in cooperation with the Swiss project Micropoll) assessing micropollutants and ecotoxicity removal in WWTP effluents;
- thermal hydrolysis (THP; Figure 1.3) plant was used to examine improvement of sludge digestion efficiency by sludge pre-treatment.

The following **laboratory setups** and **pilot reactors** have been operated and produced the first results:

- BioMac process pilot reactor (combined granular activated carbon and ultrafiltration), laboratory set up of the same process was used to compare the application of GAC and sand in the ultrafiltration part of the process.

- DPU has performed effluent upgrading with powder activated carbon on a two lane pilot set up.
- High temperature gasification (pyrolysis) pilot plant for sewage sludge mineralisation (Figure 1.4) was delivered and first tests have been carried out.
- Two parallel lab scale SBRs for cultivation of biopolymer producing bacteria have been put into operation at AnoxKaldnes and one fermenter is operated at AWMC.
- Microbial fuel cell lab reactors for wastewater treatment have been studied at LabMET and at AWMC.
- Two types of lab scale unit to study micropollutant removal with manganese oxide have been in operation

Fig. 1.4 High temperature gasification (pyrolysis) unit

The following **knowledge base tools** and **analytical methods** have been developed during the second project year:

- The strategy for start up and operation of single SBR nitritation/anammox has been submitted for publication
- Sensor characterisation has been finished as well as long term evaluation of spectral sensors for ammonia.
- A new chemical cathode was developed to increase the sustainability of MFCs.
- Loop system was developed to reduce the internal losses of MFC reactor due to the low diffusion of protons through the membrane separation anode and cathode.

- The extraction protocol for emerging pollutants, namely the brominated flame retardants and tetrachloro bisphenol A, was optimized and validated.
- Optimization of analytical methods based on GC/MS, for the determination of target organic pollutants in wastewater phase at low levels (ng/l).
- A method for the multi-residue analysis of 24 biocides, 4 benzothiazoles and polar UV-filters in wastewater and sludge was developed and validated.
- Draft descriptions of a new life cycle impact assessment (LCIA) method "EDIP 200X " based on best available practice regarding ecotoxicity and human toxicity, and drafts on how to deal with whole effluent toxicity, pathogens, site-dependent assessment, land use, land filling, and normalization and weighting
- Ecotoxicity characterisation factors for about 35 micropollutants included in Neptune have been estimated by use of the EDIP97 method.

Dissemination activities

- The homepage of the project (www.eu-neptune.org) was regularly maintained.
- Midterm workshop for NEPTUNE and INNOWATECH stakeholders was organised in Zurich in May 2008.
- Workshop for Bulgarian and Romanian end-users (with simultaneous translation) was organised in Varna in October 2008.
- First issue of Neptune newsletter was published and distributed
- Neptune was presented with the flyer and the first issue of newsletter at the European Water Research Day, EXPO ZARAGOZA 2008 as well as in the Norman newsletter

13 presentations at the conferences and 6 papers in peer-reviewed journals have been produced

1.4 Results achieved so far

Work performed during the second project year generated the following results:

- Full scale nitritation/anammox with the single sequencing batch reactor (SBR) was proven robust and resulted in considerable cost savings (2% of the total WWTP costs) compared to the conventional SBR with methanol for heterotrophic denitrification; several follow-up projects are in planning phase
- The full-scale ozonation plant including post-filtration confirmed the efficient elimination of a broad palette of micropollutants and disinfection as required by the EU bathing water regulation at total costs of 0.08 to 0.2 €/$m^3_{wastewater}$ depending on plant size. The costs are about half if the filtration already exists. Post-filtration is recommended to substantially reduce eco-toxicity of the formed by-products.

- Hospital wastewater is proved to be a significant point source for the pharmaceuticals; nevertheless current cost estimation (2 €/m^3 for treatment in the hospital with MBR + ozonation) indicate discharge into the sewer and treatment in the centralized municipal WWTP as the most cost effective solution in case micropollutant removal is done here
- Nitrogen removal efficiency could be improved 10-30% by applying online ammonia and nitrate sensors for process control.
- The sludge triage confirms that primary sludge contains significantly higher pollutants concentration and less nutrients than secondary sludge.
- Sludge pre-treatment with thermal hydrolysis will result in substantially increased biogas production and costs reduction especially for WWTP without primary clarifier.
- High temperature gasification (pyrolysis) of sludge produces gas free of tar with CO and H_2 as the major components. Higher phosphorus residue bioavailability was observed with decreasing residence time (15 to 5 min) and temperature (1400 to 1200°C).
- Polyhydroxyalkanoate (PHA) characterisation was done and indicated that the biopolymer obtained from sludge has broad application and good processing potential.
- Zeolite addition to the WWTP resulted in no significant improvement of micropollutant removal. However, significant reduction of the effluent BOD by 50% and partial nitrification was shown in two campaigns.
- PAC addition to WWTP effluent allows removing micropollutants selectively: 20mg/l PAC removed 80% of carbamazepine but 80mg/l achieved only 50% iomeprol removal.
- Wetland and pond treatment have minor effects on micropollutants removal from the WWTP effluent.
- Second order rate constant were determined for the reaction of Fe(VI) with selected micropollutants as well as model organic compounds and the obtained values were used for modelling the micropollutants elimination at pH 7 and 8. It was confirmed that the elimination efficiency of Fe(VI) observed at high micropollutants concentration (>>20µg/L) can be applied to predict the elimination at environmentally relevant conditions (<1µg/l).
- The research on manganese based oxidation of micropollutants in WWTP effluent revealed that biologically produced Mn oxides are 20 times more reactive than chemical MnO_2.

- Eco toxicity tests revealed that estrogenicity of the secondary WWTP effluent is removed by ozonation. On the other side, several toxicity endpoints showed significant increase after ozonation, but the effect disappeared after sand filtration.
- The sludge sorption studies on many micropollutants produced Kd values and Freundlich isotherms.

1.5 Expected end results

- Technical solutions for upgrading a quantitatively significant water resource: municipal wastewater.
- Options for sludge processing and disposal, allowing to evaluate feasible and safe solutions for nutrient recycling.
- Improved energy efficiency of municipal wastewater treatment.
- Reduced pollutant load discharged into the aquatic environment, by improving nutrient and micropollutant removal and by evaluating wastewater treatment options with new (eco-) toxicological methods.
- Best practice ranking based on life cycle (LCA) and cost efficiency assessment.
- Catalogue with criteria for evaluating technologies.

1.6 Use of the results and expected impact

Results of Neptune will be used to reduce environmental impact while at the same time reducing overall costs of the environmental protection. New analytical tools for micropollutants detection will enable better management of the whole effluent toxicity. By comparing existing as well as new technologies developed within Neptune, using LCA, it will be achievable to find best combination of technologies for each specific demand in WW sector.

The impact NEPTUNE is going to have can therefore be summarized in two main focuses:

- environmental impact: improving the quality of European water and the efficiency of its management (aquatic environment and drinking water resources)
- economic development: strengthening the competitive position in exporting wastewater technology