Ruhrverband

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Ruhrverband

Wastewater Treatment Plant Duisburg - Kaßlerfeld

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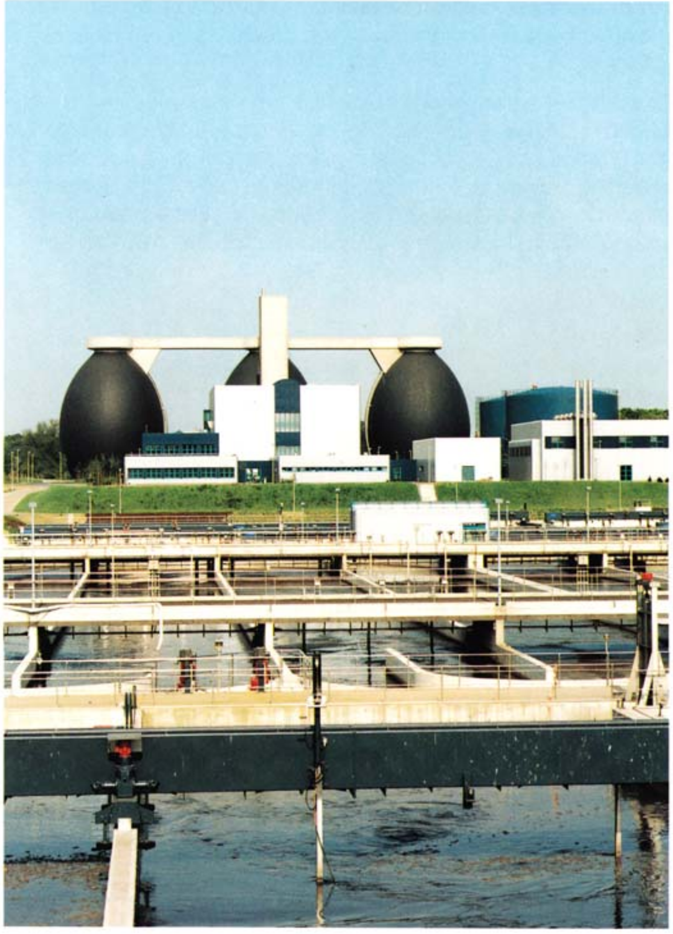


A traditional site of wastewater treatment

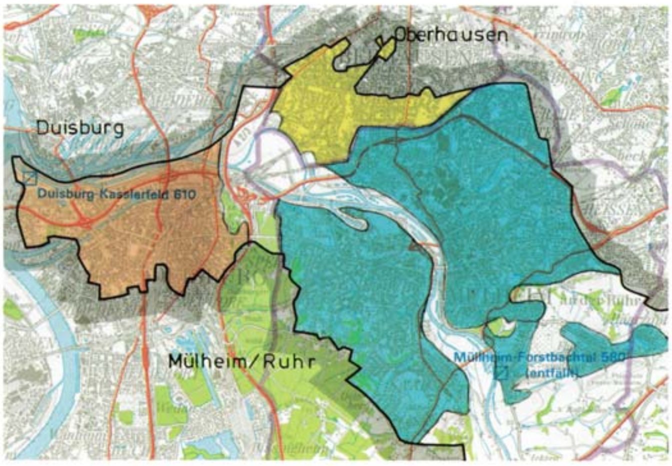
According to the plans of Dr. Karl Imhoff a programme to keep the water in the lower Ruhr clean was set up already in 1912, one year before the Ruhrverband was founded.

This was due to the bad conditions in the extremely warm and dry summer of 1911 when the lower Ruhr was nothing but a disgusting blackish cesspool. The waterworks on the lower Ruhr could provide their wells only with a stinking liquor. This caused a typhus epidemic in Mülheim which affected 1,500 people.

In order to keep the lower Ruhr clean the wastewater of the city of Mülheim as well as of considerable parts of the cities of Oberhausen and Duisburg was led into the Rhein with the help of extended collecting pipes. Thus, the wastewater was kept away from the lower Ruhr. Before being discharged into the Rhein the wastewater was to be treated in a wastewater treatment plant near the mouth of the Ruhr.

Thereafter, this anticipating concept was realized step by step with regard to future developments and again and again it was updated according to the present needs. Between 1960 and 1986 DM 77 million were spent solely on the reorganisation of wastewater discharge in the lower part of the Ruhr.

The reorganisation of the wastewater disposal system is now completed by the newly constructed wastewater treatment plant Duisburg-Kaßlerfeld.



Catchment area

The area of the mouth of the Ruhr consists of the city of Mülheim and those parts of the cities of Oberhausen and Duisburg which are located in the Ruhr basin. Due to the concentration of commercial and industrial firms this area is one of the most densely populated regions in the Ruhr district which is one of the largest urban industrial conglomerations in Europe.

The catchment area of the wastewater treatment plant is 5,560 hectare wide. The length of the Ruhr in this region amounts to 18.3 kilometres between the city boundary of Essen and Mülheim and the point where the Ruhr flows into the Rhein.

About 300,000 people live in the catchment area of this wastewater treatment plant. They produce about two thirds of the wastewater treated in Duisburg-Kaßlerfeld. One third of the wastewater comes from the local commercial and industrial firms. The influx during dry periods amounts to 2.3 m³/s. The maximal influx during times of high precipitation amounts to 4.1 m³/s.

One of the characteristics of the catchment area is the variety of different landscapes. Visiting foreigners are often surprised to see a large number of forests and parks, private gardens and sheets of water. In other places the landscape is dominated by large industries, especially steel industries. Furthermore, this area is an internationally important point of maximum traffic concentration where shipping, railways and roads conglomerate.

A good example for this is the harbour of Duisburg which can be seen in a panoramic view from the top of the 40 m high digesters of Duisburg-Kaßlerfeld.

The Ruhrinsel Raffelberg – an area flown around by the Ruhr River

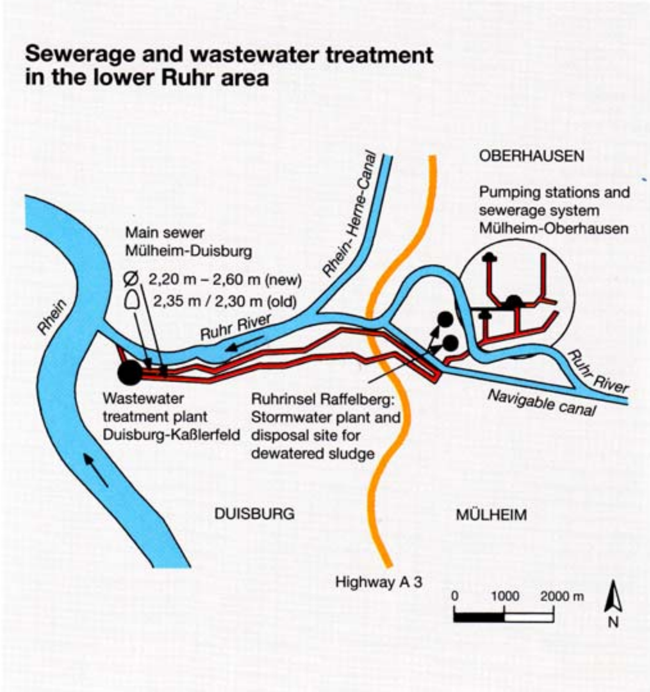
Stormwater plant

The storage of stormwater in the catchment area takes place at one central plant and not at a number of scattered plants as it is usually the case in combined sewerage systems. Together with a disposal site for dewatered sludge this stormwater plant is situated on the so-called Ruhrinsel Raffelberg in the triangle of the cities of Mülheim, Duisburg and Oberhausen seven kilometres upstream of the wastewater treatment plant Duisburg-Kaßlerfeld.

From both shores of the Ruhr the stormwater flows to the two separate parts of the plant on the Ruhrinsel via siphon pipes. Here each of the two 10,800 m³ large concrete tanks are the first to be filled. When the settling tanks are filled to a large extent the pretreated water flows over a weir into ponds with a permanent level of water. These ponds can be dammed up to a height of 1.5 m (V = 90,000 m³). Only after complete filling they discharge into the Ruhr in case of further influx of stormwater. Here a very low average period of discharge of about five hours per year is expected.

Most of the stormwater fills only the settling tanks or at most the ponds to some extent. In very exceptional cases highly diluted mixed water is discharged into the Ruhr.

Usually the storaged stormwater is discharged into the wastewater treatment plant after the end of rainfalls. Here this is done as well, but in this case the ponds do not dry up. They keep a



constant level of water of about 1 m. Due to temporalily influx of wastewater the ponds have to be aerated intermediately. Thus, the biological process of decomposition of pollutants is supported and the emission of odour is prevented.

Disposal site for dewatered sludge

Apart from the stormwater plant the disposal site for dewatered sludge is situated on the Ruhrinsel Raffelberg as well. On this disposal site only the dewatered sludge from the wastewater treatment plant Duisburg-Kaßlerfeld is disposed after being reduced to 40% dry solids in the chamber filter presses. In the first part of the construction work the disposal site 1 for dewatered sludge was built which has a volume of 750,000 m³.

In order to avoid possible pollution of the groundwater by seepage water from the disposal site, considerable means were taken. Therefore the entire construction area of the stormwater plant and the disposal site for dewatered sludge was surrounded by a tightening wall reaching down to the impenetrable underground in order to keep groundwater and floods away.

Furthermore, the surrounding dams were provided with loam sealings which are 1.5 to 1.6 m thick and reach down to the marly layer above the rock in order to seal the entire area from the underground. Deep drain pipes with two pumping stations along the toes of the dam make sure that the internal groundwater level is always at a minimum of 1 m below the bottom of the disposal site and at the same time always below the groundwater level outside the tightening wall. A large number of controlling wells connected to a computer system allow a permanent control of the groundwater levels. This artificial difference in groundwater levels makes sure that no water can emerge from the disposal site. The water which is pumped off is led to the wastewater treatment plant Duisburg-Kaßlerfeld.

About 500,000 m³ of soil were moved during the construction of the disposal site of dewatered sludge. Here an environment-friendly treatment of the precious soil could be provided in so far as the alluvial clay from the construction site could be used for the production of mineral sealings after adding bentonite. Surplusses only occured with gravel of high quality and could be used with other projects.

The disposal site 1 for dewatered sludge is a plant of highest technical standards which allows the Ruhrverband to guarantee a secure process of the waste management of the sludge from the wastewater treatment plant Duisburg-Kaßlerfeld within the next 15 years. By puddling the disposal site step by step and by recultivating these areas immediately a minimization of influences disturbing the environment could be provided.

Artificially designed landscape

The Ruhrinsel Raffelberg is part of an important area of open spaces which stretches from east to west along the Ruhr and which follows from north to south the green area of the Duisburg Stadtwald. The 60 hectare wide Ruhrinsel Raffelberg is, however, surrounded by the Autobahn 40 in the south and the Autobahn-junction Duisburg-Kaiserberg in the south-west. Additionally, several railway lines lead through the "island". Already in the past the former floodplain was protected against floods by dams and ditches and was agriculturally used mainly by the growing of corn.

The main aim while designing the plant was the maintainance of the characteristic landscape of the Ruhr meander and high-water river bed. Thus, it was of great importance to link the free spaces to each other as well as to integrate the plant into the environment. As a result of the central site in the meander and the design of the entire area the disposal site of dewaterd sludge is to form the cut-off meander spur. By designing the inclinations of the river banks as well as the hilltops variedly the plant fits well into the landscape and even improves the panorama.

The four newly constructed stormwater ponds, which permanently contain water, are new biotopes which serve as longlasting biospheres for species typical for high-water river beds. In order to allow a variety of vegetation as close to nature as possible at the more shallow parts of the ponds, reeds and floating aquatic plants were cultivated. These provide the opportunity for further plantings. Parts of the pond banks were cultivated with typical vegetation. The recultivation of the disposal site for dewatered sludge is to allow a future development of a biotope with various species and landscapes. Apart from their ecological function the alternation of areas with lawns and bushes as well as reforestated areas with surrounding plants typical for the edge of the wood provide a fine integration into the panorama. Long-term tests on the suitability of dewatered sludge as a substratum for plants initiated by the Ruhrverband led to the choice of the relevant plants. By this choice of measures the Ruhrinsel Raffelberg was considerably improved ecologically as well as in terms of landscape design and thus gained the important function of protecting biotopes and species. First positive results are already obvious. In autumn 1992 a verification of different species of birds in the redesigned area revealed a number of 21 species with different numbers of individuals. On the whole there were 270 birds living in the area, several species of which are threatened with extinction at other places. Thus, the entire area serves the function of an undisturbed resting place especially for birds in times of moulting. In winter and during times of migration further species of ducks and snipes can be observed.

Wastewater treatment

Planning and authorization

The old wastewater treatment plant Duisburg-Kaßlerfeld which was built in 1954 had a mechanical-chemical stage of treatment consisting of screen, grit removal and settling tanks as well as a digester and a sludge deposit. Already in the early 1970s first plans were made for a mechanical-biological plant which could not be realised for several reasons. The plans included a sludge incineration plant which got no approval since the air immission load was then already higher than allowed.

The new plan which was submitted in 1982 contained a concept of biological purification which was designed for the breaking up of carbon. The biological treatment had to be altered in the cause of the process of approval of the concept in such a way that a nitrification of ammonia also became possible. By the act of approval of concept the plan to renew the wastewater treatment plant Duisburg-Kaßlerfeld was authorized on 1. September 1987.

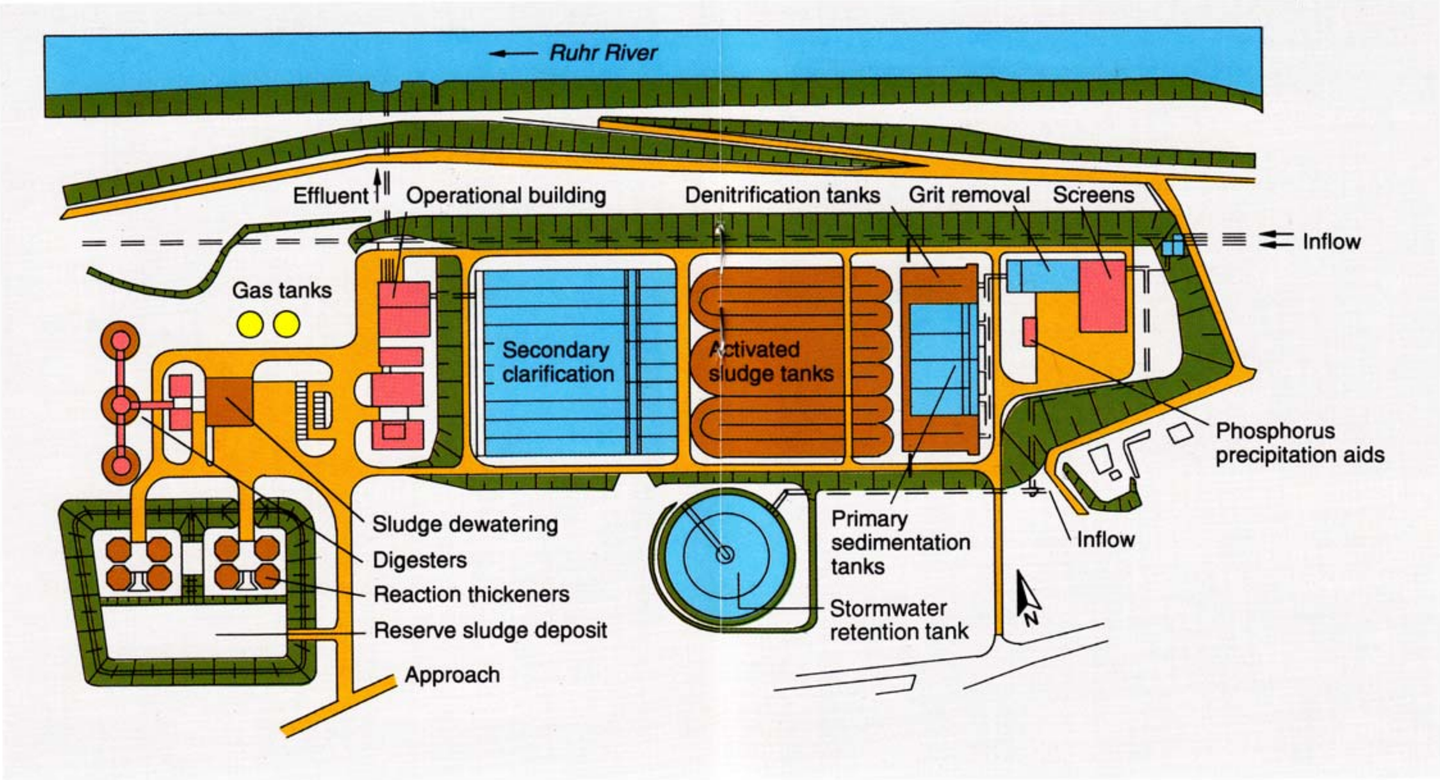
Due to recent changes in wastewater treatment standards, however, even stricter requirements exist concerning the degree of purification for wastewater treatment plants with a capacity of more than 100,000 population equivalents.

In order to make the wastewater treatment plant Duisburg-Kaßlerfeld fulfill these requirements, that part of the plan concerning wastewater technology was revised after the authorization in order to allow a specific nitrification and denitrification as well as the elimination of phosphate. The revisions were included in the authorization by an alteration of the approval of concept in summer 1989.

Due to its importance for the infrastructural development in the catchment area the realization of the wastewater treatment plant Duisburg-Kaßlerfeld was subsidised by the federal government of Northrhine-Westphalia with a subvention covering up to 80% of the costs of investment. This was part of a programme for the future development of this region where the traditional industries are those of coal and steel. The programme is called "Zukunftsinitiative Montanregionen (ZIM)". Thereby, the Ruhrverband was considerably supported in solving problems of water resources policy. The Ruhrverband was thus able to take the relevant measures in very short time.

Structural engineering and project management

The construction works started late in 1988. In summer 1992 the carcase work was completed. As a first measure the entire area was surrounded with a tightening wall in order to protect it



against ground water floods. This wall is 60 cm thick, 1,450 m long and has a surface of about 36,000 m². It reaches down to a maximal depth of 45 m in the underground. This complex construction was necessary because it was decided to avoid an intake pumping station for economical reasons. Thus, the wastewater treatment tanks lie below the level of the rest of the area.

The construction work was considerably influenced by the request to maintain the previous degree of wastewater treatment and the discharge of the wastewater during the entire time of construction. Due to the construction plans and the necessity to protect certain plants which were already or still in operation the construction work faced severe obligations. Additionally considerable masses had to be moved. In the allotment of the wastewater treatment plant alone about 500,000 m³ of soil had to be moved and about 52,000 m³ concrete had to be produced with 6,000 t of steel and 100,000 m³ of sheating.

The realization of this largest single investment in the field of wastewater treatment of the Ruhrverband with costs of DM 320 million demanded an efficient pursuance of the construction plans. For this reason the aims of the project were defined, the numerous crucial points of the plan were pointed out and the necessary outlines for the organisation and execution of the planned construction work were made. Due to a tight time schedule and estimated costs which were not to be exceeded a computer system was installed which controlled the schedules in terms of time and costs for the entire construction work. Apart from the control of time and costs another very important factor was the coordination of those involved in the construction work.

The facts that all parts of the plant could be started up in time and that the estimated costs were not exceeded prove together with the now existing operating results the success of the project management and the quality of the means of control and supervision used.

Wastewater treatment processes

The wastewater is treated mechanically, biologically and chemically. The mechanical treatment uses a screening plant, an aerated grit removal tank and primary settling tanks. The wastewater runs through the screening plant in four parallel flows with a backraking coarse screen (60 mm clearance) and a fine screen (20 mm clearance) each. The screenings are dewatered and transported via converter belts to containers. The entire plant was erected in a closed building for reasons of possible emissions and in order to guarantee an undisturbed operation even during winter.

After flowing through the grit channels the wastewater enters the primary settling tanks. Due to the fact that alterations had to be made for nitrification, denitrification and phosphate elimination the total volume of the four primary tanks was reduced to 5,200 m^3. This reduction effects a coarse sludge removal in only 0.6 hours.

The biological treatment operates according to the activated sludge process. Three carrousel basins with a total volume of 60,000 m^3 are constructed for parallel nitrification and denitrification. Additionally, two denitrification tanks were installed with a total volume of about 10,000 m^3, where temporarily a biological elimination of phosphate occurs. Recirculation into the denitrification tanks was designed for three times dry weather flow.

The carrousel basins are equipped with a fine-bubble compressed air aeration and a seperate circulation. For each basin eight disconnectable groups of aerators were installed. The entire aeration system was built for 65,000 m^3/h of air.

The separation of the aerated sludge from the treated wastewater takes place in the final clarification for which there are five rectangular tanks. These final clarification tanks have a total volume of 40,000 m^3. The sedimented sludge is removed by two sludge scrapers each. Due to the fact that the primary tanks are very small the waste activated sludge is thickened seperately. The treated wastewater is discharged through perforated pipes.

The chemical treatment (simultaneous precipitation) eliminates the phosphorous which together with nitrogen can cause an undesired mass development of algae in the receiving waters, even in the North Sea.

Operation and control

A staff of 38 people on the wastewater treatment plant Duisburg-Kaßlerfeld (incl. stormwater treatment plant and disposal site for dewatered sludge) allows a permanent control of the plant in three shifts. Despite a considerable automisation of the plant the operation center is permanently occupied.

All informations relevant for the operation and control of the plant are transmitted to the operation center. Here the information is processed with the help of a computer and thus provides the necessary data for the staff. With the help of colour screens the shift-leader gains detailed insight into the conditions of any part of the plant and can take the relevant measures in case of disturbances. A total control of the plant is guaranteed by a large mosaic plate which shows the entire plant and which immediately signals disturbances. Apart from the operation center there are several sub-centers where the power station, the dewatering of sludge, the sludge digestion and the sludge thickening are controlled.

In order to operate and control the plant according to the relevant standards and to optimise the costs of energy consumption complex plants for process control were installed. The process control is of special significance for the operation of the biological treatment.

The revision of certain laws and decrees demands that the operators of wastewater treatment plants are to take stronger measures for the control of their plants. Among others this includes the strict control of the achievement of the minimum requirements, the registration of additional parameters and the documentation of proper operation.

Influx and discharge of the wastewater treatment plant as well as the internal wastewater and sludge flow are not only controlled by the local analytical instruments which are continuously working but, more important, by the laboratory of the wastewater treatment plant and the central laboratory of the Ruhrverband in Essen. The operational data are registered in reports and can be plotted as diagrams.

The intensive control of the wastewater treatment plant executed by the Ruhrverband itself guarantees a fulfilment of the effluent quality demanded by law.

Sludge treatment processes

The sludge treatment plant consists of the unaerobic stabilization of sludge by digestion and the mechanical dewatering of sludge. This plant was started up in spring 1991.

The main part of the sludge stabilization plant consists of three digesters with a volume of 8,720 m³ each which are operated in parallel as mesophilic reactors at a temperature of 35 to 38 °C. The organic substances of the sludge are decomposed in the digesters to such an extent that the sludge can be dewatered afterwards and disposed without the emission of odour. The sludge remains in the digesters for about 21 days. The digestion process produces about 10,000 m³ of gas per day which is stored in two gas tanks with a volume of 4,000 m³ each and then used for the generation of energy and compressed air in gas motors. The waste heat thus caused is used in turn for providing the digestion tanks with the temperature needed. Additionally, the buildings of the wastewater treatment plant are heated with this waste heat.

Whereas the primary sludge can be pumped directly from the primary clarifyers to the digesters the waste activated sludge from the secondary tanks has to undergo a preliminary thickening. This can be effected statically in gravity thickeners as well as mechanically by centrifuges. Both processes can be operated either in series or in parallel.

The digested sludge is dewatered in three chamber filter presses with a volume of 14 m^3 each. In order to improve the conditions of dewatering the digested sludge is conditioned by adding slaked lime and ferric chloride. Additionally it is statically thickened in a reaction thickener for 24 hours. With the help of high-pressure pumps the conditioned sludge is pumped to the chamber filter presses. By dewatering the digested sludge is concentrated to 40% of dry solids. This means a reduction of volume of about 90%. The supernatant and the filtrate which are thus obtained are led to the influx of the wastewater treatment plant. After the pressing the chamber filter presses are opened and the dewatered sludge falls into the silos situated underneath the presses. From there lorries carry the dewatered sludge to the mono-deposit on the Ruhrinsel Raffelberg about seven kilometres away.

Environment-friendly technology

Wastewater treatment is important for the protection of surface waters and the related eco-systems in terms of environment policies. In the ecological context environment-friendly wastewater treatment nowadays has to fulfill more tasks than just the provision of the technical preconditions for wastewater disposal. Prevention of emissions, the protection of valuable resources, recycling strategies and the minimization of waste are some of the demands modern wastewater treatment has to meet.

As a good example of this policy an innovative concept concerning the use of methane gas was realized on the wastewater treatment plant Duisburg-Kaßlerfeld. Methane gas is obtained as a by-product of sludge digestion. The power station of the plant is equipped with five gas engines. Two of these engines are directly connected to turbine blowers (500 kW each). Another gas engine is connected to a generator (750 kW). The two remaining gas engines (500 kW each) were constructed as tandem aggregates and thus produce via turbine blowers the compressed air needed in the activated sludge tanks. At the same time they supply electric energy for the operation of the wastewater treatment plant via generators. In order to be more effective, heat exchangers following the system of "power-heat-connection" regain the heat of the gas engines.

In order to improve the heat balance a "sludge-sludge heat exchanger" (recuperator) is used on the wastewater treatment plant Duisburg-Kaßlerfeld. In this exchanger the defluent warm digested sludge exchanges heat with the raw sludge which is pumped into the digester.

The main aim of the entire energy concept is to use existing resources such as methane gas or the waste heat from the gas engines to such an extent that the use of external sources of energy (electricity or natural gas) can be minimized. Thus, almost 75% of the primary energy needed is produced on the plant itself.

In the case of the power station and other sources of noise extensive measures for noise protection were taken.

Architectural design

Determining for the design of the wastewater treatment plant and the individual buildings was the site parallel to the flow of the Ruhr in an area characterised by industrial sites. Due to the alignment from east to west along the Ruhr, the plant could be designed consequently and without restrictions. The modular order of the tanks causes clearly distinguishable zones of operation in the plant. The order of the buildings was designed in consequence of the clear concept of the entire plant which included linearity, horizontal and rectangular lines, smooth silhouettes and the creation of clearly defined spaces.

The buildings were carefully designed with regard to their dimensions and arranged in groups. Recurring material and elements created an architectural unity. This was underlined by the choice of the forms of the buildings: cubus, circle and arch. The form and the function, however, always form a logical unity. This technological architecture is characterized by its restrictivness and the concentration on the essential as well as by the contrast to the varied environment.

For the outward design of the buildings coated aluminium facades were attached. These facades were used as specially formed plates with a smooth surface which is resistant against the industrially influenced air in this region and which does not give opportunity for excessive accumulation of dirt. The combination of these plates as well as the matching in terms of colours makes the immense surfaces less monotonous.

Additional elements of design are the smoothly rounded corners of the buildings and the arched plate elements forming interesting roof tops. It was necessary to design these details carefully in order to allow a recognisable unity on the one hand

and to cause an effect of lightness by the choice of certain colours and material on the other.

The modular order of the buildings effected an obvious - and thus natural - caesura for the construction work. This was necessary in order to construct the plant according to the construction plans and the operational necessities.

The choice of colours and material for the interiors follows the restrictive concept of the outward design. The mechanical parts of the plant such as presses, pumps, engines and tanks were painted in clear and bright colours in order to oppose the uniformity of concrete walls and to make the different functions of the individual parts more obvious.

Wastewater Treatment Plant Duisburg-Kaßlerfeld - Summary of data -

Basic design data

Inhabitants of the catchment area and population equivalents	450,000
Influx during dry periods Q_t	2.3 m^3/s
Max. influx of stormwater Q_m	4.1 m^3/s

Stormwater plant Ruhrinsel Raffelberg

2 settling tanks with cross flush	
(tanks for basic flow)	L/W/H = 101.40/30.40/3.34 m
Volume	2 x 10,800 = 21,600 m^3
Surface	2 x 3,083 = 6,166 m^2
4 stormwater ponds (eathern tanks with clay tightening)	
Volume	30,000 + 60,000 = 90,000 m^3
Surface	30,000 + 40,000 = 70,000 m^2
Duration of discharge	5 h/a
Depth of water in dry periods	1.0 m
Depth of water in periods of high precipitation	1.82 and 2.57 m
Pumping stations with operational building	
New constructed inflow and effluent sewers:	
Siphon below ship canal	∅ 2,800 mm
Discharge canal into old arm of the Ruhr	∅ 2,000 mm to ∅ 3,000 mm, 590 m long
Sewer to the wastewater treatment plant (siphon below ship canal)	∅ 1,400 mm to ∅ 1,600 mm, 550 m long

Stormwater treatment on the wastewater treatment plant

Stormwater retention tank Duisburg-Kaßlerfeld, volume	10,400 m^3

Disposal site 1 for dewatered sludge

Area	9.3 hectare
Volume	750,000 m^3

Screens

4 automatic backraking coarse screens	60 mm clearance
4 automatic backraking fine screens	20 mm clearence
Screenings bale press 4 containers with a volume of 10 m^3 each in rotating operation	

Grit removal

Grit chamber with 4 channels	
Degritting device and grit container	L/W/H = 31.50/2.40/1.40 m
Total volume	256 m^3
Total surface	302 m^2
Automatic degritting device, sand classifier 4 containers with a volume of 10 m^3 each	

Primary settling and denitrification tanks

4 rectangular tanks with sludge scrapers	L/W/H = 32.76/13.00/3.15 m
Total volume	5,400 m³
Total surface	1,700 m²
Pre-denitrification tanks, Horizontal flush caused by stirring devices, 2 rectangular tanks with two chambers each	L/W/H = 39.20/25.00/5.30 m
Volume	2 x 5,170 m³

Activated sludge tanks

Carrousel flow caused by stirring devices, oxygen supply by fine-bubble aeration	
3 carrousel activated sludge tanks with optional anaerated zones	L/W/H = 119.80/34.50/5.20 m
Volume	3 x 20,000 m³
BOD_5 space loading	0.41 kg/(m³ · d)
BOD_5 sludge loading	0.15 kg/(kg d. s. · d)

Secondary clarification

5 rectangular tanks with sludge scrapers	L/W/H = 108.00/20.40/3.60 m
Total volume	40,000 m³
Total surface	11,000 m²

Sludge storage tanks and thickeners

2 waste activated sludge thickeners each	1,250 m³
2 storage tanks each	1,250 m³
1 storage tank	1,000 m³
3 reaction thickeners each	1,000 m³
Supernatant storage tank	

Centrifuge building

2 centrifuges (ultimate capacity 4 centrifuges), each	60 m³/h
Recuperator	580 kW

Digesters

3 pre-stressed concrete tanks each	8,720 m³
Diameter/height	22.30 m/39.00 m
Amount of raw sludge	1,250 m³/d
Dry solid content of raw sludge	4-6%
Time of digestion	21 d

Engine station

Heat exchanger, heating installations, gas metering station

Sludge dewatering building

3 chamber filter presses	
Plate size	2 x 2 m
Total filter surface	2,940 m²
Volume of each filter press	14 m³
Computer-aided control station	

Gas tanks

2 tanks, each	4,000 m³

Flare

Operational building

Control center
Computer-aided control
Remote impact

Staff building

Recreation room, locker room, sanitary facilities for 38 members of staff

Workshop

Power station

2 tandem aggregates (gas engine, generator, turbine blower) each	500 kW
2 blowers (gas engine, turbine blower) each	500 kW
1 generator aggregate (gas engine, generator)	750 kW
Computer-aided control center	

Flood pumping station

2 sumps	
6 vane-type pumps with reversable poles	
Capacity	6 x 2.6/1.3 m³/s
Elevating height	10.1/2.5 m