Münchner
Stadtentwässerung

Wastewater Treatment Plant
Gut Marienhof

Out of sight, out of mind:
Who thinks about the water that disappears down the drain after washing up, doing the dishes or the laundry? Only a few. And only a minority of these few ask for technical details on how to prevent the wastewater of Munich from polluting the environment. This is a pity, because the answers would give them reason to be proud of their city and its exemplary concept for wastewater management. Let's consider the Wastewater Treatment Plant Gut Marienhof, in which this concept comes to life.

Munich's Second Wastewater Treatment Plant

The story of the Wastewater Treatment Plant Gut Marienhof almost ended before it actually began. The first plans were made in 1940, but were shelved because the Second World War and the postwar period set other priorities. However, Munich grew – and with it the amount of wastewater. By the early Seventies environmental consciousness had grown and appropriate legal requirements were made. In 1972 the old project was ready for realisation.

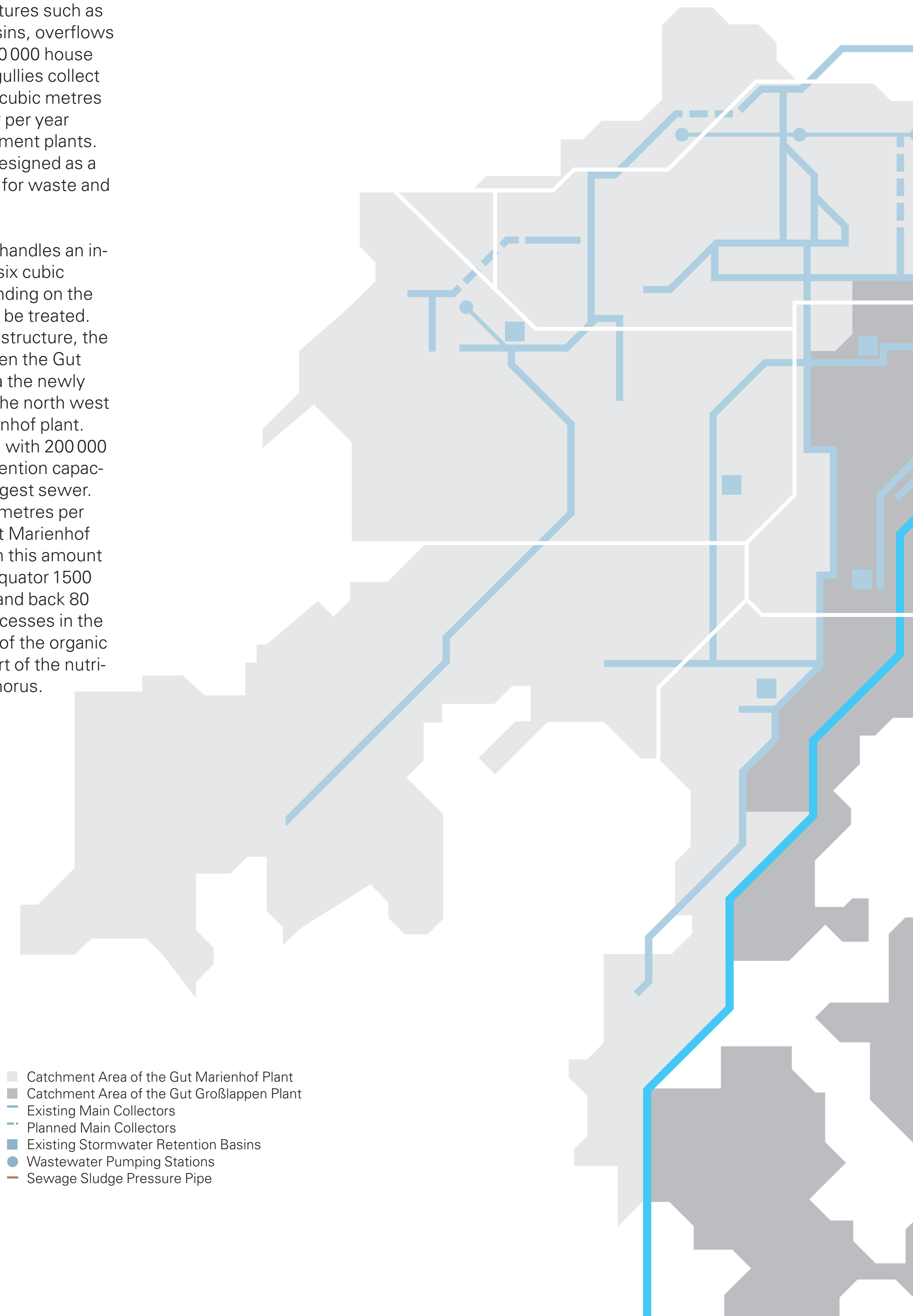
Regional planning between 1972 and 1974 decided on the plant's final location ten kilometres north of the Munich City Limit in Dietersheim, which is a district of the Community of Eching. The advantages of this location are that the wastewater can be directed there in free flow and that the receiving water, the Isar River, is nearby. Zoning and water rights procedures defined the design and performance criteria for the new plant. Construction itself took five years and the amount to be invested was 300 million Euros. In the year 1989 – 17 years after the rebirth of the project – construction was completed and the plant went into operation. This lengthy period gives an impression of the challenges that were faced during realisation.

Nature as a role model: Both of the plant's biological treatment stages copy the self-cleaning processes of natural waters – only in less time and space.

2 400 Kilometres of Sewer Network

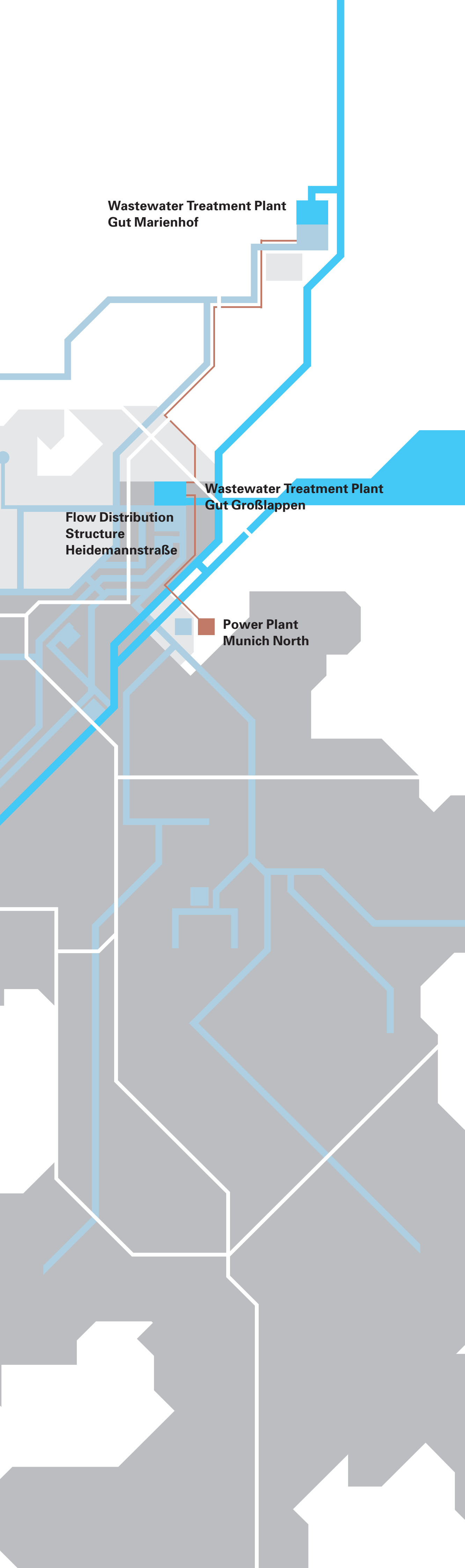
For sewage collection there is a 2 400 kilometre long network, of which 1 250 kilometres are big enough to walk through. In addition, there are numerous specialized structures such as stormwater retention basins, overflows and pumping stations. 140 000 house connections and 70 000 gullies collect and transport 180 million cubic metres of waste and stormwater per year to both wastewater treatment plants. Most of this network is designed as a combined sewer system for waste and stormwater.

The Gut Marienhof Plant handles an influent between four and six cubic metres per second depending on the amount of stormwater to be treated. At the Heidemannstraße structure, the flow is distributed between the Gut Großlappen Plant and, via the newly constructed collector to the north west of Munich, the Gut Marienhof plant. This collector is designed with 200 000 cubic metres sewage retention capacity, making it Bavaria's largest sewer. Roughly 80 million cubic metres per year flow through the Gut Marienhof Plant. A garden hose with this amount would wrap around the equator 1500 times or go to the moon and back 80 times. The treatment processes in the plant remove 99 percent of the organic pollutants and a major part of the nutrients nitrogen and phosphorus.



Wastewater Treatment Plant
Gut Marienhof

Wastewater Treatment Plant
Gut Großlappen



Two for 1.5 Million

The Gut Marienhof Plant shares its workload with Munich's other large-scale plant, Gut Großlappen. Together they have a treatment capacity of three million population equivalents which includes 1.5 million inhabitants. Together these plants treat the domestic, commercial and industrial wastewater from Munich and another 22 neighbouring communities.

The Isar River, a Sensitive Receiving Water

Optimal water protection is one of the objectives of the Münchner Stadtentwässerung. Complex technologies ensure a clean Isar River even in the center of a metropolis.

After treatment, the wastewater is discharged back into natural waters. In the case of the Gut Marienhof Plant, this is the Isar River – or what is left of it by the time it reaches the north of Munich. The abundant flow of earlier times has been diverted in order to produce hydroelectric power, making an extraordinary treatment plant efficiency necessary to protect the strongly diminished Isar River flow. The effluent quality significantly surpasses all pertinent European standards. Additionally, the allowed suspended solids concentration has been further limited by the local water authority. Through multi-stage treatment processes, even this parametre can be easily met.

Complex technology in harmony – numerous awards confirm the successful blend of various demands at the Gut Marienhof Plant.

It began with locating the plant in the middle of the nature reserve in the meadows of the Isar River. The complex technology of the plant needed to be in harmony with the environment; at the same time the architecture has to symbolize the cultural dimension and social meaning of water preservation as a vital element. On the one hand the digester structures with the lucidity of their technical esthetics and on the other hand 200 000 newly planted bushes and 1 000 trees, a large extension of the existing meadow landscape and the creation of new hiking paths: These are just two aspects of the same task.
How successful this task has been solved, is demonstrated lastly by the numerous awards received: BDA-Preis Bayern 1989 (association of German architects), Deutscher Achitekturpreis 1989, Preis des deutschen Stahlbaus (steel construction) 1990 and the Constructa-Preis / Europäischer Preis für Industriearchitektur 1990.

Landscape and Architecture

Architecture and Operation

Preliminary thickeners (foreground) separate water from waste sludge before its 24-day retention in the digesters (background).

Wastewater Treatment Plant Gut Marienhof

- 1 Mechanical Treatment
- 2 Biological Treatment, First Stage
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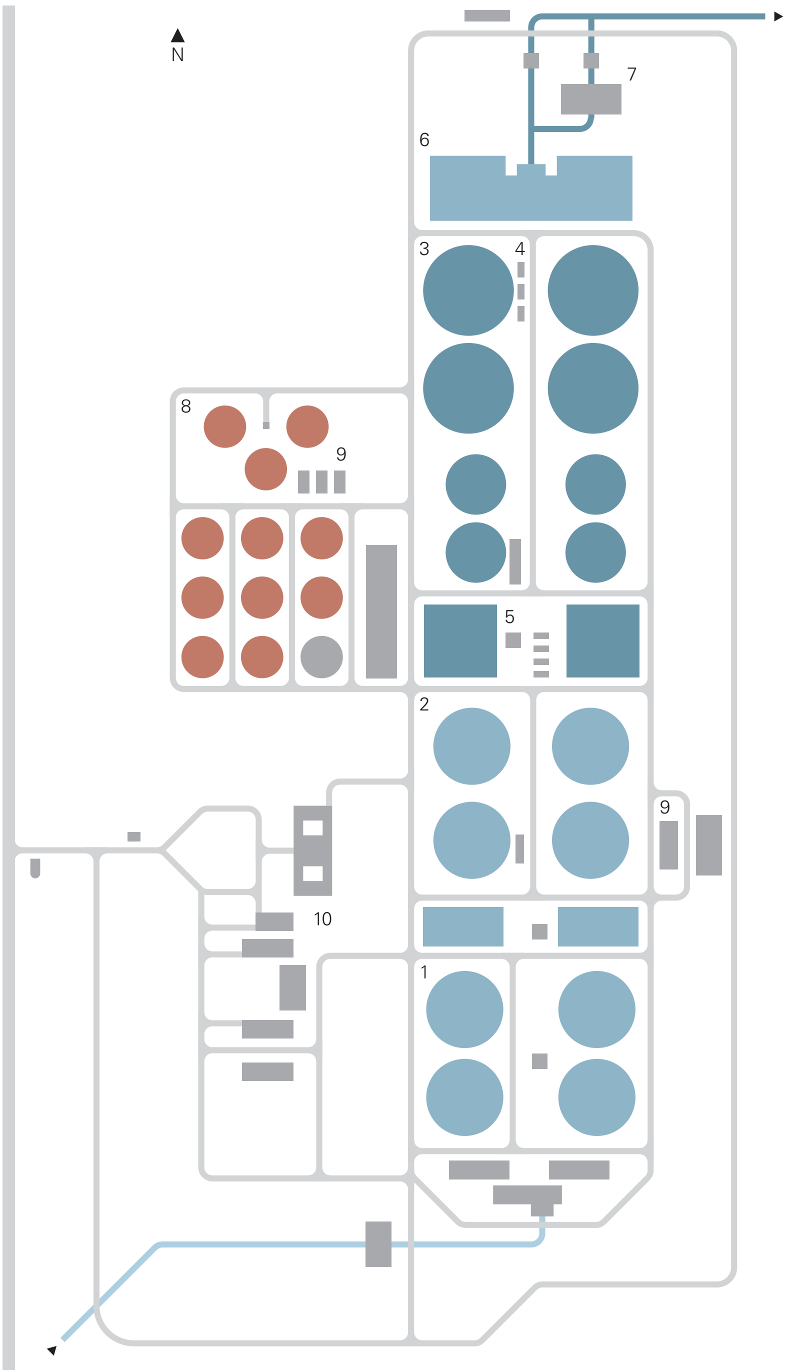
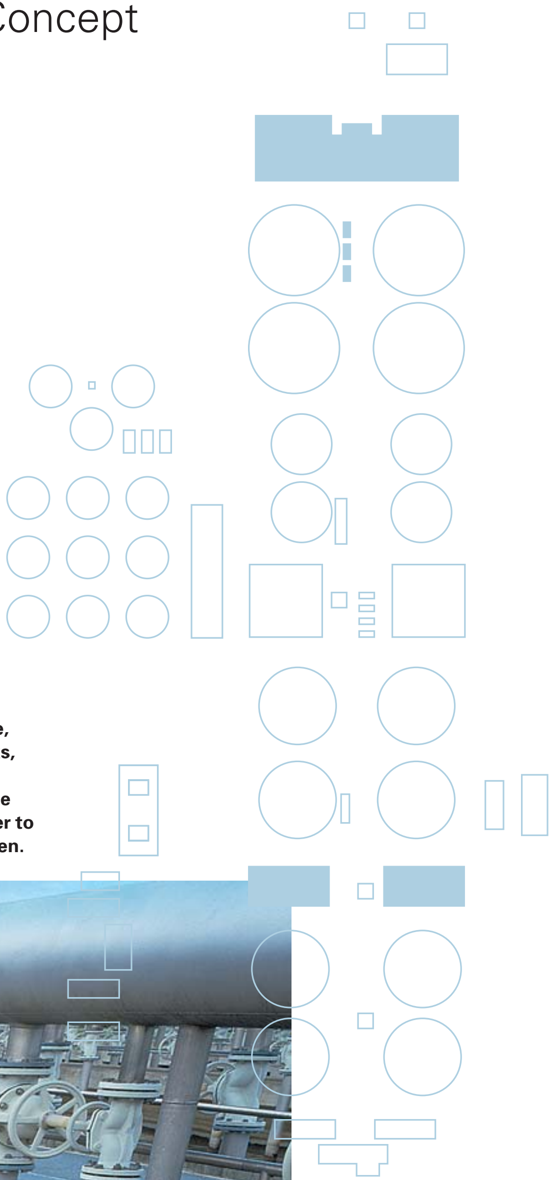
- 4 Methanol Dosage
- 5 Phosphate Precipitation
- 6 Sand Filtration
- 7 Wastewater Disinfection
- 8 Sludge Treatment
- 9 Exhaust Air Treatment
- 10 Operational and Social Buildings



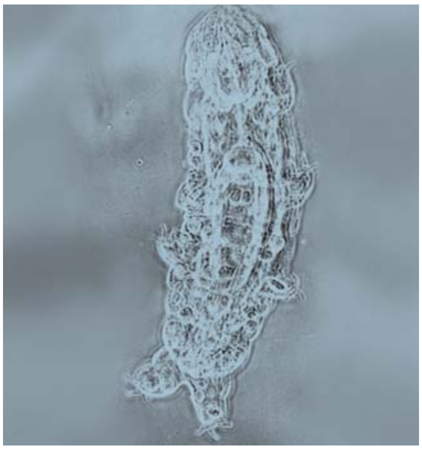
The Treatment Concept

The wastewater flows through 24 filter cells, each with a 1.5 m thick sand layer in order to remove the remaining suspended solids.

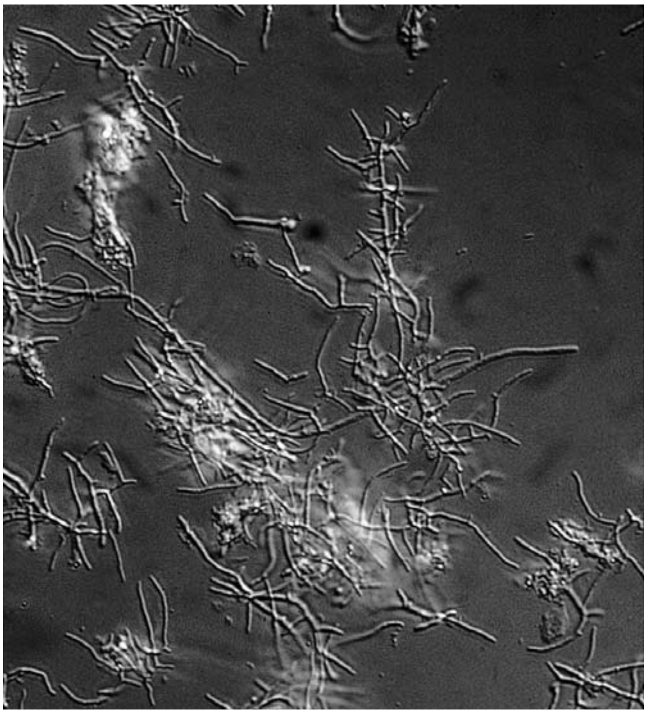


Breeding of microorganisms: Bacteria and other low forms of life, which are kept in the aeration tanks, feed on dissolved organic matter. Up to 150 000 cubic metres of air are blown into the tanks hourly in order to supply these organisms with oxygen.

Wastewater treatment entails the retainment of solid materials and the removal of organic pollutants and nutrients. This is done at the Gut Marienhof Plant by a mechanical and two biological stages, one which primarily removes organic and the other one nitrogen compounds. Additionally, the microorganisms in both biological treatment stages incorporate phosphorus which then can be removed along with the waste sludge. To further improve the treatment performance, an alum-ferric salt solution is added in the second biological stage to precipitate dissolved phosphorus. The plant's concept for removing the nutrient nitrate is worth special mention: Ammonia is oxidised to nitrate in the second biological stage (nitrification). Some of this nitrate is removed by recirculation to the first biological stage, where microorganisms reduce this nitrate to gaseous nitrogen (predenitrification). Additional nitrate removal is made possible in the sand filter through the same biological process (postdenitrification). However, here it is necessary to add easily degradable methanol as a substrate. This dual denitrification contributes significantly to the high overall process stability and low nutrient concentrations in the plant effluent.



Water Bears (Tardigrada)



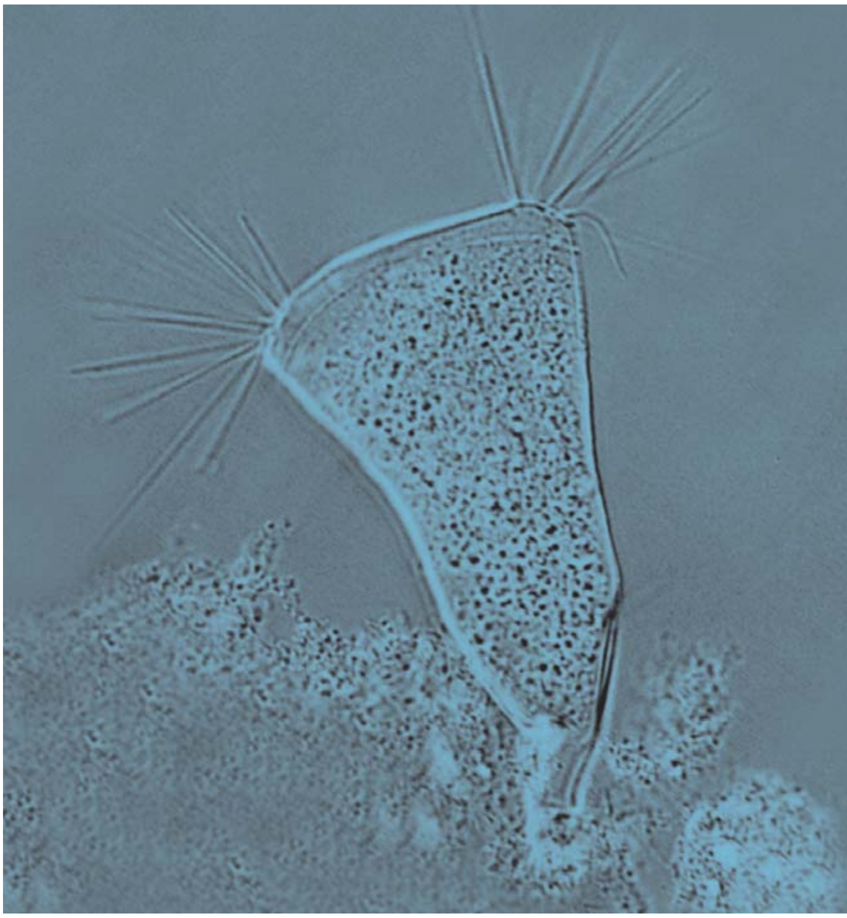
Little Helpers in the Plant

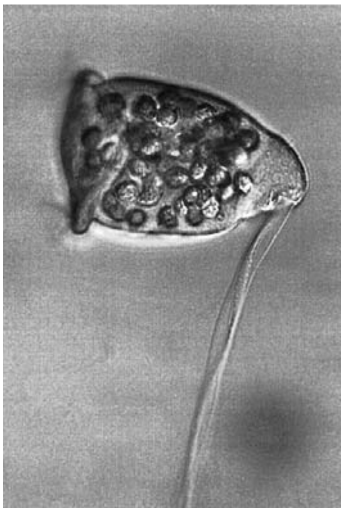
Nocardia bacteria are also named “Deer Antlers” due to their characteristic branched and thread-like form.

Numerous single cell organisms and bacteria are at work in the plant. The initial treatment is done by various bacteria, which are then eaten by higher organisms, e.g. Paramecia, which in turn are eaten by Rotatoria. The frequent occurance of these organisms in activated sludge indicates a stable treatment process. While the Chilodonella Paramecia float freely between the sludge flocs, the Tokophyra and Vorticella Campanula types attach themselves to the flocs by a long stem.

The filamentous bacteria Nocardia is an unwanted organism, because it indicates unfavourable conditions in the biological process.

Chilodonella, Tokophyra and Vorticella campanula belong to the genus of Paramecia.





Wastewater Disinfection

Log rafting is still a tradition on the Isar River. Thanks to a new project, which is unique across Europe, bathing water quality is being restored in the Isar River by improving the hygienic conditions.

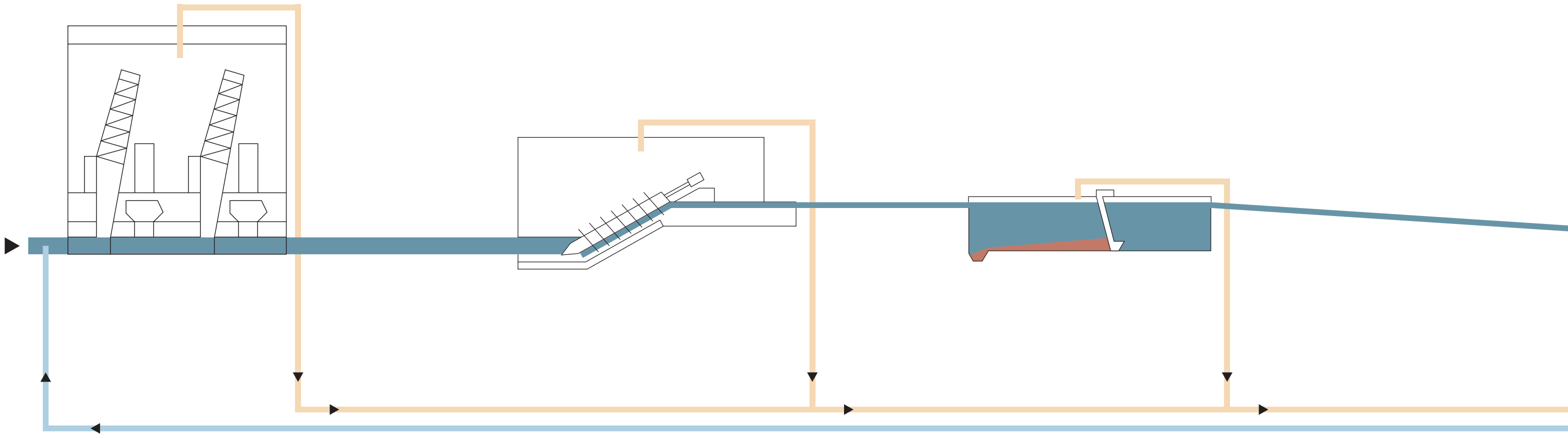
99 percent treatment performance of the Gut Marienhof Plant means excellent water quality for the Isar River with abundant oxygen supply and a diversity in microorganisms and other lower life forms, insect larvae and fish. What question remains is, whether it is also harmless for bathing humans. Wastewater disinfection, which kills potential harmful germs, is usually not common for German wastewater treatment, even though this is something many citizens desire.
The Munich City Council catered to these wishes. As early as 1994 pilot-scale wastewater disinfection experiments were successfully carried out by the Münchner Stadtentwässerung using ultraviolet light.

Munich's Mayor Hep Monatzeder, together with the Münchner Stadtentwässerung, other neighbouring communities and the authorities involved insisted on bathing water quality. After round table consultations, the mayors of the surrounding Isar River communities decided on adding wastewater disinfection units to their plants to improve the hygienic quality of their effluents.
In May of 1999, the Munich City Council authorized design work for a wastewater disinfection unit at the Gut Marienhof Plant.The project realisation however, was made dependent on the willingness of the river communities north of Munich to implement these measures as well.

Four years later, the operators of the municipal wastewater treatment plants north of Munich in Garching, Ismaning, Grüneck and Freising also agreed on installing disinfection units. The final decision by the Bavarian Capital City of Munich to build a disinfection unit at the Gut Marienhof Plant fell in June 2003. Its commencement ceremony in August 2005 represented a milestone in restoring the bathing water quality in the Isar River. The attained goal of bathing in the Isar River from its source in the Alps up to the City of Moosburg 30 kilometres north of Munich is unique across Europe.

The disinfection unit at the Gut Marienhof Plant is operated during the bathing season from Mid-April till October together with those of the other neighbouring Isar River communities.
Bavaria's environmental ministry supported the project with the amount of one million Euro. The disinfection costs Munich's citizens 1.5 Cents per cubic metre wastewater yet did not result in an increase in the user fees.

The wastewater disinfection plant reduces the germ count in the treated water to a hundred thousandth part.



Mechanical Treatment

Screening Building

Wastewater arrives at the plant via two main collectors. Coarse matter is removed in four parallel lines, each equipped with a 40 mm and a 20 mm spaced bar screen. Daily there are approximately five tons of screenings, which are eliminated and properly disposed.

Influent Pumping Station

Three Archimedean screw pumps lift the wastewater 2.5 metres, bringing it to the aerated grit chambers. From here on it flows through the rest of the plant by gravity.

Aerated Grit Chambers

The flow rate is reduced in the grit chambers allowing the sand to settle, which would otherwise disturb plant operation. Greases and oils are also removed here.
The settled sand is pushed into funnels with scraper shields. Air-lift pumps take out 730 tons of mineral substances annually, which are sorted and also properly disposed.

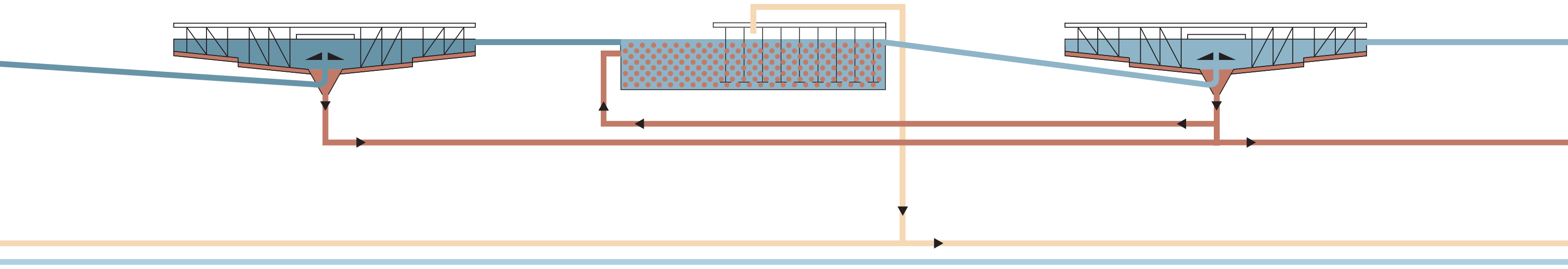
Technical Specifications

Treatment Plant Capacity
1 000 000 PE*

Maximum Dry Weather Influent
4.0 cubic metres per second

Maximum Combined Influent
6.0 cubic metres per second

* Population Equivalent (PE) is a parameter for designing wastewater treatment installations. Each living inhabitant is represented by 1 PE, which corresponds to 60 g of BOD per day. BOD (biological oxygen demand) is a cumulative parameter for biologically degradable organic pollution. Population equivalents are also used to quantify commercial and industrial organic water pollution.



Biological Treatment, First Stage

Primary Sedimentation Tank

After distributing the wastewater into four tanks, each being 60 metres in diameter and 6 000 cubic metres in volume, most of the organic solids are removed by gravity within one to two hours. A bottom scraper pushes the so called primary sludge to a center funnel, from where it is pumped to the sludge treatment section.

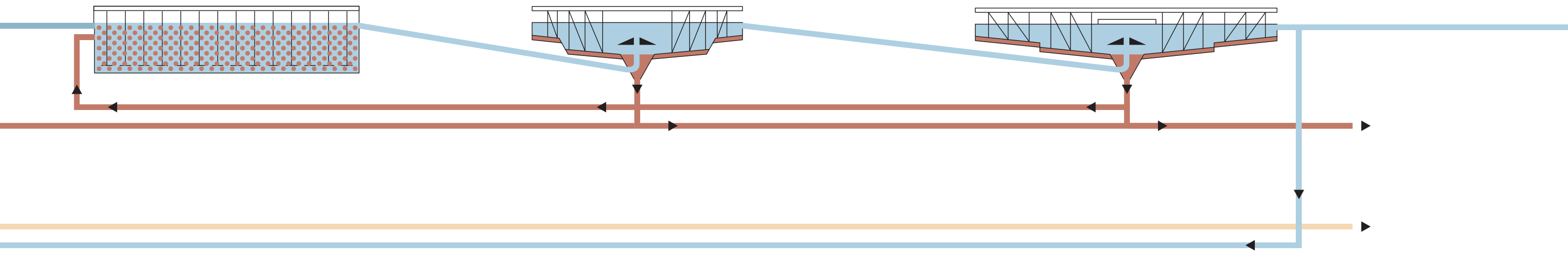
Activated Sludge Tank

The two biological stages are the most important part of the wastewater treatment. Principally it imitates the self-cleaning process of natural waters, only in less time and space. In these tanks bacteria and other microorganisms feed on non-settling and dissolved organic pollutants. They grow in high concentrations and form small flocs called activated sludge. This process requires a permanent supply of oxygen provided by intense aeration. Special ceramic aeration tubes, which are installed 6 metres deep, provide 40 000 to 150 000 cubic metres of finely dispersed air per hour. The air supply is constantly controlled by submersed online oxygen metres.

Intermediate Sedimentation Tank

Since the activated sludge is heavier than water, it settles in the slowly moving water of the sedimentation tanks. As in the primary sedimentation, the activated sludge is collected in a center funnel, but this time most of it is pumped back into the aerated tanks to maintain a constant biomass concentration. The surplus biomass resulting from continuous growth, the so called secondary or waste sludge, is removed and also pumped to the sludge treatment section.
The degradation of carbon compounds (fats, proteins, carbohydrates) and also denitrification (nitrogen removal) takes place in the first biological stage. After this first stage, 85 percent of the wastewater pollutants are removed.

Flow Diagram of the Wastewater Treatment Plant



Biological Treatment, Second Stage

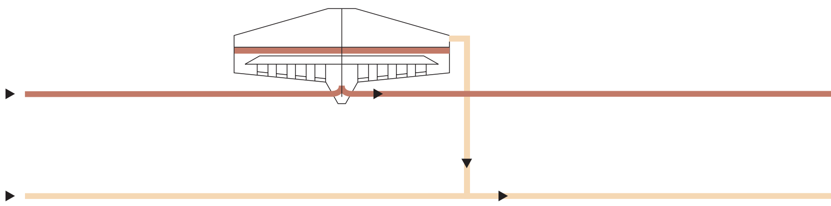
Aerated Sludge Tank

In the second biological stage, highly specialised and slowly growing microorganisms are at work. These so called nitrifying bacteria oxidate ammonia to nitrates, which originates from nitrogen-containing compounds like urea. Ammonia, or rather its partner compound ammoniac, would be poisonous for fish and other animals in natural waters. The plant's nitrifying process has an efficiency of about 98 percent and removes the remaining organic compounds at the same time.

Through the growth of the biomass a part of the influent phosphorus is incorporated and removed with the waste sludge. To improve this nutrient's removal efficiency, a chemical precipitation is necessary. Alum-ferric salt solutions are added and react with the phosphorus forming floc compounds, which settle and can then be removed with the waste sludge.

Final Sedimentation Tank I

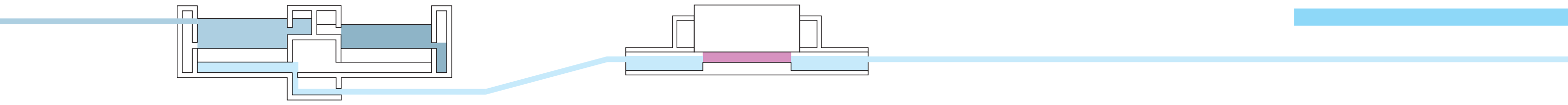
Final Sedimentation Tank II



Sludge Treatment

Sludge Thickener

The final products of the treatment of wastewater are clear water and waste sludge.
This sludge comes from the primary sedimentation tanks and the two biological treatment stages. However, the solids content of the sludge is only 0.5 to 1 percent, the rest being water. To reduce the volme for the following digestion stage, it is again thickened by sedimentation. The thickeners, tanks with a volume of 2 500 cubic metres each, increase the solids content to six percent, which in turn reduces the volume by 90 percent. The excess water is routed back into the biological treatment process.



Filtration

Disinfection

Sand Filter

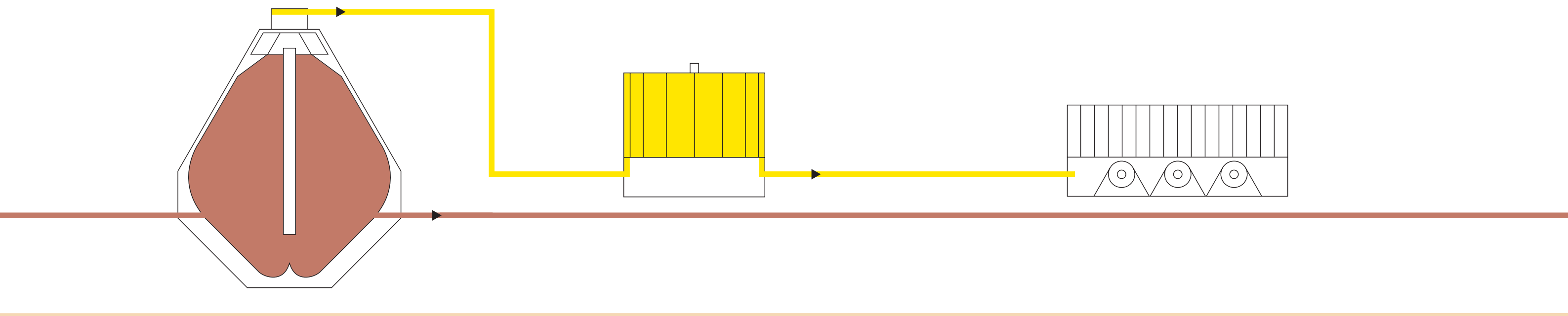
After biological treatment most of the organic substances have been converted to biomass, which has settled in the sedimentation tanks. However, some of the matter is still suspended, making an additional filtration stage necessary. 24 filter cells, each having a 1.5 metre thick sand layer, remove these remaining particles from the treated wastewater. These filter cells are periodically backwashed with water and air to keep the filtering process efficient.
With this filtration stage the total removal of pollutants increases to 99 percent.

Disinfection Unit

This unit ensures that the plant effluent has bathing water quality. Ultraviolet radiation reduces the living germ count in the effluent to a hundred thousandth part. The short-wave light damages the nuclei of the microorganisms thusly preventing their further growth.
Depending on the current water flow, up to 1300 ultraviolet lamps arranged in six lines are in operation. The radiation intensity is controlled continuously to guarantee a continuous disinfection performance.

Denitrification Concept with Recirculation and Sand Filter

The Münchner Stadtentwässerung has developed a unique and economic process to reduce effluent nitrates, which act as unwanted nutrients in natural waters. A part of the wastewater stream is recirculated from the end of the second biological stage to the beginning of the first. The nitrates produced in the second stage are reduced in the first stage to gaseous nitrogen and escape into the atmosphere.
The other location for this reaction is the sand filter. Here denitrifying bacteria feed on externally added methanol and simultaneously convert nitrates to gaseous nitrogen. This combinated denitrification guarantees a high process stability while complying with allowed nitrogen effluent concentrations.



Digestion Tank

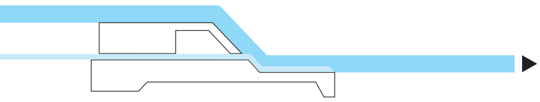
In the digestion tanks thickened waste sludge ferments in absence of oxygen for approximately 24 days at 38 degrees Celsius. During this process specialised bacteria convert organic matter to methane-containing biogas, which is used to run the power plant generators. Approximately two thirds of the entire treatment plant's electrical energy demands are met through this source.
Each of the three digesters has a volume of 11 800 cubic metres, a height of 25 metres while reaching 15 metres below the surface. About 1 100 cubic metres of biogas are produced hourly.

Biogas Storage

After removing water and sulphur, the biogas is stored in a membrane tank with 5 000 cubic metres volume.

Machine Building

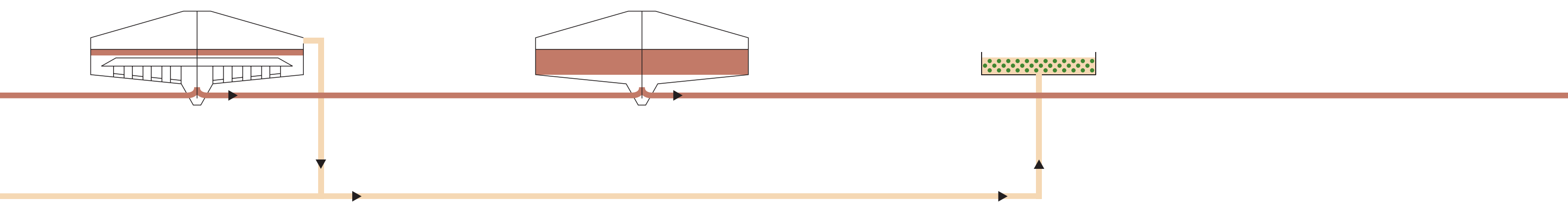
Here three gas-diesel engines burn the biogas from the digestion process each driving generators which produce up to 1600 kilowatts of electrical power. Two additional gas-diesel engines provide pressurised air for the biological treatment stages via turbo blowers. Next to these aggregates are yet two more turbo blowers driven by electric motors. The waste heat of the engines' cooling system is utilised throughout the entire treatment plant.
The systems combined efficiency (thermal and electrical) attains a high efficiency of more than 70 percent.



Effluent Discharge into the Isar River

Discharge Structure

The treated effluent enters the Isar River via a specially designed discharge structure.
It replaced an existing weir. The interior is hollow with evenly spaced outlets to enable the treated wastewater to be dispersed along the entire river width. This way it is mixed completely with the Isar River and simultaneously enriched with oxygen. A flood water pumping station guarantees the plant discharge even at high water levels.



Exhaust Air Treatment

Final Sludge Thickener

The water content of the waste sludge after digestion is reduced here.

Digested Sludge Storage Tank

The last station for the waste sludge is the storage tank. From here it is pumped to Munich's other wastewater treatment plant Gut Großlappen.

Biofilter

A series of installations eliminate the unpleasant odours from the exhaust air in the plant. The air from the encapsulated screening building and the covered aerated grit chambers is blown into the aeration tanks of the first biological stage. These tanks are also covered and their exhaust air is in turn blown through a specially designed biofilter, in which microorganisms feed on the odorous substances. The biofilter can treat up to 90 000 cubic metres of air flow per hour. At the sludge handling and storage area the exhaust air is treated by a wet scrubber combined with a downstream biofilter.

Supervision

The treatment plant is controlled by a central process control system in connection with numerous subsystems, online instruments and measurement transmitters. Employees supervise the processes in the central control room around the clock. The treatment plant effluent is monitored continuously for all relevant parameters with online probes. Additionally, samples are taken regularly from every process stage and analysed at the in-house laboratory.

Service Water

Instead of wasting valuable ground water, specially treated recycled water from the plant effluent is used for cooling and cleaning purposes. This is yet another contribution to water conservation.

Waste Sludge Handling

Waste Sludge Pumping Station and Pressure Pipe

Digested and thickened waste sludge is pumped through a 12 kilometre long pressure pipe to Munich's other wastewater treatment plant Gut Großlappen where it is dewatered, dried and finally incinerated. The pressure pipe is kept free of deposits by periodical "pigging". This "pig" is an elastic body with steel brushes that fits tightly into the pipe and is pumped together with the sludge.

Sewage Sludge Incineration Plant

As opposed to solid waste, sewage sludge cannot be avoided. On the contrary, the more effective the treatment processes are, the more sewage sludge accumulates. Due to the difficult general sludge disposal situation, the Münchner Stadtentwässerung operates its own incineration plant since 1998. The thermal energy from approximately 22 000 net tons is utilized at the wastewater treatment plant Gut Großlappen.

Technical Specifications
Gut Marienhof

Complex structures: A subsurface tunnel, 1 110 metres long, connects the individual treatment units.

Plant Size

Design Capacity		1 000 000 Population Equivalents	
Design Influent Quantity	Dry Weather Combined Flow	3.3 m^3/s 5.0 m^3/s	

Actual Values 2004

Influent Quantity (85 %-Percentile)	Dry Weather	2.1 m^3/s	
Concentrations (Annual Averages)			
Plant Influent	BOD COD Suspended Solids NH_4-N Total-N Total-P	269 mg/l 685 mg/l 359 mg/l 37 mg/l 59 mg/l 9.9 mg/l	
Plant Effluent	BOD COD Suspended Solids NH_4-N Total-N Total-P	2 mg/l 27 mg/l 2 mg/l 0.31 mg/l 16 mg/l 0.7 mg/l	 (April – October) (May – October)
Annual Loads	Influent BOD Effluent BOD	18 127 t/a 166 t/a	
Allowed Discharge Limits 2h-Mixed Samples (Homogenized)	BOD COD Suspended Solids NH4-N Total-N Total-P	13 mg/l 30 mg/l 13 mg/l 2.3 mg/l 13 mg/l 1.0 mg/l	 (as of 2005)

Mechanical Treatment Stage

Screen System		4 Coarse Screens with 40 mm Bar Spacing 4 Fine Screens with 20 mm Bar Spacing
Influent Pumping Station		3 Screw Pumps at 2.5 m^3/s each
Grit Chamber		6 Aerated Chambers
Primary Sedimentation	 Total Volume Total Surface	4 Round Tanks 52 m in Diameter V = 24 146 m^3 A = 8 404 m^2
	Dry Weather Retention Time (Design)	2.0 h

Biological Treatment, First Stage

Activated Sludge Tanks	 Total Volume	4 Rectangular Tanks with 3 Cascades each (Partial Upstream Denitrification, Fine-Bubble Aeration) V = 13 572 m^3
	Dry Weather Design Values: Volume Load Sludge Load BOD Reduction	 3.18 kgBOD/m^3 per day 0.80 kgBOD/kg per day 75 %
	Intermediate Sedimentation Total Volume Total Surface	4 Round Tanks 60.5 m in Diameter V = 35 840 m^3 A = 11 840 m^2

Biological Treatment, Second Stage

Activated Sludge Tanks		4 Rectangular Tanks
	Total Volume	$V = 27\,414\ m^3$
	Dry Weather Design:	
	Volume Load	0.39 kgBOD/m^3 per day
		0.28 kgNH_4-N/m^3 per day
	Sludge Load	0.076 kgBOD/kg per day
		0.053 kgNH_4-N/kg per day
Two-Stage Final Sedimentation		
		4 Round Tanks 42.0 m in Diameter
Tank I	Total Volume	$V = 20\,584\ m^3$
	Total Surface	$A = 5\,340\ m^2$
		4 Round Tanks 60.5 m in Diameter
Tank II	Total Volume	$V = 35\,088\ m^3$
	Total Surface	$A = 11\,049\ m^2$
		24 Downward Flow Filter Cells
Sand Filter	Total Surface	$A = 1\,956\ m^2$
	Filter Speed with 2 Cells	$v = 670$ m/h
	Backwashing	

Technical Installations

Machine Building	Power Generation	3 Gas-Diesel Engines 1.65 MW Mechanical each 2.5 MW Thermal each 2.1kVA Generator each
	Pressurised Air Production	2 Gas-Diesel Engines and 2 Electric Motors, all with Turbo Blowers 77 500 Nm^3/h each
Service Water Plant	Effluent Sand Filtration and Disinfection with Chlorine Dioxide or Ultraviolet Light	936 m^3/h Peak Flow

Sludge Treatment

Primary and Final		6 Covered Round Tanks
Sludge Thickeners	Total Volume	$V = 13\,890\ m^3$
Anaerobic Digesters		3 Closed Conical Tanks
	Total Volume	$V = 35\,490\ m^3$
	Retention Time	Approx. 24 Days
Biogas Storage Tank	Low Pressure Type	Cylinder Shaped, Membrane
	Volume	$V = 5\,000\ m^3$
Digested Sludge Storage		2 Covered Round Tanks
Tanks	Total Volume	$V = 5\,944\ m^3$

Sludge Handling

Waste Sludge Incineration Gut Großlappen	Dewatering	4 Centrifuges with 50 m^3/h followed by 4 Disc Dryers
	Incineration	2 Floating Bed Furnaces with 3 t/h Dried Solids each
	Steam Turbine	1.15 MW Power Generation
Power Plant Munich North	Dewatering	3 Centrifuges with 70 m^3/h
	Incineration	Together with Solid Waste (2 Units with 3 t/h and 1 Unit with 6 t/h Dried Solids)

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