LIFE Project Number

LIFE04 ENV/D/058

TECHNICAL INTERIM REPORT

Reporting Date

25/08/2006

LIFE PROJECT NAME

Enhanced Nutrients Removal in Membrane Bioreactor (ENREM)

Data Project

Project location	KompetenzZentrum Wasser Berlin gGmbH Cicerostrasse 24 10709 Berlin	
Project start date:	01.01.2004	
Project end date:	30.12.2006	**Extension date:** n.r.
Total Project duration (in months)	36 months	**Extension months** n.r.
Total budget	3,417,378 €	
EC contribution:	562,463 €	
(%) of total costs	16.5 %	
(%) of elibible costs	30.0 %	

Data Beneficiary

Name Beneficiary	KompetenzZentrum Wasser Berlin gGmbH
Contact person	Mr Ludwig Pawlowski
Postal / vist address	Cicerostrasse 24, D-10709 Berlin
Telephone	+ (0) 49 30 53653 802
Fax:	+ (0) 49 30 53653 888
E-mail	Ludwig.pawlowski@kompetenz-wasser.de
Project Website	www.kompetenz-wasser.de (…/R&D/ENREM)

Preamble

This Technical Interim Report presents the activities and outcomes of the ENREM project from project start-up (01.01.2004) up to commissioning of the ENREM demonstration plant (28.02.2006).

Authors:

Boris Lesjean	Project Manager for Berlin Centre of Competence for Water boris.lesjean@kompetenz-wasser.de
Regina Gnirss	Project Manager for Berliner Wasserbetriebe regina.gnirss@bwb.de

Berlin, 25/08/2006

1. List of Contents

2. LIST OF KEY-WORDS AND ABBREVIATIONS

Key-Words.

membrane activated sludge, membrane bioreactor (MBR), semi-central treatment, remote catchment, periurban zone, sensitive area, bathing water, nitrification, denitrification, enhanced biological phosphorus removal (EBPR), disinfection

Abbreviations.

BWB	Berliner Wasserbetriebe
AR	Anjou Recherche
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
KWB	Kompetenzzentrum Wasser Berlin (Berlin Center of Competence for Water)
HRT	Hydraulic Retention Time
MBR	Membrane Bioreactor
MLSS	Mixed Liquor Suspended Solids
pe	population equivalent
TMP	Transmembrane Pressure
TN	Total Nitrogen
TP	Total Phosphorus
TUB	Technical University of Berlin
VFA	Volatile Fatty Acid
WWTP	Waste Water Treatment Plant

3. EXECUTIVE SUMMARY

The ENREM project aims at demonstrating a novel wastewater treatment process based on the technology of membrane bioreactor (MBR), set up in a configuration to enable enhanced biological elimination of nutrients. A new plant, and the related sewer system, was built in a unsewered periurban area of Berlin. The plant is to be operated over more than one year, and the process to be optimised. Performances and costs of the treatment system will be then assessed for the size 250 – 10,000pe, corresponding to semi-central schemes.

The plant was started on 28 February 2006 with **8 month delay** on the program identified in the LIFE proposal. As a consequence, a project extension request of 8 months will be lodged, in order to match the initial duration of 18 months for the optimisation, evaluation and dissemination phase. This delay incidentally caused also a 6 month delay for the preparation of this Interim Report.

Despite these aspects, the management of the project has been achieved according to the organisation identified in the LIFE proposal. **Annex 7.1** presents and discusses the key deliverables and milestones depending on the LIFE proposal and the current status.

In relation to the technical content, Task 2 “Site and process definition” and Task 4 “Detailed design” were completed early 2005. Task 3 “Preliminary testing on representative site” was completed in September 2005 and enabled to validate the design, operation and start-up criteria of the MBR demonstration plant. The public tenders for the construction of the sewer network and the MBR container unit occurred during the first semester of 2005, and the construction of the scheme was completed by end 2006. In parallel, the required legal permits were acquired (for plant construction & operation, water discharge), as well as the parcel hosting the treatment unit. A relationship with the inhabitants of Margaretenhöhe was maintained in order to ensure a smooth construction phase, and a quick connection to the new sewer system.

The dissemination activities covered several communication vectors (Tri-lingual website www.kompetenz-wasser.de, press-release and articles and bi-lingual KWB Newsletter, local press, scientific press, plant visits and inauguration, communication material etc). The project results will be widely communicated in the national and international medien, and a final project workshop will be organised in June 2007.

The main task in 2006 will be the operation, optimisation and technical / economical evaluation of the low sewer system and the MBR demonstration plant.

So far, the budget is generally in line with the expectations, or slightly below. **The project finances allow the project extension of 8 months**, required to achieve all announced technical outcomes of the project. After the 8 month extension the final project budget is expected to remain about 20% below the planned proposal, i.e. approx. € 600,000 savings on the total budget should be recorded, corresponding to a subvention reduction of approx. € 100,000 (also close to 20% reduction).

4. INTRODUCTION

Still today in Berlin, some remote small catchments are not connected to the central sewer system. The technology of membrane activated sludge, or membrane bioreactor (MBR), could well provide a technical and economical solution for semi-central wastewater treatment plants in environmentally sensitive areas. Such a process could indeed achieve complete disinfection and advanced biological phosphorus removal down to 0.1mgP/L or lower, with no or very limited addition of metal salts for phosphorus precipitation. This treatment enables to comply with the European guidelines on bathing water and to reduce eutrophication of surface water bodies. The implementation of MBR technologies on small or medium-size catchments could be achieved in containerised turn-key units in order to reduce construction costs, and should not entail the usual inconveniences of wastewater treatment plants to the local neighbourhood, namely odour and noise emissions, and increased truck traffic.

In order to validate the technical and economical feasibility of this concept, Berliner Wasserbetriebe and Veolia Water have undertaken and completed the 3-year “IMF project” from 2001 to 2003 in the frame of the Berlin Centre of Competence for Water. During this R&D project, an innovative membrane process was optimised at pilot plant scale for advanced treatment of municipal wastewater. This patented process developed with the MBR technology, combines enhanced biological phosphorus and nitrogen removal in a post-denitrification step, and provides an effluent quality surpassing any conventional technologies utilised to date for decentralised treatment. In addition to complete disinfection through the microfiltration membrane, improved removal of nutrients and pollutants were achieved with elimination rates of 99% for phosphorus (<50µgP/L) and 95% for nitrogen (<5mgN/L). This outstanding treatment performance was achieved over a broad range of operation conditions, confirming the flexibility and robustness of the process configuration, and without resorting to any chemical additive such as metal salts (for phosphorus precipitation) or carbon source (for improved denitrification). Moreover, cost estimations underlined the economical benefits of this solution, for the water utility as well as for the concerned households, to equip remote and unsewered areas when compared with conventional treatment processes achieving a similar effluent quality.

The ENREM demonstration project aims at undertaking the first full-scale assessment of this innovative process. A treatment plant was built in Berlin to serve a community of about 250 inhabitants on a site representative a such periurban areas (no industry). The newly built separated (low pressure) sewer warranties the wastewater to be devoid of storm water.

The ENREM project includes the selection of a representative site for demonstration in Berlin, the completion of a preliminary pilot study to validate the design and operation criteria, the final design, bid and construction of the sewer and the full-scale MBR demonstration plant, the commissioning of this plant as well as 18-month continuous operation and follow-up, which should be concluded by a technical and economical assessment of the concept. Best economical operation conditions (energy, chemicals and man-power) should be identified, as the BWB will continue to operate this first decentralised plant after completion of the project.

The ENREM demonstration plant will be the first full-scale MBR plant designed and operated with biological phosphorus removal in Europe. Furthermore, it is designed to be the MBR plant achieving worldwide the greatest rate of phosphorus and nitrogen elimination. A successful completion of the project would open the implementation of this process to other applications in Germany, Europe or worldwide.

5. LIFE-PROJECT FRAMEWORK

5.1. Project structure

The ENREM project is organised in 8 tasks reflecting the specific activities of the demonstration undertaking:

- Task 1: Management and reporting to EC (Mth 1-36)
  Successful management and organisation of the project

- Task 2: Site and process definition (Mth 1-8)
  Selection of demonstration site in Berlin
  Definition of basic process scheme
  Fine cost estimation of project

- Task 3: Preliminary testing on representative site (Mth 4-15)
  Pilot plant construction
  Detailed raw water characterisation of representative site
  Verification of design and operation criteria

- Task 4: Detailed design (Mth 7-14)
  Detailed specifications and planning of demonstration plant and new sewer
  Tender process for selection of suppliers (civil work and container plant)
  Legal permits (construction, discharge etc)

- Task 5: Construction phase (Mth 9-18)
  Construction of sewer and demonstration plant

- Task 6: Special investigations and assistance to plant operation & monitoring program (Mth 16-36)
  Detailed monitoring of demonstration plant
  Required special technical investigations

- Task 7: Demonstration plant start-up & operation (Mth 19-36)
  Plant commissioning
  Continuous plant operation and optimisation over 18 months
  Identification of best operation practices and procedures
  Technical & economical evaluation
  Education and training of future operation staff

- Task 8: Dissemination (Mth 1-36)
  Communication on project objectives, progress and outcomes
  Site visits
  Final presentation workshop

5.2. Project organigram

Figure 1 presents the organisation chart of the ENREM project, built up around the following consortium:
- KompentenzZentrum Wasser Berlin (KWB) as beneficiary
- Berliner Wasserbetriebe (BWB) and Anjou Recherche (AR) as partners

These main sub-contractors were involved in the project:
- Technical University of Berlin (TUB) to conduct the preliminary pilot plant study on representative site (Task 3);
- Jung Pumpen, designer and supplier of household pumping systems, selected by BWB for a 5-year contract after tender process;

- Tepe, construction company of pressurised system and civil work, selected after local tender process; and
- Martin Systems, manufacturer of the container MBR-plant, selected after restricted European process.

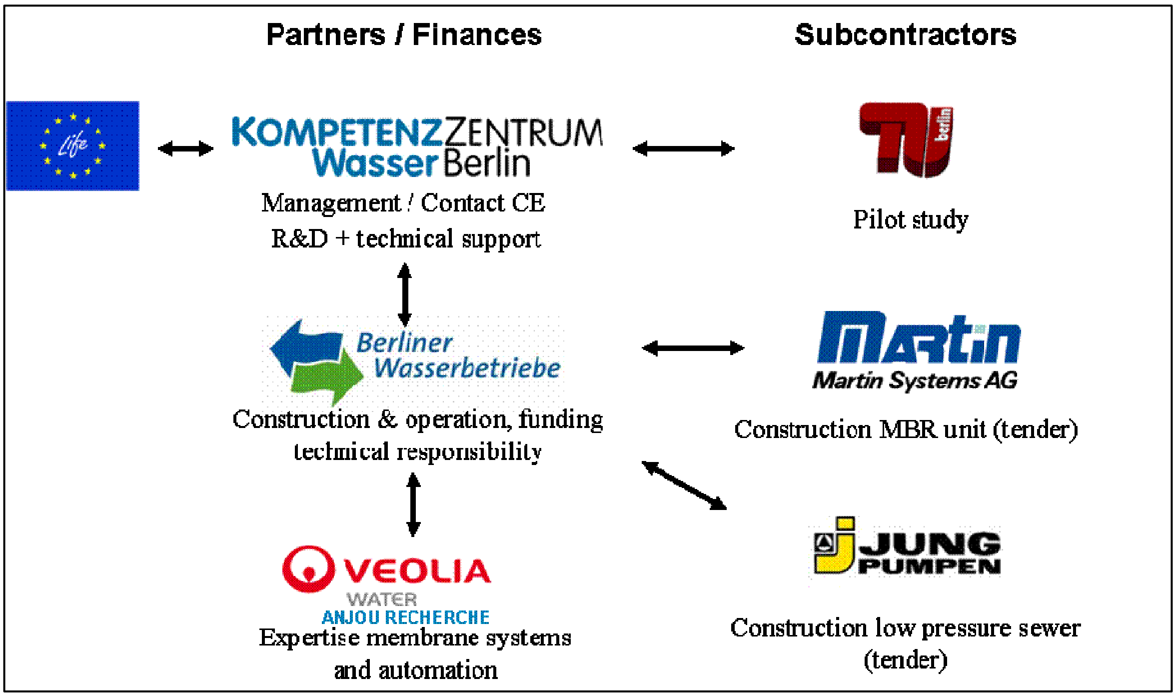


Figure 1. Organisation chart of the ENREM project

The main tasks and contributions of the collaborators involved in the project from beneficiary and partners are shown in Annex 5.1.
To be noted that a Project Partnership Agreement was signed between beneficiary and partners, as well as a sub-contract agreement with the TUB. The commercial relationship between BWB and Martin Systems, Jung Pumpen and Tepe was in the contractual frame negotiated during the tender process.

5.3. Project modifications

Due to several circumstances detailed later, the commissioning of the plant was postponed by around 8 month (March 2006 instead of July 2005). The plant is expected to reach the full design capacity by June 2006, once all costumers are connected to the new sewer. Consequently, a **request for a project extension of 8 months** (up to August 2007) is pending, in order to ensure the evaluation of a **full representative year of operation**. This will also enable to organise the dissemination based on the results of the first complete year (including a final project presentation workshop planned in June 2007).

In Task 6 "special investigations", a pilot plant was supposed to be built and operated in parallel to the demonstration plant. It was rather decided to **extend Task 3 "preliminary testing" by 6 months up to September 2005**, and therefore to address most of remaining uncertainties on the process operation, and to **strengthen the monitoring capacities of Task 7** "Demonstration plant operation". In particular, it was decided to build and operate a parallel filtration unit to help investigating the filtration and fouling behaviour of the system and to optimise the use of the membrane fouling diagnoses planned to be undertaken by Anjou Recherche in Task 7.

6. TECHNOLOGY

The technology selected for the ENREM demonstration plant is the wastewater treatment process of membrane activated sludge, commonly referred to as membrane bioreactor (MBR), designed for enhanced biological elimination of phosphorus and nitrogen. The MBR technology consists in the combination of an activated sludge system together with a micro- or ultra-filtration step to achieve the physical separation of the treated effluent from the mixed liquor. The membrane filtration ensures complete removal of suspended solids and colloids, together with pathogens.

Over the last decades, since the first demonstration of membrane filtration systems of low pressure submerged module, in Japan in the early 90's, the MBR technology went through a quick development and application pace. The first European MBR plant for municipal wastewater was built in 1998 (in Porlock, UK, 3,800 p.e.). In 2004, the largest MBR plant worldwide was commissioned to serve a population of 80,000 p.e. (in Kaarst, Germany).

Meanwhile, the technology was adapted to different technical conditions, and many products are now available on the market for the different application sizes. In particular, two types of submerged module designs are proposed with polymeric membranes: the flat-sheet membrane modules, and the hollow fiber membrane modules. A non-exhaustive list of European producers is given below for the sizes corresponding to decentralised and semi-central applications:

- 4 to 50 p.e. (decentralised treatment): Busse, Huber, Martin System, MallBeton, etc
- 50 to 500 p.e. (containerised-like turn-key plants for semi-central treatment): Kubota, Huber, A3, Puron, etc
- 500 to 5,000 p.e. (with standardised filtration units for semi-central treatment): Kubota, Zenon, Mitsubishi, Memcor, Huber, Puron, etc

The main advantages of the MBR technology, compared with the conventional activated sludge (CAS) technology, are:

- outstanding quality of treated effluent: the membrane insures a particle- and pathogen-free effluent, complying with unrestricted irrigation and bathing water criteria;
- stable treatment performance in time, with greater robustness to load variation (daily or seasonal), and no risk of sludge bulking or sludge lost in the clarifier; and
- compactness: no needs of large-footprint clarifiers, sludge concentration 3 to 4 folds higher than conventional activated sludge process, possibly no need of primary sedimentation. The overall footprint of an MBR plant is considered to be twice as small as this of a CAS technology.

For semi-central sanitation systems up to 10,000 p.e., the technology of membrane bioreactor can offer the further following advantages in comparison with other processes:

- broad operational window (sludge age 10 to > 100d, sludge concentration 6 - 18 g/L, etc), adaptable to sometimes unpredictable population growth of remote areas
- reliable and excellent quality in time without degradation of treatment performance over years
- possibility of remote control with on-line detection of process disturbances
- containerisation of entire plant (up to 2,000p.e.) or the filtration units (up to 10,000p.e.) with modularity of filtration system, therefore flexibility of plant volume increase
- the MBR plant should not entail the usual inconveniences of wastewater treatment plants to the local neighbourhood, namely odour and noise emissions, or increased truck traffic.

The main drawback of the membrane bioreactor technology still remains the capital and operation costs due to use of the high-tech membrane filtration aggregates, and depending from both membrane fouling and effective module lifespan. This is also a "high-tech system" which requires qualified and committed staff, clear operational guidelines, and quick reaction in case of any process or system disturbance.

Figure 2 compares recent capital cost of MBR plants with capital costs of CAS plants and wetlands. It shows that the capital costs of the MBR technology have become competitive with other conventional processes, which however do not achieve a similar degree of treatment.

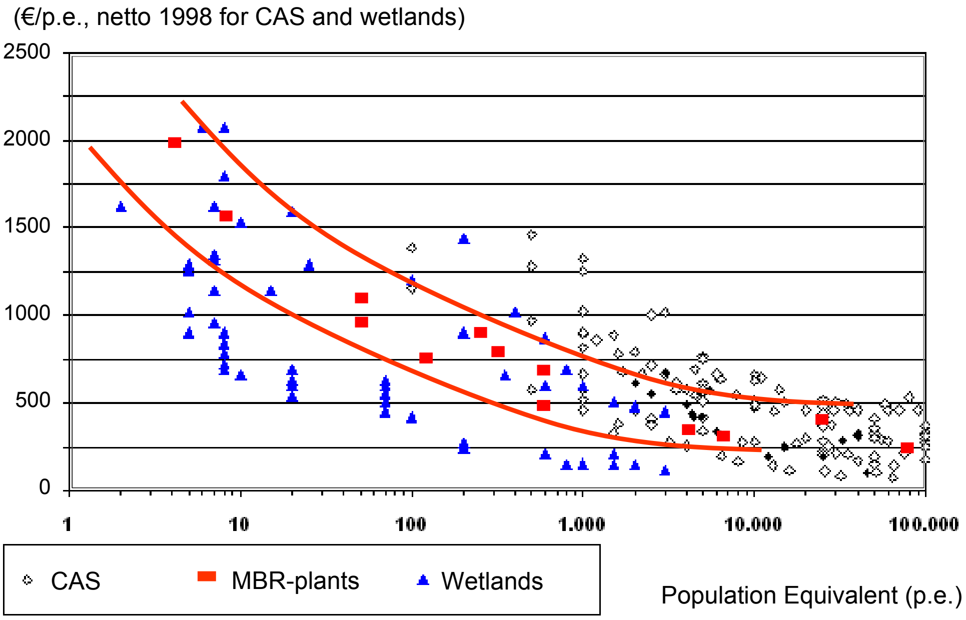


Figure 2. Capital costs of MBR plants, CAS plants and wetlands (Lesjean, 2005, adapted from Reicherter, 1999)

Similarly, the continuous efforts of the MBR systems suppliers to reduce the operation costs led to minimised energy, labour and chemical requirements. As example, the total plant energy needs of MBR systems, initially greater than 1.5 kWh/m3, has reached now 0.9 kWh/m3 in recent large municipal applications (> 10.000 p.e.), with the objective to optimise this value down to 0.75 kWh/m3. We have however to bear in mind that this remains much greater than the energy requirement of a CAS plant (0.1-0.2 kWh/m3), even when combined with tertiary filtration (0.3-0.6 kW/m3), as provided by Gnirss et al. (2001). These results from the needs of important membrane aeration rates required to run the submerged filtration system under relatively stable hydraulic conditions. This high energy requirement impacts significantly on the net present values (NPV) of MBR plants, which are consequently greater than CAS systems.

7. Progress, Results

7.1. General

This section presents for each task the activities and output achieved during the reporting period, from project start-up, up to the plant commissioning (01.01.2004 – 28.02.2006), except for the dissemination activities (Task 8) which are discussed in details in section 8.
Figure 3 shows the planned and revised GANTT chart of the ENREM project. The progress of each task is detailed and discussed below, and the status of the associated deliverables and milestones is presented in Annex 7.1.

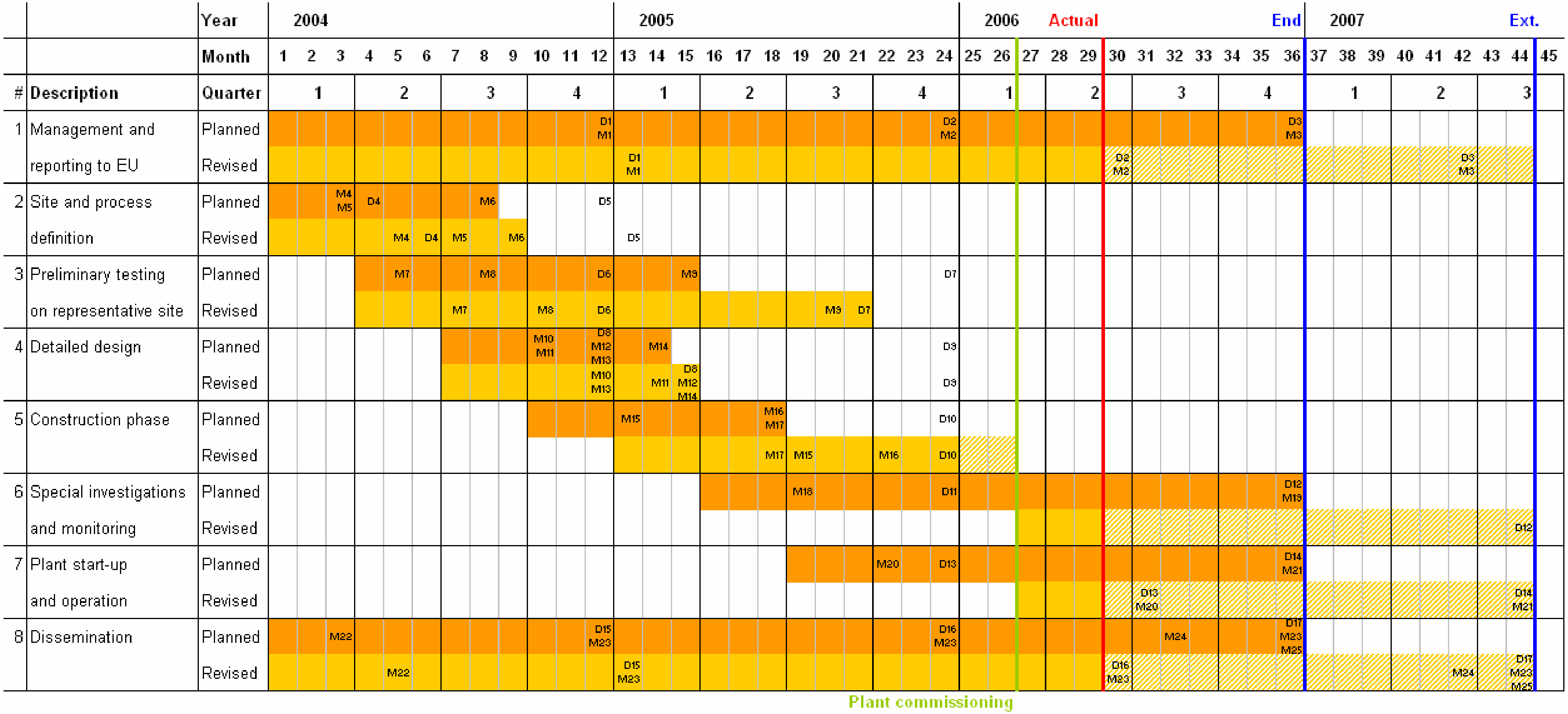


Figure 3. GANTT chart (planned and revised) of ENREM project. Status Mai 2006.

Task 1 “Management & reporting to EC” and Task 8 “Dissemination” are performed over the entire duration of the project. Task 2 “Site and process definition” and Task 4 “Detailed design” were completed with one month delay. Task 3 “Preliminary testing on representative site” was purposely extended of 6 months up to September 2005. Task 5 “Construction phase” was completed in December 2006 after 6 month delay. Task 6 “Special investigations” started only concomitantly to the plant start-up in March 2006, due to the decision to abandon the operation of a parallel pilot plant. Task 7 “Demonstration plant start-up and operation” commenced in March 2006 after 8 month delay.

As a consequence of this delay resulting from several unforeseen events, **a request for project extension of 8 months (up to 30th August 2006)** will be lodged. This will allow for one full year of process operation and optimisation (summer / winter season with change of temperature, load and biocenosis) before technical and economical evaluation. Moreover, this will provide sufficient time to complete the dissemination activities planned for the project (final workshop, publications etc).

7.2. Task 1: Management and reporting to EC (Mth 1-36)

On-going task over the full duration of project. The following actions were completed:
- Project partnership agreement (signed on 03.12.2004) and subcontract agreement with TUB (signed on 02.04.2004)
- Organisation of official kick-off meeting between KWB and BWB
- Preparation and reporting of meetings
- Controlling of project progress
- Controlling of project financial status
- Preparation of progress report (February 2005)
- Preparation of interim technical and finance report (June 2006)
- Finance audit

7.3. Task 2: Site and process definition (Mth 1-8) and Task 4: Detailed design (Mth 7-14)

The two tasks are reported together given the overlapping of period and actions. They were completed with one month. The following actions were performed.
- Cost-comparison of decentralised treatment solutions to serve 20 unsewered areas of Berlin and selection of demonstration site. Completed in April 2004. (detailed provided in progress report delivered in February 2005). The area of Margaretenhöhe (250 pe), with pressure sewer, was finally selected as demonstration site.
- Revision of cost evaluation for infrastructure. Completed in July 2004. The infrastructure costs are in line with the budget proposed in the LIFE-proposal.
- Literature research on small MBR-plants (50-5,000 pe) focused on pre-treatment and sludge handling strategy. Completed in August 2004. The main outcomes were as follows: (i) the pre-treatment should be selected and implemented depending on the type of membrane technology, with 1mm holes screen for hollow fibre, (ii) the plant should be equipped with a 10m3 tank for excess sludge storage, (iii) given the size of the plant, it should be more efficient and economically advantageous to tender the entire plant as “integrated turn-key plant”.
- Visit of MBR plant of Merkendorf, Thüringen, on 16.11.2004 (230pe, equipped with Kubota Membrane system).
- Planning and specification of MBR plant. Completed in December 2004. Annex 7.2 provides a description of the plant specification.
- Preparation and release of call for tender of MBR plant (in German with summary in English). Completed in January 2005. Annex 7.3 provides the list of eleven MBR-system suppliers that were offered to tender for the delivery of the MBR demonstration plant. Four suppliers submitted an offer, among which **Martin Systems** was selected.

- Planning and specification of low-pressure sewer. Completed in December 2004. A description of the sewer specification was provided in the progress report of February 2005.
- Preparation and release of call for tender of low-pressure sewer construction. Completed in January 2005. Nine German construction companies were offered to tender for the construction of the low-pressure system. The company Tepe was selected to perform this task.

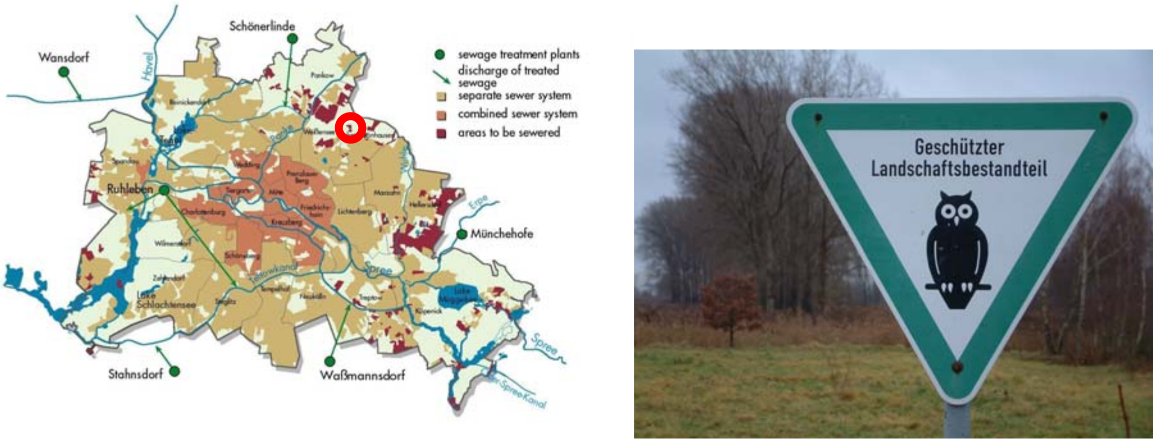


Figure 4. Demonstration site in Margaretenhöhe, a protected natural area in the North-East of Berlin.

Figure 5. Visit of Merkendorf MBR plant (230pe), Thüringen 16.11.2004.

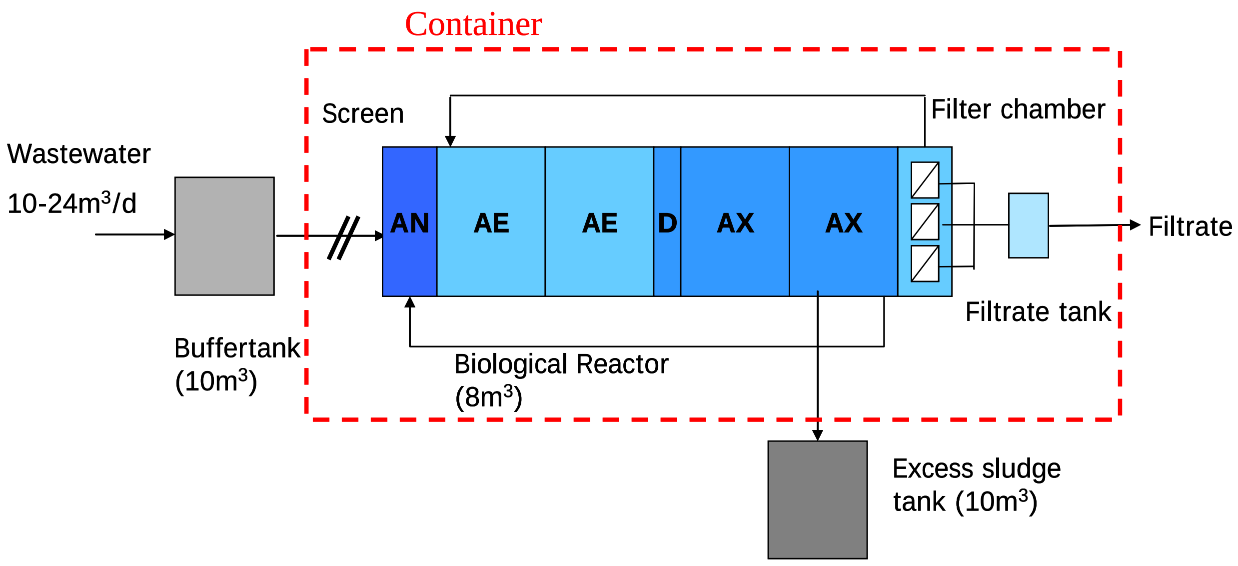


Figure 6. Selected process scheme for the Margaretenhöhe MBR plant (simplified)

Legal permits, mitigative measures and purchase of parcel.
Several permits were requested to construct and operate the MBR-plant, which led to intense discussion and negotiations with the local authorities:

1. „Baugenehmigung einer semizentralen Abwasserreinigungsanlage (Membranbelebungsanlage MBR-Anlage) in Margaretenhöhe" (Authorisation to construct the semi-central MBR treatment plant)
2. „Eingriffsgenehmigung nach §14 Naturschutzgesetz" (Authorisation of intervention after the law of nature protection)
3. „Wasserbehördliche Erlaubnis zur Einleitung des gereinigten Abwassers (WHG)" (Permit of discharging the treated effluent from the Water Authorities)

All documents were received but on the following conditions: no higher building than 3 m, the storage tanks are located under earth (already planned), no noise or odour nuisance for the citizens, the pre-defined colour of the container, the construction of a weir on water discharge body to store the effluent, and the plantation of some specific bushes around the parcel. These compensatory measures were bound to the purchase of the parcel for MBR plant, which occurred in the first semester of 2005 (after contract preparation).

The permit of treated effluent discharge was bound to monitoring and effluent quality requirements as specified in Table 1. In addition, this permit describes (i) the specific sampling procedure (ii) the sampling methods to be conducted and (iii) the reporting of the analysis and operation parameters every six months. This current permit will terminate on 31.12.2007. At this time, the overall performance of the demonstration plant will be evaluated with the Water Authorities. All operational problems of the demonstration plant will be discussed and the permit will be reviewed (monitoring and quality requirements).

Parameter	unit	concentration
SS	mg/L	< 1
BOD5	mg/L	< 5
COD	mg/L	50
Phosphor (TP)	mg/L	**0,1**
Totale Nitrogen (TN)	mg/L	**10**
Ammonia	mg/L	1
Escherichia coli	MPN/ 100ml	**250**
Enterococcen	MPN/100ml	**100**
AOX	µg/L	50
Mercury	µg/L	0,8
Cu	µg/L	50
Lead, Nickel, Chrom	µg/L	30
Cadmium	µg/L	1

Parameters must be analysed as qualified grap sample

Table 1. Effluent quality requirement (from “Wasserbehördliche Erlaubnis” for Margaretenhöhe, §§2,3,5,7 WHG, 16.06.2005)

7.4. Task 3: Preliminary testing on representative site (Mth 4-15)

This task was subcontracted by KWB to the Technical University of Berlin (TUB). The reasons for the selection of the TUB to perform this task without open tender are provided in **Annex 7.4**.

The following tasks were achieved during the reported period:

- Selection of representative site for pilot plant study (Grünau pumping station, a gravity flow catchment for 800 pe). Completed in May 2004.
- Construction and commissioning of pilot plant. Completed in July 2004.
- Detailed characterisation of wastewater (quality & flow profile, comparison between Grünau pumping station and a representative low-pressure sewer). Completed in October 2004.
- Investigation on effect of puffer tank on hydraulic and pollution load, and validation of design volume. Completed in April. 2005.
- Validation of design and operation criteria of demonstration plant. First scenario (irregular sludge withdrawal), July 2004 - December 2004. Second scenario (regular sludge withdrawal) January 2005 – August 2005.
- First progress report, including details on achieved actions and outcomes of “Scenario 1” trials, released by TUB in January 2005 (report available separately).
- Final report, including details on achieved actions and outcomes of “Scenario 2” trials, released by TUB in September 2005 (report available separately).

Given the delay expected up to the commissioning of the full-scale demonstration plant, it became clear that the parallel pilot plant, planned to be installed and operated on the demonstration site, could not start without delay. It was therefore decided to extend Task 3 “preliminary testing” by 6 months up to September 2005. This enabled to address the remaining identified uncertainties on the process operation (completion of “scenario 2” trials with regular sludge withdrawal, included the full investigations on an extended lost of nitrification in winter, the switch to warmer temperatures, then the apparition of worm blooms. The main recommendations of the preliminary study are presented in **Annex 7.5**.

Figure 7. Site (Grünau pumping station) and pilot unit of preliminary study

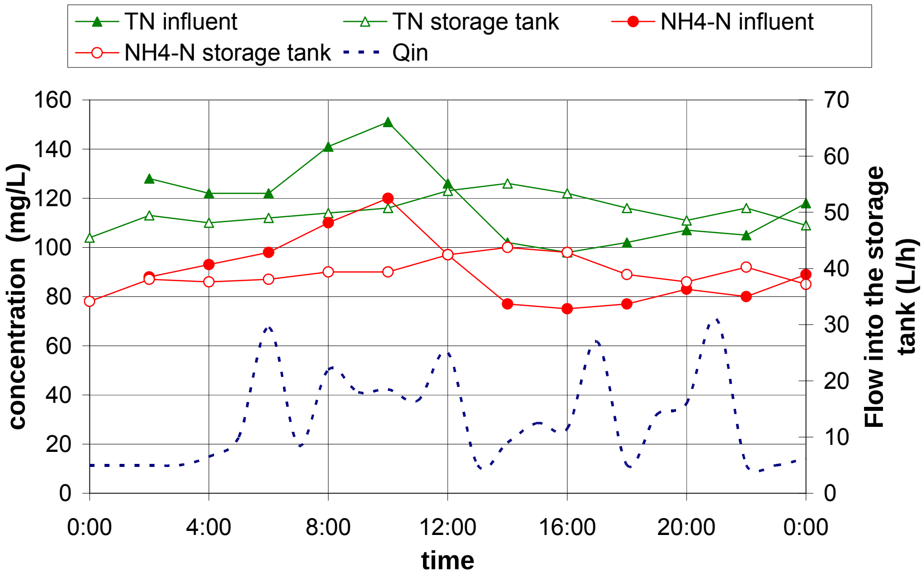


Figure 8. Impact of buffer tank: flattening of N-pollution load

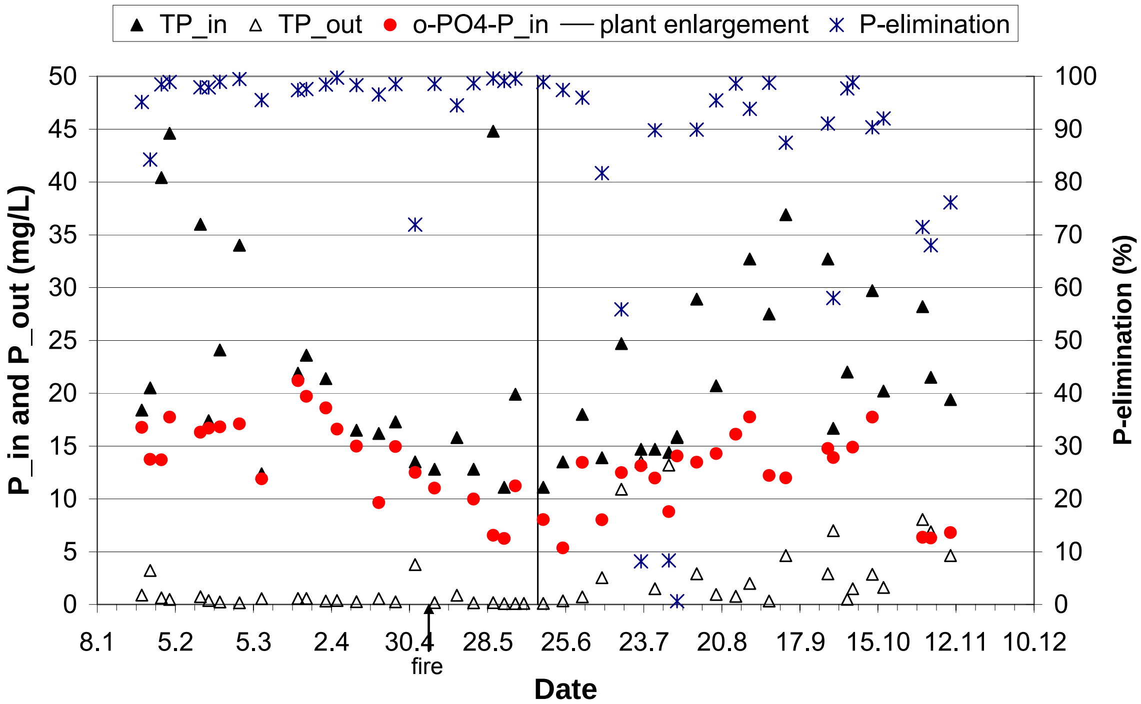


Figure 9. "Scenario 2 trials": P-elimination performance (worms from July onwards)

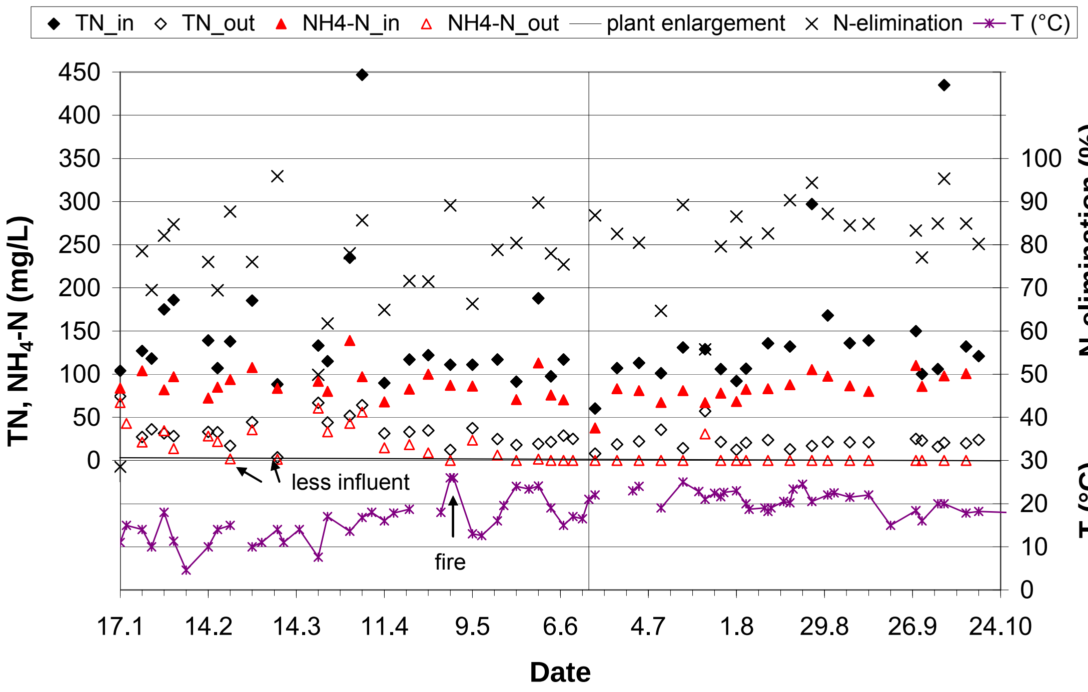


Figure 10. "Scenario 2 trials": N-elimination performance (worms from July onwards)

7.5. Task 5: Construction phase (Mth 9-18)

This phase, initially planned to start in October 2004, started effectively in January 2005 with the first actions related to the sewer construction. The sewer construction continued over the whole year 2005. The containerised demonstration plant was constructed by Martin Systems and **delivered on 23 November 2005**. After final assembly, dry and wet commissioning, the plant was ready for sludge seeding and start-up in January 2006. However, the container was forced and the central computer was stolen. This occasioned a further delay up to the **effective start-up** of the plant which occurred on **28 February 2006**. The four week "test operation" of the plant was performed in April 2006 before official take over ("Abnahme") of the unit from Martin Systems by Berliner Wasserbetriebe.

Figure 11. Container plant (incorporation of biological reactor, after construction on site and machine room)

Figure 12. Pump shaft installed in private households and one membrane rack with 6 modules

A crucial aspect of the project related to the willingness of the inhabitants of Margaretenhöhe to quickly connect in order to reach promptly the design capacity of the plant (“Connection strategy”). Dedicated actions were undertaken in order to inform the population and increase this willingness:

- 11 January 2005: the Berliner Wasserbetriebe organised an ”open council” with the inhabitants of Margaretenhöhe. The participation was intense, with an estimation of 270 inhabitants attending the meeting. The participants showed interest, without any major opposition to connect. The collaborators of BWB could estimate that 50% of the households should connect very quickly, and an additional 30% in the first six months, which would lead rapidly to 80% connection rate.
- In February and March 2005, the collaborators of BWB met individually each of the house tenant in order to agree upon the position of the pump shaft on the parcel and to enter into a connection agreement. This confirmed that 80% of the people in Margaretenhöhe were prepared to connect in short time after they are allowed to do so.
- In end **November 2005**, by the time of the plant delivery, **around 30% of households** were connected to the scheme. The generated wastewater was stored in the plant buffer tank and regularly trucked away.
- However, the deep soil frost provided further connection up to April 2006. The plant was therefore start-up in under-loading conditions of about 30% the design capacity. It is expected that at least **70% of households will be connected by June 2006**. With a project extension of 6 months, this will enable a full year investigation under conditions close to the design capacity.

In the last months of the construction phase, a commissioning protocol was developed (**Annex 7.6**), as well as a trials and monitoring program (**Annex 7.7**). These programs were agreed upon between the project partners (BWB, KWB, AR) and the contract partners (Martin Systems, TUB).

7.6. Task 6: Special investigations and assistance to plant operation & monitoring program (Mth 16-36)

This task did effectively start in March 2006, after the commissioning of the MBR demonstration plant. As previously explained (in section 7.4-Task 4), no parallel pilot plant was built up and operated on the site of the demonstration plant.

The special investigations on biokinetics and membrane filtration performances and fouling will be undertaken throughout the evaluation period. Samples of fouled membranes will be regularly extracted from a membrane module operated in parallel, and sent out to Anjou Recherche for complete diagnosis of foulants characteristics.

Two different cleaning regimes of the membrane modules will be implemented and assessed, one per filtration line:

1. regular low-concentration maintenance cleanings
2. unfrequent high-concentration recovery cleanings

Both cleaning regimes will be based on hydrogen peroxide in order to avoid the use of chlorine-type cleaning agents. The parallel evaluation of these two cleanings will enable to select the most appropriate in terms of sustainable filtration performances and chemical / operator costs for the long term operation of the plant.

In addition to these trials, other specific investigations will be undertaken according to the needs during the plant operation (trouble shooting).

7.7. Task 7: Demonstration plant start-up & operation (Mth 19-36)

The commissioning protocol was implemented as described in **Annex 7.6**, and the trials and regular monitoring program started straight after commissioning as per **Annex 7.7**. With further connections of the parcels, it is expected that the plant reaches its nominal design flow in the course of June. The plant will be then operated and optimised over one full year (summer / winter seasons) in order to undertake a complete technical and economical evaluation of the treatment scheme.

8. DISSEMINATION ACTIVITIES

8.1. Dissemination strategy

The dissemination on the project is organised around the following vectors of communication throughout the project:

1. **Tri-lingual KWB webpages (www.kompetenz-wasser.de)**: pages dedicated to ENREM projects with detailed info and downloads;
2. **Press-releases and articles in bi-lingual KWB-Newsletter**: for all relevant milestones of the project;
3. **Articles in local press** for general public;
4. **Technical and scientific communications**: in journals or local, national or international conferences (incl. two participations in “KWB Wasserwerkstatt”), towards expert public;
5. **Visits of MBR-demonstration plant**: the team is committed to organise visits of the site and presentations of the project on demand in the course of the project;
6. **Communication material (general info)**: preparation of posters, flyers, fact sheets, information board etc
7. **KWB activity report**: 1-page presentation of project and progresses in yearly reports since 2004.

In addition to this regular dissemination activities, special events will be organised:

1. **Official inauguration of the plant** (planned for 19th June 2006): with representatives of partners, local authorities, local scientific community and journalists. A press conference will be organised, as well as a “day of opening doors” in the afternoon for the local residents.
2. **Final project workhop** (planned in June 2007): the one-day final project workshop will present the full outcomes of the project. Other similar projects will be invited for presentations in order to offer further exchange of experiences.

The communication activities led to the elaboration of the following graphical material (subcontracted to communication agencies), which have been used intensively:

1. A project logo, to be inserted in all communication material (posters, presentations, flyers etc) in order to enhance the visual identity of the project
2. A series of 2-D and 3-D graphics in order to explain easily the process scheme with pleasant illustrations

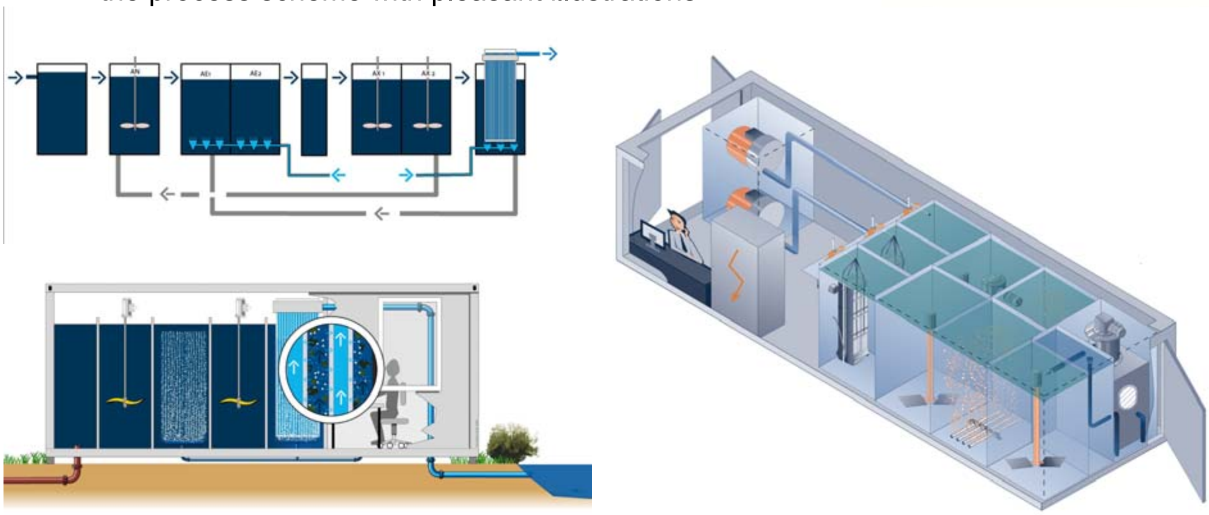


Figure 13. Graphical illustration elaborated for the communication activities of the project

8.2. Dissemination activities undertaken to date

Annex 8.1 presents the full list of presentations and publications performed in appropriate symposia and conferences. **Annex 8.2** draws the full list of other communication activities (press release, newsletter, etc) and **Annex 8.3** provides the full list of official meetings / visits during which the project was presented.

The salient communication activities were:

1. **Tri-lingual KWB webpages (www.kompetenz-wasser.de)**: Project presented online since March 2004. Actualisation in January 2005 with full details and downloads. A new actualisation of the website is pending (the update on quaterly basis happened to be too time consuming);
2. **Press-releases and articles in bi-lingual KWB-Newsletter**: A press-release was distributed for the official start of the project and the official inauguration of the plant; On top of these events, the KWB Newsletter announced the completion of the preliminary tests and the delivery of the demonstration plant;
3. **Articles in local magazines and journals**: 4 articles were published in the local journals “Das Grundblat” (October 2005), “Das Tagespiegel” (November 2005), “Grünblick” (March 2006), and “Wasserspiegel” (March 2006);
4. **Technical and scientific communications**: Beyond the participation in “KWB Wasserwerkstatt” numerous oral or poster presentations were accepted in national or international seminars and conferences. The most reputed events were:
   - IWA Marrakech 2004, Morocco (19-24 September 2004)
   - International conference on sustainable water systems, Berlin, Germany (4-6 Oct. 2004)
   - 6th International Conference and Exhibition « Wastewater 2005 », Teplice, Czech Republic (10-12 May 2005)
   - IWA Specialist Conference “Nutrient Management in Wastewater Treatment Processes and Recycle Streams”, Krakow, Poland (18-21 September 2005)
   - 6. Aachener Tagung "Membrantechnik in der Wasseraufbereitung und Abwasserbehandlung", Aachen, Germany (25-26 Oktober 2005)
   - Water Environment Research Foundation (WERF) Workshop, Washington U.S., (9-11 March 2006)

5. **Visits of MBR-demonstration plant**: Since the start-up of the plants, several visits have been organised on demand.
6. **Communication material**: 3 posters (2 in English and 1 in German) were prepared to present the projects in seminars and conferences, as well as one fact sheet (in English, 2,000 copies) and one flyer (in German, 1,000 copies). A project information board was prepared and clearly set up on the demonstration site.

9. EVALUATION AND CONCLUSIONS

9.1. Project implementation

a. The process

The wastewater treatment process implemented in the ENREM project is based on the used of the membrane bioreactor technology for biological advanced nutrients removal. It is thought to be an economical solution to equip remote and small wastewater schemes (200 – 5,000 e.p.) where high treatment performances are required for sensitive and/or bathing areas: disinfection and low nutrients concentration in the treated water.
The technology of membrane bioreactor offers the following advantages over conventional systems:

- reliable treatment quality
- possibility of remote / central control of a decentralised system
- compacity and therefore reduced nuisances (odours, visual disturbance etc)

The combination with a separated collection sewer enables in addition to optimise the size of the reactor volume and membrane surface. The use of low-pressure sewer could be an additional advantage, as the 1 to 2 day residence time in the shafts + sewer enhance the presence of Volatile Fatty Acids required for the biological nutrients removal.
The vision of the project is to demonstrate the construction and operation of an MBR system in a container with a simple and patented configuration for advanced nutrients removal, to assess the technical performances and the economical viability when implemented with a low pressure sewer.

b. Project management and problems encountered

The project was implemented as per the LIFE proposal, however unforeseen events during the preparation and construction phases of the project caused a project delay of 8 months up to the start of the demonstration plant, which occurred in month 27 instead of month 19. This global delay can be accounted for by the following individual items: belated official project start-up, difficulties to collect the construction permit, late unit delivery, period of deep soil frost (no connection possible), and break-in of container plant (lost of supervision unit).
During the second phase of the project, the operation and monitoring of the performances should enable sound technical and economical evaluation.

c. Technical and commercial application

The concept tested in the ENREM project could be showed to be technically and economically viable for small and remote communities (200 – 5,000 pe) in sensitive or bathing water areas. This could be especially appropriate in rural regions with a low connection rates, such as some districts of ex-East Germany or the East-European countries. If the concept is proven to be viable, other non connected peri-urban zones of Berlin will be similarly equipped.

9.2. Analysis of long-term benefits

a. Environmental benefits

1. Direct / quantitative environmental benefits

The concept may provide a technical and sustainable solution for the handling of the wastewater produced by small communities (200 – 5,000 e.p.). To date, the communities of this size are very often not equipped with central sewer or adequate treatment scheme, and they release partly treated wastewater effluent in surface water or in ground water. The emissions originating from these areas can therefore be considered as a semi-diffuse

source of pollution. It was for example stated at the meeting “Bundestagung und Landesverbandstagung 02/03.09.2003” in Wolfsburg that 44% of the DOC emitted by waste water treatment plants result from small decentralised waste water treatment plants with an input of less then 8 m³/d even if they are used only by 9,5% of the population. Similarly, a recent study (Behrendt, 1998) showed that in Mecklenburg-Vorpommern, the Northern area of east-Germany, the emissions of point source contribute to the total emission of 10% nitrogen and 25% phosphorus. This is also much likely that most of this pollution originate from disperse small decentralised plants of households and small communities.
This shows the need of technical enhancement for decentralised plants, especially for sensitive areas and/or bathing water areas. The used technique of combining enhanced biological phosphorus removal with post-denitrification in a MBR could be an efficient and cost-effective alternative to conventional processes to match enhanced effluent quality. Compared to conventional systems it offers a nearly axenic effluent which contains only little organic, nitrate and phosphate concentrations. Hence, it can make a valuable contribution to keep our waterbodies hygienically clean and prevent eutrophication. This is especially significant in decentralized areas, where the treated water is often discharged into small waterbodies.

2. Relevance for environmentally significant issues or policy areas

The “EU-Bathing Water Directive” was passed 25 years ago. However, to date, still 10% of the coastal and 28% of inland bathing water in the EU does not meet the European guide values. We can expect that the contribution of small plants lacking efficient disinfection or pathogen reduction steps is also significant in this domain. In the next years, stricter EU regulations will be implemented for sensitive areas and/or bathing waters.
The concept of wastewater treatment scheme tested within the ENREM project could contribute to the technical solutions offering complete disinfection and low nutrients concentrations in treated effluents of small communities locatded in sensitive or bathing water areas.

10. PLANNED PROJECT PROGRESS

By the end of the project, the MBR demonstration plant will be operated continuously, treating 100% of the wastewater collected on site. The operation and performance of the plant will be optimised and assessed under full loading capacity over about 12 months. Any technical trouble occuring during the operation of the plant will be analysed and corrective measures will be proposed and implemented (trouble shooting).

The performance of the systems (both the biology and the membrane performance) will be thoroughly monitored and assessed according to the trials and monitoring program described in **Annex 7.7**. Ultimately, the concept will be assessed from both technical and economical points of view.

The communication strategy will continue as described above (Section 8) up to the term of the project, with both aims to advertise the projects and to disseminate the results and outcomes. Regular visits of the demonstration scheme will be organised on request, and a final project workshop will organised in June 2007, as well as the official plant inauguration in June 2006.

The GANTT chart presented in Figure 3 summarises by task the current progress of the project and the planned activities.

11. COMMENTS ON FINANCIAL REPORT

Table 2 provides the summary of the project costs incurred at the period of reporting (mid 2006), at completion of the project phases related to the preparation, the plant construction and the commissioning stage (remark: some final billings still missing for the infrastructure costs of the scheme).

	Cost category	Total cost according to the Commission's decision	Costs incurred from the start date	%
1.	Personnel	790,640	293,139	37%
2.	Travel	41,100	12,071	29%
3.	Outside assistance	100,682	116,645	116%
4.	*Durables: total non-depreciated cost*	*2,120,000*	*1,009,994*	*48%*
	- Infrastructure sub-tot.	1,930,000	946,271	49%
	- Equipment sub-tot.	190,000	63,722	33%
	- Prototypes sub-tot.	0	0	-
5.	Consumables	191,300	2,308	1%
6.	Other costs	51,000	15,780	31%
7.	Overheads	122,656	56,025	46%
	SUM TOTAL	**3,417,378**	**1,503,184**	**44%**

Table 2. Project costs incurred at period of reporting (at completion of preparation, construction and commissioning phase)

Comments on budget posts:

- Overall budget: To date, 44% of the planned budget was spent for the project.
- Personnel: Only 37% of the planned budget was incurred after commissioning of the demonstration plant. The activity should increase during the operation and monitoring phase (1 engineer and 2 technician full time over 18 months). With the planned project extension of 8 months, the personnel post should be under the prevision of the proposal, and in the range €500,000 to 600,000 (60 to 75%).
- Travel: 29% of the planned budget was effectively spent so far. As the results will come during the operation and monitoring phase, more needs of meeting with the project partners in Anjou Recherche will be required. In addition, more communications will be performed in international events. It is anticipated to spend around € 25,000 by the end of the project (about 60% of plans).
- Outside assistance: Single post exceeding the planning (by 16%). Despite minor expenses (car hiring), the main subcontracting activity of the project refers to the preliminary pilot trials undertaken by the Technical University of Berlin. A contract of € 116,467 was executed. This is around 23,000€ more than planned due to unforeseen 25% overheads claimed by the administration of the University (subcontract agreement between KWB and TUB available on request).
- Infrastructure: To date, the bills gathered for the construction of the infrastructure amount to € 946,271. Some final bills are still expected from contractors and administrative costs, and the final cost related to the infrastructure is anticipated not to exceed € 1,700,000. This is below the € 1,930,000 initially planned, and can be explained by the small size of the site selected for the demonstration (250 inhabitants served; the size range of 250 up to 1,000 inhabitants was considered at the proposal stage).
- Equipment: 33% of the budget was incurred so far. At project completion, 50 to 60% should be reached.
- Consumables: Most of these costs will occur during the operation of the plant, including € 100,000 for analyses. No major change of budget expected.
- Other costs: 31% of the budget was attributed. 80 to 90% of this budget should be reached by the completion of the project.

- Overheads: The overheads of the three partners are much beyond the maximal value of 7% of eligible costs allowed in the LIFE program (see Appendix “Calculation of overheads expenses” in Finance Report). The initial budget planned for the overheads, fixed on the maximal value of 7% of eligible costs, should be matched.

Conclusion on financial issues:
So far, the budget is generally in line with the expectations, or slightly below. **The project finances allow the project extension of 8 months**, required to achieve all announced technical outcomes of the project. After the 8 month extension **the final project budget is expected to remain about 20% below the planned proposal, i.e. approx. € 600,000 savings** on the total budget should be recorded, corresponding to a **subvention reduction of approx. € 100,000** (also close to 20% reduction).

12. References

Gnirss R. and Dittrich J. (2001). Microfiltration of municipal wastewater for disinfection and advanced phosphorus removal: Results from trials with different small-scale pilot plants. Wat. Env. Res., 72 (5), pp. 602-609 (2001).

Lesjean B., Gnirss R., Tazi-Pain A. (2005). Membrane bioreactor for semi-central sanitation with enhanced treatment performances. Proceedings of 6th International Conference and Exhibition « Wastewater 2005 », 10-12 May 2005, Teplice, Czech Rep.

Reicherter E. (1999). Kosten und Betriebsdaten von Kleinkläranlagen. Seminar des Bayerischen Industrieverbands Steine und Erden e.V., 6 October 1999, Hirschaid, Germany.

13. Appendices

List of Annexes:

Annex 7.1 List of key deliverables and milestones
Annex 7.2 MBR plant specification (summary)
Annex 7.3 List of 11 MBR suppliers proposed to submit an offer
Annex 7.4 Reasons for selection of TUB as subcontractor of the preliminary trials
Annex 7.5 Recommendations from preliminary trials
Annex 7.6 Commissioning protocol (in German)
Annex 7.7 Trials and monitoring program

Annex 7.1 List of key deliverables and milestones

Task	Deliver. Milestone	Description	Date	Status
Task 1	**D1 & M1**	Progress report	Month 12 12.2004	Completed in Mth 14
Task 1	**D2 & M2**	Interim report	Month 24 12.2005	Covering period up to plant start-up (Mth 27) Completed in Mth 30
Task 1	**D3 & M3**	Final report	Month 36 12.2006	-
Task 2	**D4**	Report on technical and economical comparison of potential demonstration sites	Month 4 04.2004	Completed by Month 6. Data of 20 potential sites in Annex 5.1 and cost comparison of pre-selected sites in Annex 5.2. Full report (19 pages + Annexes, German, available on request)
Task 2	**D5**	Documentation of public tender preparation and bids from suppliers, first project plans	Month 12 12.2004	Completed by Month 13. Design of plant and sewer presented in Annex 5.3 and Annex 5.4. Available on request (German): specification of MBR plant (15 pages); call for tender of MBR plant (80 pages + annexes), call for tender of sewer (30 pages + annexes)
Task 2	**M4**	Selection of demonstration and test site	Month 3 03.2004	Completed in Month 4 and 5. Demonstration site: Margaretenhöhe Test site: Grünau pumping station
Task 2	**M5**	Budget revision (infrastructure and equipment cost)	Month 3 03.2004	Completed in Month 7. To the latest estimation, the budget should fit with the LIFE proposal
Task 2	**M6**	End of preparative work & decision from EU LIFE	Month 8 08.2004	Completed in Month 9.
Task 3	**D6**	Plan, flow sheet and photos of pilot plant, first test results, raw water characterisation	Month 12 12.2004	Completed on time. Report available separately.
Task 3	**D7**	Complete results of preliminary tests, confirmation of process parameters	Month 24 12.2005	Completed in Month 21. Report available separately.
Task 3	**M7**	Start-up of pilot plant	Month 5 05.2005	Completed in Month 7
Task 3	**M8**	Verification of basic process design	Month 8 08.2004	Completed by Month 10.
Task 3	**M9**	End of testing on representative site	Month 15 03.2005	Completed in Month 21
Task 4	**D8**	Detailed project plans, documentation on public tender process and sub-contactors selection	Month 12 12.2004	Call for tender released in Month 13. Selection of subcontractors completed in Month 16
Task 4	**D9**	Project plans of IT-System	Month 24 12.2005	IT architecture & requirement identified and included in MBR specifications. Details were agreed upon with subcontractors
Task 4	**M10**	Design & planning of sewer system completed	Month 10 10.2004	Completed in Month 12
Task 4	**M11**	Main equipment supplier identified	Month 10 10.2004	Completed by Month 14
Task 4	**M12**	Orders issued for main equipments	Month 12 12.2004	Completed by Month 15
Task 4	**M13**	Design and planning of demonstration plant completed	Month 12 12.2004	Completed in Month 12
Task 4	**M14**	End of detailed design	Month 14 02.2005	Completed in Month 15
Task 5	**D10**	Evidence of sewer and demonstration plant construction, written protocols for start-up, operation and experimental trials	Month 24 12.2005	Completed in Month 24
Task 5	**M15**	Start of demonstration plant construction	Month 13 01.2005	Completed in Month 17
Task 5	**M16**	End of plant and sewer construction	Month 18 06.2005	Completed in Month 22
Task 5	**M17**	Legal authorisation obtained for operation	Month 18 06.2005	Completed in Month 24

Task 6	**D11**	First important test results from testing on real site	Month 24 12.2005	Cancelled
Task 6	**D12**	Investigations made during operation, troubles occurred and solutions found	Month 36 12.2006	Will be available at term of project
Task 6	**M18**	Start up of pilot plant on real site and parallel operation	Month 19 07.2005	Cancelled
Task 6	**M19**	End of pilot operation on real site	Month 36 12.2006	Cancelled
Task 7	**D13**	Reports on demonstration plant start-up and first operation performances	Month 24 12.2005	Will be available in Month 36
Task 7	**D14**	Reports on operation performances and process evaluation & optimisation	Month 36 12.2006	Will be available at term of project
Task 7	**M20**	End of commissioning and start-up phase, 100% connection	Month 22 10.2005	Plant started up in Month 27. 80% connection rate reached in Month 30
Task 7	**M21**	End of demonstration phase	Month 36 12.2006	Subject to submission of project extension
Task 8	**D15**	Update on dissemination actions	Month 12 12.2004	Available in Progress Report 1
Task 8	**D16**	Update on dissemination actions	Month 24 12.2005	Available in Interim Report 1
Task 8	**D17**	Update on dissemination actions	Month 36 12.2006	-
Task 8	**M22**	Set-up of project description on internet	Month 3 03.2004	Completed in Month 5
Task 8	**M23**	Fixed update of internet pages	Mth 12, 24, 36	First update completed in Month 13 Second update in Month 30
Task 8	**M24**	Organisation of final project workshop	Month 32 08.2006	Planned for June 2007
Task 8	**M25**	Publication of project CD-ROM	Month 36 12.2006	Planned before term of project

Annex 7.2 MBR plant specification (summary)

Dimensioning criteria

Connection	250 pe
Actual water demand	12 m³/d (50 L/pe/d)
Expected connection rate	80%
Most probable operation flow	10 m³/d (design for biology)
Increase potential	Up to 24 m³/d

(Hydraulic load only no increase of pollution load expected)
100% treatment. No by-pass or safety overflow.

Raw water characterisation

Wastewater of domestic origin only, collected by low-pressure system:

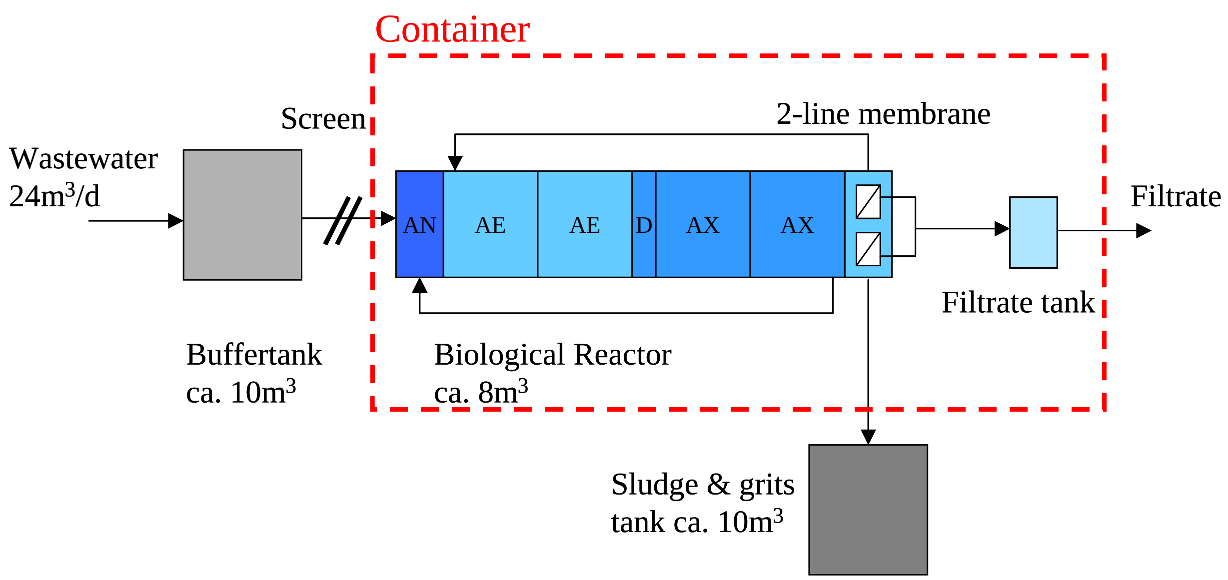
- No industrial wastewater or stormwater
- Grinding of wastewater < 7mm

50%-tile concentrations (based on wastewater characterisation of Grünau Pumping station and Rahnsdorf catchment)

Parameter	Concentration	Load
BOD5	493 mg/L	5.9 kg/d
COD	986 mg/L	11.8 kg/d
TS	356 mg/L	4.3 kg/d
TN	108 mg/L	1.3 kg/d
TP	15 mg/L	0.2 kg/d
VFA	94 mg/L	1.1 kg/d

85%-tile concentration of TN = 131 mg/L (120 mg/L after 12h-buffer tank)
=> 120 mg/L as peak-load for nitrogen
Min. Temperature: 12°C

Overall design



Equipment included in plant (in container)

- Screen (if required)
- Pumps
- Membrane & biology aeration
- Online-Sensor and analysers
- IT control and data acquisition

- Remote control and supervision with alarms

Pre-treatment

- $10m^3$ buffer reactor with bottom drain and outflow 50cm over bottom, inflow below water level, excess air to biology through ventilators
- Screen without bypass or overflow: place and type up to contractor (<1mm for HF, at the discretion of manufacturer for FM)
- PID control of flow to biology
- No possibility of mixed liquor return to buffer tank

Biological reactor

Zone	Volume	Remark
Anaerobic	400 L	+/- 10%, with mixer
Aerobic	2x 1,750 L	+/- 10%, with aerators
Deox	> 40 L, < 120 L	Eventually with mixer
Anoxic	2x 1,750 L	+/- 10%, with mixer
Membrane	Preferred < 600 L	As small as possible
Total	Ca. 8,000L	-

1.5 to 2m deep (except perhaps membrane reactor), with min. 50cm overboard
Sludge recirculation loops: 80-200% and 400-1000% (based on 12m3/d)

Biology aeration

2x fine bubble aeration (in AE1 and AE2) for oxygen transfer + sludge mixing
1 energy-efficient compressor
Removable aerators (crane)
Should warranty 2mgO2/L in both reactors, even in extreme conditions (COD-load = 11.8kg/d, TN-load = 1.3kg/d, MLSS = 18g/L, Sludge age = 50d, T° = 25°C, α = 0,5-0,7)
=> transfer of 10 g/(nm3 * mET)) required
Total aeration requirement between 2.9 and 29 Nm^3/h (without account for O2 carry-over from membrane reactor)
To be confirmed by contractor depending on DO carried over from membrane reactor and final technological choices (aerator type, reactor depth, etc). Calculation requested with demonstration of functioning in first year of operation.

Filtration system

- 2 filtration lines with separated reactors preferred but not imposed given the size of the system.
Constraint: the filtration should not be completely off-line (for cleaning, maintenance etc) for more than 5h (1/2 HRT in buffer tank).
- If 2 lines: Autonomous and independent functioning of two filtration systems, with interlocking in case of trouble on one of two lines.

- Designed with an instant flux of max. 10lmh and a throughflow of 12m3/d.
- Place reserve for addition of membrane surface to cope with up to 24m3/d (at instant flux of max 15lmh)
- Net volume: as small as possible, and preferred below 600L, with at least 50cm overboard
- Hydraulics: preferred sludge overflow from membrane tank to aerated zone (no bulking sludge in membrane tank)
- Removable modules and aerators (crane)
- If 2 lines: preferred autonomous and independent aerator per membrane line, with two separated air blowers (investment costs vs. energy efficiency + redundancy: if one fails, the other one should serve both systems). Capacity to be determined by contractor

Cleaning concept

Full protocol to be proposed by contractor.

Evidences and references should be given.
Constraints:

- no use of chlorine
- no heating preferred
- duration no longer than 5h when filtration completely off-line

On-line sensors and analysers

1. Biology (supplied by contractor, except sludge concentration)
    - 1x influent flow (before buffer tank?)
    - 2x sludge recirculation flow
    - 2x air flow
    - 1x redox (AX1)
    - 2x O2 (AE1, AE2)
    - 1x temperature (AE1)
    - 1x pH (AE1)
    - 2x sludge concentration (Membrane reactor + AE1)
    - 2x water level through pressure sensor (AX1 + buffer tank)

2. Filtration units (supplied by contractor)

Per filtration line:

- 1x TMP (differential)
- 1x filtrate flow
- 1x aeration flow

Plus 1x turbidity (in bypass from either filtration line)

3. MBR-filtrate (supplied by KWB)
    - 1x TP / PO4
    - 1x NO3

Annex 7.3 List of 11 MBR suppliers proposed to submit an offer

	Company	**Membrane type**	**Country**
1	A3	FM	Germany
2	Earth-Tech	FM (Kubota)	Germany
3	HUBER	FM	Germany
4	Martin System	FM	Germany
5	Memcor	HF	UK
6	PALL	HF	Germany
7	PURON	HF	Germany
8	Rotreat	HF (Mitsubishi)	Austria
9	Toray	FM	UK
10	VWS	HF (Zenon)	France
11	Zenon	HF	Germany

FM: Flat sheet membrane HF: Hollow fibre membrane

Annex 7.4 Reasons for selection of TUB as subcontractor of the preliminary trials

The subcontractor of Task ID 3 was identified as the Technical University of Berlin as early as the first proposal to the EU-LIFE programme submitted in November 2003. This choice was confirmed in the revised and final version of June 2004, following the comments received from the European Commission on 07.05.2004. In meanwhile, a subcontract agreement was signed between TUB and KWB in April 2004.

The decision not to resort to a public tender or a consultation (3 independent offers) can be justified as follows:

- In order to respect the schedule of design, construction and commissioning of the demonstration plant, this task had to be started in April 2004, which did not allow for proceeding with a public tender or even a consultation.
- The facilities of the TUB (laboratory, workshop, small pilot plants, etc), their competences (broad experience with MBR technology and realisation of pilot studies), and their location (local R&D team in Berlin) enabled them to perform task ID 3 successfully with optimised time and budget.
- The TUB was involved as sub-contractor in the 3-year R&D phase (2000-2003) undertaken between Berliner Wasserbetriebe and Anjou Recherche in the frame of the KWB to develop the considered MBR process in the ENREM project. The TUB is therefore very much familiar with the process, and a good pre-existing working relationship prevails between the TUB and the partners.

To be noted that TU Berlin is no longer shareholder of the KWB since January 2003, and that the budget of this contract has been thoroughly negotiated in relation with the expected services, according to the rules of non profit companies in Germany (as per § 55 – 3 of “Abgabenordnung” – fiscal code).

Annex 7.5 Recommendations from preliminary trials

The preliminary trials led to the following recommendations in terms of design, start-up and operation of the demonstration plant:

The plant should be seeded with recirculation sludge from another plant with a TS concentration of 8 – 10 g/L to prevent an intense fouling of the membrane during start-up. It will also ensure sufficient COD elimination directly from the start.

The start-up of the demonstration plant should be done if possible with in-plant-temperatures above 15°C to enhance the growth of nitifiers. In case this is not possible, the throughput of the plant should be reduced by 30% of the targeted average flow in order to prevent inhibitory ammonia concentration in the plant and nitrite build up. When the nitrification rate is reaching values above 4 mgN/h/gVSS in standard batch test, full throughput can be implemented.

To build up biomass no excess sludge should be drawn in the first days. Depending on growth, excess sludge removal can start after 1 to 2 weeks. 2 weeks shall no be exceeded in order not to overload the sludge with phosphorus.

Comparison of biological performance during the two different periods

	Irregular excess sludge removal	Continuous excess sludge removal
P-effluent concentration	0.1-0.5 mg/L	0.1-0.5 mg/L
Denitrification rate	1-1.5 mgN/h/gVSS	1-1.5 mgN/h/gVSS
Nitrification rate	unsteady, Ø 2 mgN/h/gVSS	stable 4 mgN/h/gVSS
Complete nitrification	Often not before membrane chamber	In aerobic zone

For excess sludge removal strategy a continuous withdrawal is recommended for several reasons. As can be seen in the Table above, most biological kinetics were not affected by the excess sludge removal strategy, but nitrification was, and the aerobic zone would have to be build two times bigger with irregular removal. Secondly, fouling was lower in the period with regular excess sludge removal. Due to the high influent concentrations for all parameters, always a high TS concentration is needed for good nutrient elimination. In Berlin, the possible savings by not building an extra tank for excess sludge storage are small. And finally, the extra tank can be used as a storage in a contingency.

An SRT of 25d to 30d is recommended to achieve both, good nitrification and good P-removal.

Recommended hydraulic contact times are at least 30 min for the anaerobic zone, 15 min to 20 min for each of the two aerobic zones and 30 min to 40 min for each of the two anoxic zones. Concerning the recirculations in the plant, this would lead to an overall hydraulic retention time of 14h to 15h. These calculations are based on an average ammonium inflow concentration of 90 mg/L.

Oxygen concentrations in the first aerobic reactor should be controlled to 2 to 3 mg/l and in the second aerobic reactor to 1 to 2 mg/L. Between the aerobic and anoxic zones a degassing chamber should be installed. The design of this chamber should avoid sludge accumulation by e.g. a stirrer or top-to bottom through flow.

Because of possible foam formation the walls should exceed the water surface by 50 cm. Very big anaerobic foam layers can cause P-release and therefore reduce the effluent quality. Foam destroyers should therefore be mounted on the stirrers of the anoxic zones.

No clear strategy could be developed to prevent worm blooms, but it is recommended to observe metazoa growth and fight worms directly from the start. Otherwise the risk of massive accumulation of worm eggs in plant exists which makes it difficult to fight the worms afterwards.

Annex 7.6 Commissioning protocol (in German)

The commissioning protocol presented in the next 10 pages was agreed between project partners and was thoroughly applied during the start-up phase of the demonstration plant.

	Inbetriebnahme, Probebetrieb, Abnahme/Übergabe	
1	**Allgemeine Voraussetzungen**	
2	**Gerätetechnische Inbetriebnahme**	Die gerätetechnische Inbetriebsetzung beinhaltet die Inbetriebnahme der einzelnen Geräte und Aggregate (interne Funktionsprobe), die Überprüfung der Verkabelung, den Test der einzelnen Antriebe kalt (mit freigeschaltetem Leistungsteil) und warm (mit zugeschaltetem Leistungsteil zur Drehrichtungsprobe) und den Test des Zusammenspiels zwischen Mess- und Steuerungstechnik und Antriebstechnik (komplexe Funktionsprobe). Während der gerätetechnischen Inbetriebsetzung werden die Messeinrichtungen in Betrieb genommen, es erfolgt die Voreinstellung der Geber, die Einstellung der Überstromauslöser und die Programmierung der Frequenzumformer.
3	**Funktionsproben "Trocken"**	Überprüfung beweglicher Teile auf ihre richtige mechanische Funktion, die Richtigkeit der Drehrichtung, die Kontrolle hinsichtlich erforderlicher Schmiermittel usw.
4	**Funktionsproben "Mit Klarwasser"**	Hierbei werden die Anlagen auf ihre Funktionsfähigkeit hin überprüft und die erforderlichen Einstellarbeiten ausgeführt, es erfolgt des weiteren die Prüfung von Rohrleitungen und Behältern auf Dichtigkeit usw..
5	**Erstinbetriebnahme**	Befüllung der Becken mit gereinigtem Abwasser und belebtem Schlamm, Zulauf von Abwasser, Anfahren der Anlage. Die Erstinbetriebnahme ist beendet, wenn die einwandfreie Funktion aller Anlagenteile nachgewiesen wurde, die Anlage mit Schlamm und Abwasser gefüllt und für den verfahrenstechnischen Betrieb bereit ist.
6	**Probebetrieb**	Der Probebetrieb dient zum Nachweis der Einhaltung der Parameter der Anlage, zum Nachweis des störungsfreien Anlagenbetriebes und des Erreichens der geforderten Ablaufwerte. Die Dauer des Probebetriebes erstreckt sich über 4 Wochen.
7	**Schulung**	
8	**Abnahme/Übergabe**	
9	**Sonstiges**	- Begehung Arbeitssicherheit - Bauabnahme gem. BWG (siehe Wasserbehördliche Erlaubnis) - Bauzustandsbesichtigung (siehe Baugenehmigung)

1 Allgemeine Voraussetzungen

		Datum	Unterschrift
1.1	Die Anlage ist komplett montiert und steht zur Inbetriebnahme bereit.		
1.2	Übereinstimmung der Anlage mit den vorhandenen Unterlagen Erforderliche Unterlagen: - R&I-Fließbild - Anlagenkennzeichnungsliste - Antriebsliste Maschinentechnische Ausrüstung (Lastenheft, Anlage 1) - Messstellenliste (Lastenheft, Anlage 2) - Lastenheft		
1.2	Die gesamte Anlage ist gereinigt.		

2 Gerätetechnische Inbetriebnahme

3 Funktionsproben "Trocken"

		Datum	Unterschrift
2./3.1	Funktionsnachweise für alle Antriebe in Einklang mit - R&I-Fließbild - Anlagenkennzeichnungsliste - Antriebsliste Maschinentechnische Ausrüstung (Lastenheft, Anlage 1)		
2./3.2	Funktionsnachweise für alle Messstellen in Einklang mit - R&I-Fließbild - Anlagenkennzeichnungsliste - Messstellenliste (Lastenheft, Anlage 2)		

4 Funktionsproben "Mit Klarwasser"

		Datum	Unterschrift
4.1	Vorliegen des Befüllungskonzeptes		
4.2	Die Module sind nicht eingebaut		
4.3	Befüllung der Anlage mit Klarwasser		
4.4	Durchführung der Funktionsproben mit - Kontrolle des Blasenbildes in der aeroben Zone bei unterschiedlicher Luftzufuhr		
4.5	Einbau der Module		
4.6	Durchführung der Funktionsproben mit - Kontrolle der gleichmäßigen Modulanströmung - Variation des Fluxes mit jeweiliger Messung der Permeabilität (Abfolge: 0 – 10 – 20 – 30 – 20 – 10 – 0 $L/h*m^2$)		
4.7	Abfahren des Reinigungsprogrammes		

5 Erstinbetriebnahme

		Datum	Unterschrift
5.1	Beschickung der Anlage mit Abwasser		
5.2	Befüllung der Anlage mit Belebtschlamm (Überschussschlamm aus dem Klärwerk Schönerlinde (TSÜS = ca. 6 kg/m³, QÜS = 10 m³)		
5.3	Anfahren der Anlage unter Betriebsbedingungen		
5.4	Freigabe zum Probebetrieb		

6 Probebetrieb

		Datum	Unterschrift
6.1	Abstimmung der Fahrweise (Normalbetrieb und Leistungsfahrten)		
6.2	Vorlage eines vorläufigen Betriebshandbuches		
6.3	Bereitstellung des späteren Betriebspersonals (AG)		
6.4	Beginn des Probebetriebes		
6.5	Erstellung von Tagesprotokollen		
6.6	Bericht über den Verlauf des Probebetriebes, besondere Vorkommnisse, evtl. aufgetretene Mängel mit Darstellung der Ursachen)		
6.7	Ende des Probebetriebes		

7 Schulung

		Datum	Unterschrift
7.1	Die Schulung erfolgt während des Probebetriebes		
7.2	Zur Schulung muss das Störfallkonzept vorliegen. Die Simulation verschiedener Störfälle erfolgt nach vorheriger Absprache.		

8 Abnahme/Übergabe

			Datum	Unterschrift
8.1	Vorlage einer vorläufigen Dokumentation und eines revidierten Betriebshandbuches			
8.2	Abnahmeprotokoll			
8.3	Übergabe			

9 Sonstiges

			Datum	Unterschrift
9.1	Begehung Arbeitsicherheit Kontakt: PM – ASI, Herr Riedel			
9.2	Bauabnahme (gem. § 70 Abs. 1 BWG (schriftliche Beantragung)) Kontakt: Senatsverwaltung für Stadtentwicklung, Herr Schmidt			
9.3	Bauzustandsbesichtigung Anzeige: NA-P/S, Herr Frielinghaus			
	Benötigte Unterlagen:	Verantwortlich		
	- Schlussüberwachungsbericht des Prüfstatikers	NA-I/P, Frau Sixtus		
	- Gewährsbescheinigung der Errichterfirma der Continer (Anlagen- und Laborcontainer)	Hersteller über MartinSystems		
	- Gewährsbescheinigung der Errichterfirma der semizentralen Abwasserbehandlungsanlage	MartinSystems		
	- Vertrag mit dem Amt für Umwelt und Natur über das Wegerecht auf der verlängerten Florentinestr. und Teilstück B des Flurstücks 40 (Zufahrt)	AE-T, Herr Sahlmann		

Annex 7.7 Trials and monitoring program

The following trials and monitoring program was agreed upon between project partners:

Routine analyses and wastewater characterisation

- BWB labor analyses (standard)
  - Chemical parameter (24h-m, incl. VFA): 1x / 8d
  - Heavy metals (24h-m): 1x / mth (32d)
  - Microbiology + AOX (grab sample): 1x / 8d (1 lane / 16d)
  - Sludge (incl. TP/TS and TN/TS): 1x / 8d

- Site analyses (Doc Lange)
  - IN / OUT chemical parameters (24h-m, incl. VFA, lactate, glucose, TS, VSS, fat & grease): 3x / w
  - Sludge: 1x / w (2x on-line TS)
  - Foam (Volume, TS, N, P): 1x / w
  - Reactor-through profile: 1x / w (COD, N, P, TS, incl TP/TS and TN/TS)
  - IN / OUT daily profile: 1x / mth (each 4h over 72h)

- Few objectives, not to forget
  - Mass balance TS, N, P
  - Sludge yield (determination of excess sludge volume on plant?)

Batch-tests

- Standard batch tests (1x / w)
  - 1h AN, 1.5h AE, 2h AX

- Specific / parallel batch tests (min 1x / w)
  - 24h batch tests for endogen. deni (overnight AE or AX, pH<8)
  - Temperature impact on post-deni winter/sommer
  - Carbon source impact in AN (acetate, lactate etc)
  - Impact of NO3 on Bio-P ? PO3 on post-deni?

- Carbon balance in AN zone (in, out, CO2, storage)

- Objectives
  - Understanding post-deni mechanism + kinetic rates (for design and modelling)

Fouling

- Full-scale modules (3 racks of 6 modules in 2 lines)
  - Online acquisition system: operation & fouling parameters (weekly critical flux, determination of permeability per module etc)
  - 1 cleaning strategy per line : evaluation of maintenance cleaning vs recovery cleaning with H202 (alternative to chlorine-based substances)
  - Before / After cleaning:
    - permeability measurement in water on all 6 modules (in 3rd vessel)
    - module weighting? (biofilm estimation)
    - critical flux

- EPS analysis
  - PS, PR in wastewater, sludge & permeate 2x /w

- Long-term parallel fouling test

- A third filtration rack will e installed in the third filtration chamber
- Start after full connection and normal operation
- Same sludge and operation / cleaning conditions
- Every two months, one of the six modules of the rack will be extracted and replaced. An autopsy will be performed (visual observation + membrane samples sent to Anjou Recherche) in order to investigate the fouling pattern of the membrane.