Semi-decentralized infrastructure in the development area of Knittlingen, Germany

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Introduction

The waste water treatment in Germany has today reached a really high standard. Referring to German statistics in the year 2001 94.6 % of all the inhabitants had access to the public sewer system. 98 % of the waste water was cleaned up to the recommendations of the EU rules. If it is additionally assumed that Germany is rich in ground water resources and situated in a region with sufficient rainfall, why to look for new solutions for urban infrastructure and water management.

But there are several reasons for a revision towards sustainability:

The reconstruction of 485 000 km of public sewers which have been invested in the last 100–120 years is very expensive and will become even more expensive the older the canal system gets.

In the different water bodies an increase of organic micro pollutants (hormones like substances, pharmaceuticals) have been recorded which can not be degraded in standard waste water treatment plants. Additionally there is no hygienic barrier between treatment plants and the receiving water bodies, causing the distribution of polyantibiotic resistancies in the microbial world.

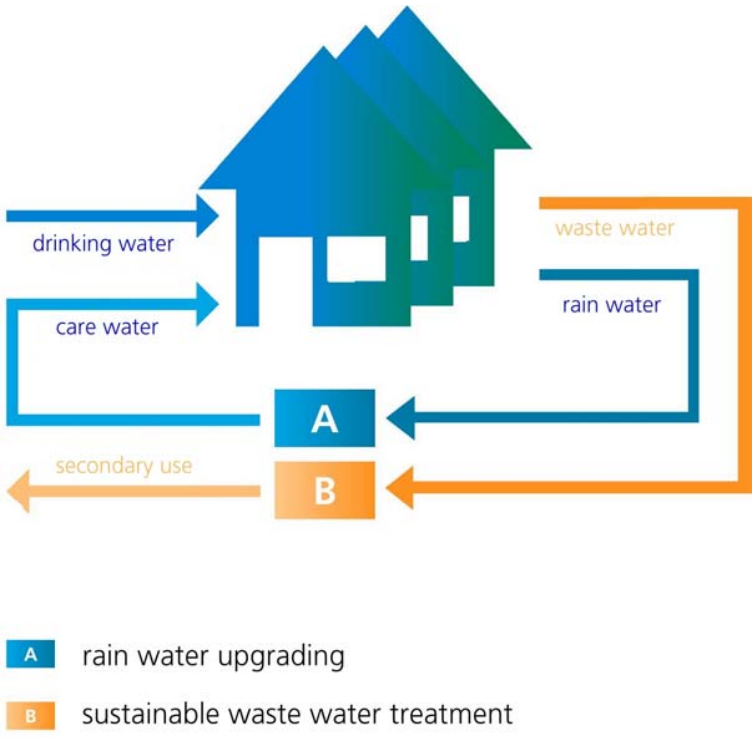
By climatic change along with the global temperature increase it has been analyzed that rain events tend to be shorter and heavier without changing the yearly quantity resulting in increased hydraulic problems and floodings. In addition with a prolongation of the climatic trend drinking water resources may also be shortened in Germany.

The demographic change especially in the new federal states of Germany shows the inflexibility of the existing infrastructure and state of the art technique for waste water treatment: By reduction of inhabitants in several regions the specific costs for the water treatment have increased to non acceptable levels.

The increasing global demand for energy which is covered mainly by fossil materials results in increasing costs for energy, stimulating savings of energy and the search for new resources.

This challenge is mirrored by a new innovative water management concept of Fraunhofer-IGB in the frame of the Project DEUS 21, which is funded by the Ministry of Education and Research (BMBF) as a technical demonstration.

Whereas standard water management is mainly operated in centralized big installations DEUS 21 tends to semi decentralized systems. In a first order of magnitude systems of 100 to 10,000 inhabitants are in the focus of basic designs. Main principal of the design is circuit processing. Thus biogas is the recycling product in respect to the carbon bone of organic pollutants. Additional value recycling substances are Ammonia and Phosphorous to be used as artificial fertilizer. Rain water collection and reuse as new resource of a specific quality of drinking water is incorporated to the concept. The demonstration plant is set in operation in the small town Knittlingen near Pforzheim, Germany, in a new residential zone for about 100 individual houses.



Rainwater from the roofs of the buildings and the residential streets is collected separately and stored in underground stainless steel containers. This water is cleaned up according the requirements of the drinking water rule of the European Union and achieves drinking water quality. As so called „care“ water it is redistributed to the households in a separate net.

Waste water is collected by a vacuum sewer system. In a central station the vacuum is

generated. The waste water of the buildings is collected in a buffer store and sucked away by opening an air valve at the end of the pipe grid. As option the vacuum sewer system can be installed inside the building to make use of water saving toilets and kitchen waste mixers.

The semi decentralized waste water cleaning unit is situated in the centre of the residential zone to minimize the sewer grid. By using an anaerobic low temperature process water depollution is realized along with biogas production. Biogas is used in a cogeneration unit to produce electricity and heat. The value substances Ammonia and Phosphorous are recycled in form of crystalline artificial fertilizer, which easily compete economically to synthetic fertilizers. The outflow of the treatment plant is free of solids especially pathogens in regard of the micro filtration integrated to the bioprocess. The effluent shows bathing water quality (EU-recommendations) and can be reused as irrigation water without poisoning soil and ground water.

Water house

The water house is the operation centre for all techniques of the DEUS 21 water management concept. It is also information and presentation centre for the population and external national and international visitors. The building itself is a cube partially with underground floor. The big window front allows insight to the process and the operation units.

Water house Knittlingen

The water house contains the following process steps and containers:

. • The upgrading and redistribution techniques for rainwater and a 10 m^3 big container for "care" water ready to use
. • The vacuum station, which causes the depression in the canal system and does by means of this extract the waste water by suction
. • The waste water treatment plant as pilot unit for 50 – 70 inhabitants and later on for all inhabitants of the residential zone

As the water house is situated in direct neighbourhood to residential buildings with the advantage of short distances for the sewer, care water and drinking water nets the zero emission standard must be very high: Especially noise emission has to be decreased and individual noise reduction techniques have been installed for individual noise sources.

Rain water use

Rainwater is not only available in a certain quantity covering about 50 % of the drinking water demand but also represents water in a special quality. Rain is a product of solar irradited evaporation of surface water which is recondensed by natural climatic conditions. Source collected rain water has compared to drinking water reduced salinity and therefore is qualified to be used in all cases where water is heated to reduce calzification: dish washer, washing machine, water heater inside buildings for showers etc.
In addition rainwater collection and storage if used area wide reduces the danger of flooding.

In Knittlingen rain water of roofs and residential streets is collected. In a first filtration step (0.6 mm) rain water is cleaned from coarse solids. Included in the first separation apparatus is a possibility to get rid of the higher polluted first liquid flush. The precleaned water is then stored in tanks of 300 m^3 total volume. It is soften oxiginated during storage to prevent fouling.

Cisterns for rainwater storage

To create care water in quality (hygienically) of drinking water the rain has to pass a ceramic ultra filtration (60 nm) membrane with an extremely sharp cut off to make sure to retain all the bacteria and viruses. The cleaned care water is stored in a 10 m^3 container to cover demand peaks.

In a circuit distribution tube the soft care water is transported to the households in comparable pressure as the drinking water net is operated. The circuit is hold at constant circuit flow to pass cyclic a UV-desinfection unit to prevent back contamination by microorganisms.

Vacuum sewer system

As an advantage over conventional flushing sewer systems the vacuum sewer uses tubes with reduced diameter so that investment and operating costs can be saved at infrastructure realisation. In addition the system is flexible to demographic changes (ups and downs). The user has in principle two options to get use of the system. The first option is conventional dewatering of buildings. Waste water is collected in a special underground reservoir which acts as fitting system to the vacuum sewer. Second option is the integration of the vacuum tube inside the building to get use of vacuum toilets and kitchen waste mixer.

Vacuum station installed in the water house

The vacuum itself is generated inside the water house in a vacuum tank by two redundant vacuum pumps. The tank is the reservoir and equilibration volume for the waste water.

Waste water treatment

Waste water from the vacuum station is pumped into the anaerobic psychrophilic waste water treatment reactor where the waste water is digested by anaerobic bacteria at inflow temperatures. The reactor is equipped with a ceramic micro filtration unit in form of a rotating disc filter. The filtration is operated in dead end mode to increase bacteria concentrations together with incoming solids inside the bioreactor.

Rotation disc filter and reactor for waste water treatment

The special operating mode as dynamic filtration unit allows "in operation" cleaning from fouling layers at disc surfaces by centrifugal forces. Thus high constant flux rates are obtained. The anaerobic organisms digesting at first organic substances to methane and CO_2 (biogas), which are used in a cogeneration unit to cover the energy demand of the cleaning process, liberate nitrogen components during digestion of organics as NH_4^+ and soluble Phosphorous, too. By the addition of Magnesium salt to the filtrate of the membrane bioreactor MAP is precipitated and can simply be recovered. The quality of the concentrate is so good that the fertilizer is ready for use in agriculture.

Residual NH_3 is adsorbed to an ion exchange material to concentrate the value substance. From the regenerate is will be possible to strip Ammonia in an economic form to recover a second artificial fertilizer: Ammoniumsulfate for example.

Conclusion

The demonstration waste water treatment plant in Knittlingen shows that it is possible to recover value substances from the water stream along with water regeneration ready for secondary use: infiltration, irrigation, service water. The recycled products are biogas from

C-bone of pollutants and fertilizer components. In regard of exporting the system to developing countries or arid zones the water treatment can be stopped after biogas recovery if the water is sustainably used to irrigate and fertilize agricultural zones.

Semi-Decentral urban Water- and Waste Water Management

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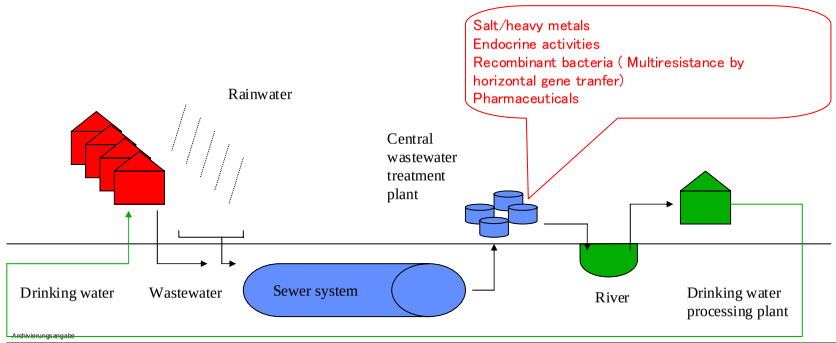

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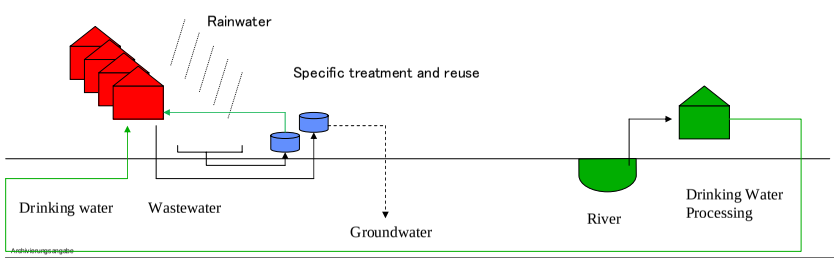
Rainwater storage reduce the danger of flooding



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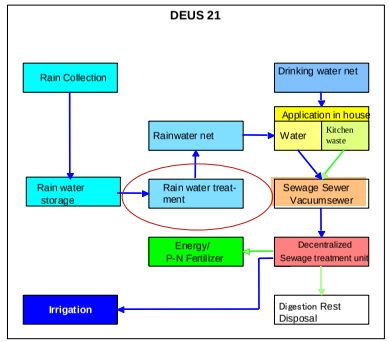
Knittlingen „ Am Römerweg“



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Quality of rainwater in Stuttgart: 10.10.2002
(unfiltrated, private rainwater collecting unit, Trösch)

	Desalinated water	Rainwater	Drinking water rule (EU)
COD (mg O_2/l):		9,5	5,0
Conductivity : (mS/cm)	0,01	0,06	2,5 (0,3)

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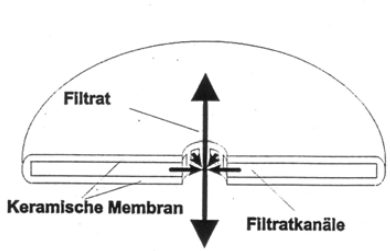
Ultrafiltration disc for rainwater cleaning

- Material: Al_2O_3
- pore diameter: 0,2- 0,02 µm
- Discdiameter ∅: 152-312 mm
- Thickness: 4,5 mm
- Membrane surface: 352-1450 cm^2
- **Excellent Cut-off**



Cross-section of a single disc

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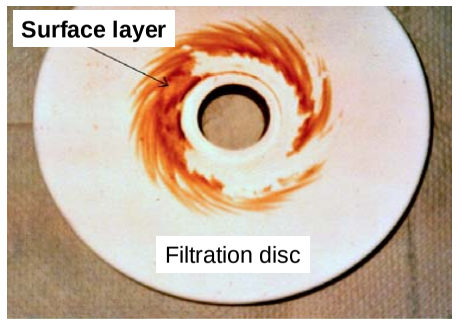
Fouling prevention by centrifugal forces / in operation cleaning



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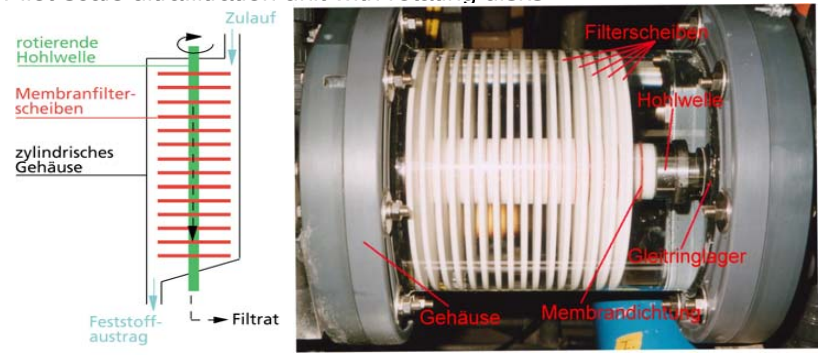
Pilot-scale ultrafiltration unit with rotating disks



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Dynamic ultrafiltration units (2 x 7,4 m^2) and pressure station for care-water distribution

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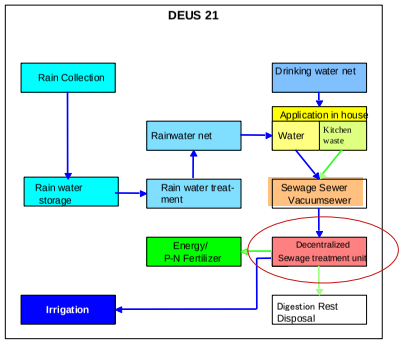

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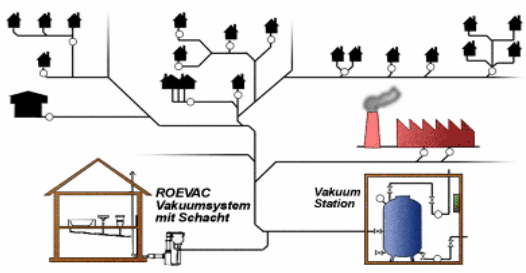

Scheme of a vacuum sewer system

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Development area Knittlinen: Vacuum sewers DN 60

Reduced digging costs

Reduced investment costs for the sewer

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Vacuum station

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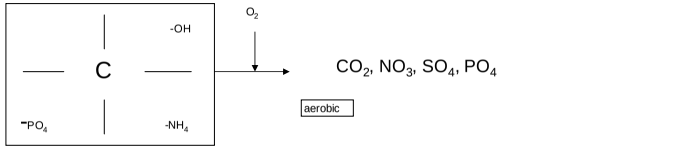
Biologically catalysed reactions within biodegradation - gaseous products escape to the atmosphere



1g/l COD = 0,4 l Biogas (70%CH_4)

Consequence: Anaerobic psychrophilic waste water treatment

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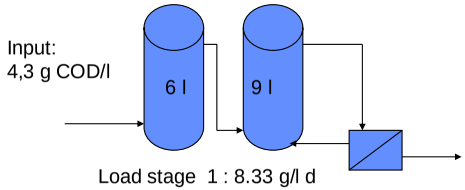
Anaerobic Waste Water treatment: Two stage cascade with intergrated Microfiltration at 15-20° C



Load stage 1 : 8.33 g/l d
stage 2 : 2.60 g/l d

Total organic load : 3.6 g/l d

Output COD: < 100 mg/l

Biomass concentration: 12 g/l

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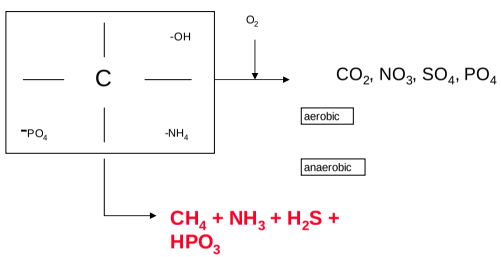
Biogas lift loop bioreactor with surplus sludge containment

Photo of the technical plant; in the front and on right hand side the rotation-disc-filter
and in the back the anaerobic gas lift loop bioreactor

Biologically catalysed reactions within biodegradation - gaseous products escape to the atmosphere



Aerobic biodegradation = Reduction of waste without economical benefit

MAP - Precipitations from digestion filtrate

Recycling and recovery of phosphor components is possible:

Precipitation of Mg-ammonia-phosphate

without the addition of chemicals

Precipitation of Ammoniumsulfate to recover the remaining Ammonia after MAP

Ionexchange to concentrate the dissolved Ammonia

Air stripping at elevated Temperature and precipitation in an appropriate acid

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Final conclusion:

Modular Water Infrastructure system including
rainwater catchment, water redistribution
and waste water purification
In modules:
for 1.000 Inhabitants
for 10.000 Inhabitants
for 50.000 Inhabitants ??

Industrially preconstructed, each identical, remote controlled

High poduction numbers reduce investment costs !

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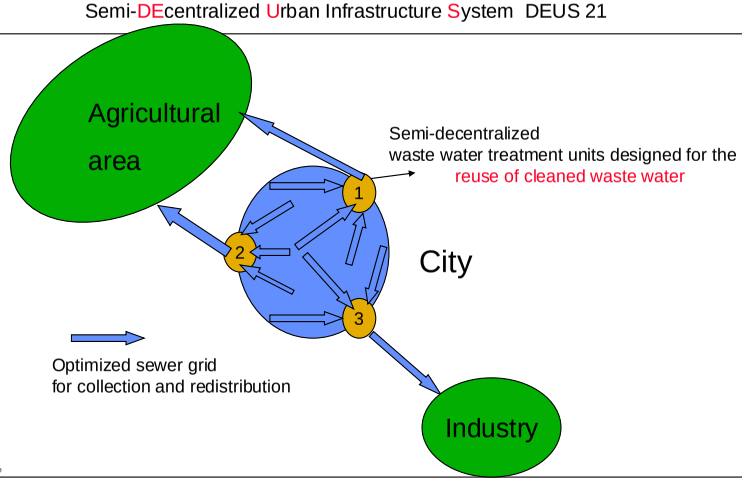

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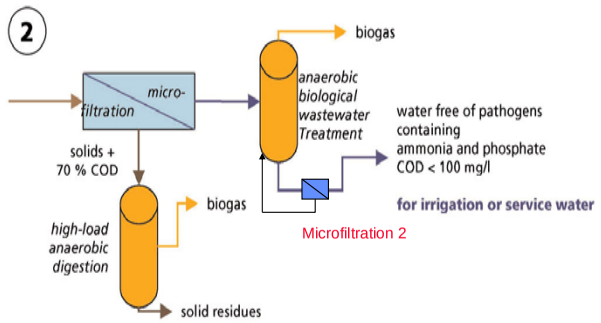

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Liquid soil technique:

Rainwater collection
without problems of
infiltration/exfiltration

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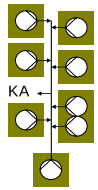
Picture of the settlement:

Sewer development

Pressure sewers:
(Variant 2)



- Construction of 7 pumping stations with 180 l pumping volume per pumping act

Advantage:
- No flushcleaning necessary
- Reduced costs compared to vacuum sewers or free flow systems

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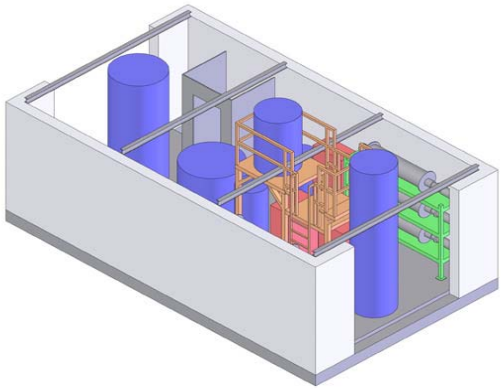
3D-graphic of the module



- Blau: Bioreactors
- Rot: Pumping station
- Grau: Microfiltration

Technical installation of a high load aerobic waste water treatment plant:

Microfiltration of raw waste water to separate solid and volatile COD
Microfiltration of nitrification effluents to produce a Microorganisme free water stream for infiltration or irrigation

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MBR in Heidelberg Neurott

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