

# Wastewater Treatment Plant Amsterdam West: New, Large, High-Tech and Sustainable

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**Abstract** This paper presents the new wastewater treatment plant Amsterdam West: a high-technology and sustainable wastewater treatment plant with a biological capacity of 1.0 million population equivalents. The design is based on the modified UCT process. Due to the limited space, deep activated sludge tanks (8.2 m) and secondary sedimentation tanks (side depth 3.45 m) are applied. The WWTP Amsterdam West was constructed within a period of app. 27 months and started-up in three months. The WWTP Amsterdam West operates well and produces a high-quality effluent, with yearly average concentrations of 6.7 mg N<sub>total</sub>/l and 0.8 mg P<sub>total</sub>/l. Biogas and sludge are combusted with high-rate energy retrieval at the nearby Waste and Energy Enterprise Amsterdam.

**Keywords** BNR, energy retrieval, large scale WWTP, modified UCT, nutrient removal, sustainable wastewater treatment

## Introduction

By the year 2000, Amsterdam had three wastewater treatment plants (WWTPs): one in the East of Amsterdam (Zeeburger Island), one in the South (Amstel industrial area) and WWTP Westpoort in the Amsterdam West Port Area. By 2005, the WWTPs in the East and the South could no longer comply with the new effluent discharge and environmental requirements. It would have taken huge investments to meet these requirements. Beside this, the municipality of Amsterdam had planned to build houses and offices on Zeeburger Island and to renovate and develop the Amstel industrial estate. The existing WWTPs did not fit in with these new plans (Reitsma *et al.*, 2006). Therefore, the regional water authority of Amstel, Gooi and Vecht (AGV) and the municipality of Amsterdam decided to translate the total treatment capacity of the current WWTPs into one new centralised wastewater treatment plant in the Amsterdam West Port Area: the WWTP Amsterdam West (see fig. 1.1), currently the second largest WWTP of the Netherlands. A network of pressure mains has been constructed to transport the wastewater from the former WWTP sites in Amsterdam South and East to the new WWTP in Amsterdam-West. Due to the large distances the pressure mains are equipped with booster pumping stations. This also involved modifying the pumping stations of the Amsterdam sewerage system. In total 49 km of pressure mains with diameters ranging from 600 to 2,400 mm and four booster pumping stations have been built (Mulder *et al.*, 2005).



**Figure 1.1** Locations of the previous WWTPs Amsterdam East and South and the new WWTP Amsterdam West, with connecting pressure mains and booster pumping stations.

The WWTP Amsterdam West has been designed with state-of-the-art technology, based on primary sedimentation, activated sludge – configured as the modified University of Cape Town (mUCT) process – and secondary sedimentation tanks. The treated water is discharged into the nearby harbour.

The selected biological treatment process removes nutrients at minimal (or even zero) chemical input. Energy consumption is minimised by selection of energy-efficient process configuration and aeration equipment. The energy content of the sludge and biogas is very efficiently utilised through co-operation with the neighbouring Waste and Energy Enterprise Amsterdam (AEB). The digested and dewatered (24% dry solids, DS) sludge of the WWTP is combusted in the high-efficiency incineration furnaces of the AEB. Co-incineration of wastewater sludge improves the heat balance of the furnaces, which enables the AEB to process more solid waste and produce a higher energy output. The biogas from the sludge digestion process is converted into electricity by gas engines at the AEB site, producing app. 40% of the electricity demand of the WWTP. The hot exhaust gases of the biogas engines are used to pre-heat the combustion air of the furnaces. The heat content of the cooling water is returned to the WWTP by means of a hot water circuit, to heat the buildings and sludge digestion. In this way, the energy content of the biogas is utilised with an overall 85% efficiency. Thus, the new WWTP not only produces clean water, but also helps the AEB to generate sustainable energy.

Noise and odour emissions are controlled by covering the surfaces of all process units in the water treatment and sludge line, except the secondary sedimentation tanks. The ventilation air from these units is treated by biofiltration, with pre-treatment of the most sulphide-loaded streams in a chemical scrubber.

The WWTP Amsterdam West was constructed within a very short building phase between spring 2003 and autumn 2005. On 18 July 2005 the first treatment units were taken into operation, while the last treatment tanks and the sludge treatment facilities were still under construction. The plant was started up in phases, resulting in full operation of all facilities in October 2005 (see table 1.1).

## Design of WWTP Amsterdam West

Being the main treatment facility of Amsterdam, with a capacity of 1.0 million population equivalents (P.E.), the WWTP Amsterdam West must be very reliable, functioning well under average as well as extreme conditions (peak flows and changing wastewater characteristics). Of main importance is also that the WWTP should be easily operated and maintained. Last but not least, the waterboard has committed itself to environmental friendly and sustainable wastewater treatment systems, therefore the design of the WWTP is aimed at minimum use of fossil fuels and chemicals, and a minimum production of waste, noise and odour.

All this had to be constructed on a very confined space of 1,100 x 120 m in the middle of the Amsterdam harbour area. The design of process units, piping and lay out had to be adopted to fit such a large WWTP within the available space.

The total design capacity is based on wastewater production prognoses for the year 2010. The WWTP is designed in such a way that a future expansion of the capacity by 10% is possible. If necessary due to the implementation of the European Water Framework Directive, tertiary treatment facilities like sand filters and/or UV disinfection can be added easily in the future.

**Table 1.1** Design treatment capacity of the WWTP Amsterdam West

Average dry weather flow	m <sup>3</sup> /h	7,000
Peak flow	m <sup>3</sup> /h	30,000
Average flow (wastewater + storm water)	m <sup>3</sup> /d	200,000
N <sub>total</sub>	kg/d	8,900
N <sub>kjeldahl</sub>	kg/d	9,000
NO <sub>3</sub> -N	kg/d	140
NO <sub>2</sub> -N	kg/d	30
P <sub>total</sub>	kg/d	1,250
BOD	kg/d	44,000
COD	kg/d	97,000
TSS	kg/d	52,800
Waste load as P.E. = 136 g TOD/d	PE	1,000,000

The effluent discharge standards for WWTP Amsterdam West are compliant with the European Union Municipal Wastewater Directive.

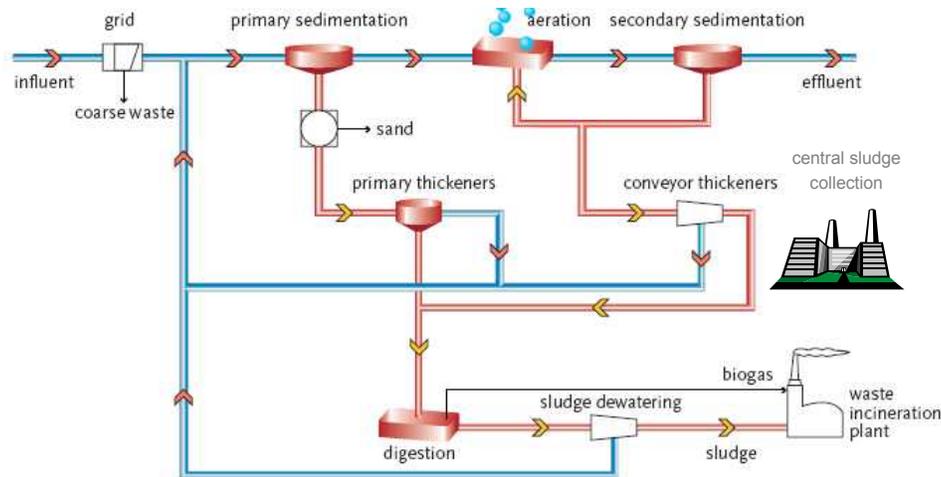
**Table 1.2** WWTP Amsterdam West effluent discharge standards

COD	125 mg/l	
BOD	20 mg/l	
N <sub>total</sub>	10 mg/l	yearly average
P <sub>total</sub>	1.0 mg/l	rolling average of ten 24 hours-samples
TSS	30 mg/l	

Two pressure mains (1,800 mm and 1,600 mm diameter) deliver the wastewater at the reception works of the WWTP, at a hydraulic level of 12 m above groundlevel. From there, the water flows by gravity through the treatment units of the WWTP. These include:

- 4 6 mm fine screens, with screenings press and containers;
- 1 flow partition works No. 1;
- 4 primary sedimentation tanks, each 49.6 m in diameter and 5,800 m<sup>3</sup> in volume;
- 1 flow partition works No. 2;
- 7 aeration tanks, each 8.2 m deep and 17,100 m<sup>3</sup> in volume, with degassing chambers;
- 14 secondary sedimentation tanks (2 tanks per aeration tank), with a side depth of 3.45 m and a diameter of 52.2 m;
- 2 effluent pipes, each with flow measuring flume;
- 1 effluent discharge works.

Figure 1.2 displays the flow scheme of the WWTP Amsterdam West (an aerial overview over the WWTP site is presented in figure 1.4).



**Figure 1.2** Process scheme of WWTP Amsterdam West

### Advanced biological nutrient removal

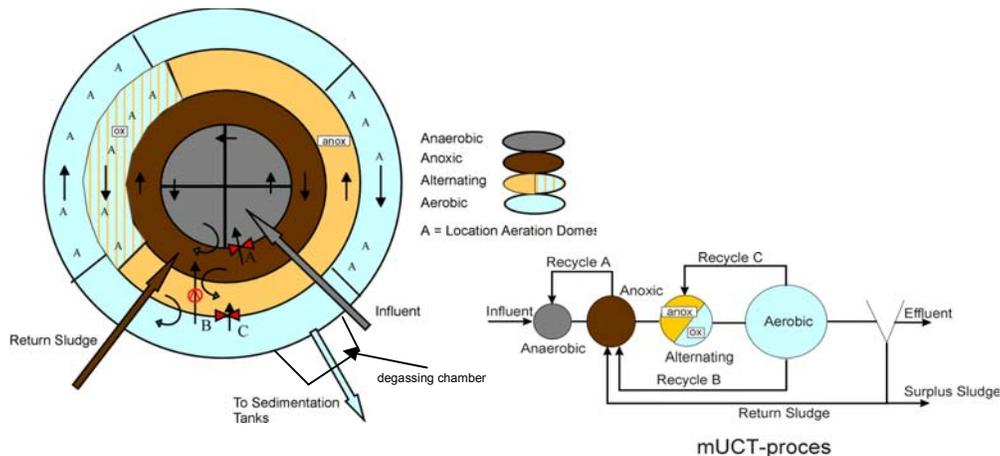
The wastewater treatment process of WWTP Amsterdam-West is based on the modified University of Cape Town (mUCT) process (Reitsma *et al.*, 2001a). Within this treatment concept enhanced nitrogen removal by nitrification and denitrification is combined with biological phosphorus (Bio-P) removal with secured prevention of bulking sludge (see right scheme in figure 1.3). To save space the activated sludge tanks have a water depth of 8.2 m.

In the anaerobic compartment growth of bio-P micro-organisms is stimulated. In the anoxic compartment predenitrification occurs. In this compartment the nitrate which is recirculated from the aerobic compartment (recirculation B) and the nitrate in the return activated sludge are denitrified. At the end of this anoxic compartment, after consumption of the nitrate, sludge is recirculated to the anaerobic compartment (recirculation A). In the facultative compartment the remaining nitrate is denitrified during summer, with the aeration turned off; in wintertime the facultative compartment is aerated to achieve sufficient

nitrification. In the aerobic compartment nitrification takes place and the remaining COD, which has not been used by the bio-P or denitrifying micro-organisms, is oxidised. The nitrate is recirculated from the aerobic compartment to the facultative compartment by recirculation C.

Investigations carried out in the Netherlands (STOWA, 2001; Kruit *et al.*, 2001) indicate that sludge bulking can be prevented by separating the anaerobic, anoxic and aerobic processes into a series of compartments, thus approaching plug flow conditions. The biological treatment system of the WWTP Amsterdam consists of a series of 7 compartments.

To prevent flotation, due to the high nitrogen gas concentration absorbed in the deep aeration tanks, a degassing chamber is provided between the aeration tanks and the secondary sedimentation tanks.



**Figure 1.3** Layout of the cylinder-shaped compartmented aeration tank at WWTP Amsterdam West and the process scheme of the modified UCT process

### Deep secondary sedimentation tanks

In the Netherlands the commonly accepted design method for secondary sedimentation tanks is the so-called 'STORA-method', which is based on the 1976 German design standard (ATV, 1976). The STORA-method is adapted to the Dutch tradition of relatively shallow sedimentation tanks, due to the high ground water tables (with consequently high construction costs for deep tanks), limiting the side depth to 2 metres. Because of the limited space, Waternet and Witteveen+Bos Consulting Engineers investigated whether the diameter of the secondary sedimentation tanks could be reduced by increasing their surface loading. ATV design rules (ATV-directive A131, 2000) apply larger side depths that allow a higher surface loading. It was decided to apply a combination of the ATV-directive A131 and the STOWA-method for the design of the secondary sedimentation tanks at WWTP Amsterdam West (Reitsma *et al.*, 2001b; Reitsma and Kramer, 2004; STOWA, 2002). This resulted in secondary sedimentation tanks with 52.2 m diameter, 3.45 m side depth and a surface loading  $1.0 \text{ m}^3/\text{m}^2\text{h}$ . To accommodate future capacity increase, deflection baffles can be installed in the tanks.

### Sludge treatment and biogas processing

The sludge processing at WWTP Amsterdam includes the following treatment units:

- 2 Gravitational primary sludge thickeners, each with a diameter of 26 m and 3 m deep;
- 5 Secondary sludge belt thickeners;
- 3 Digestion tanks, each 11,500 m<sup>3</sup>;
- 4 Centrifuges with a total capacity of 4 \* 1,500 kg DS/h;
- 2 Dewatered sludge cake silos, each 500 m<sup>3</sup>;
- 1 Truck loading bay for dewatered sludge transport;
- 2 Gas storage tanks, each 1,875 m<sup>3</sup>;
- 1 Biogas emergency flare



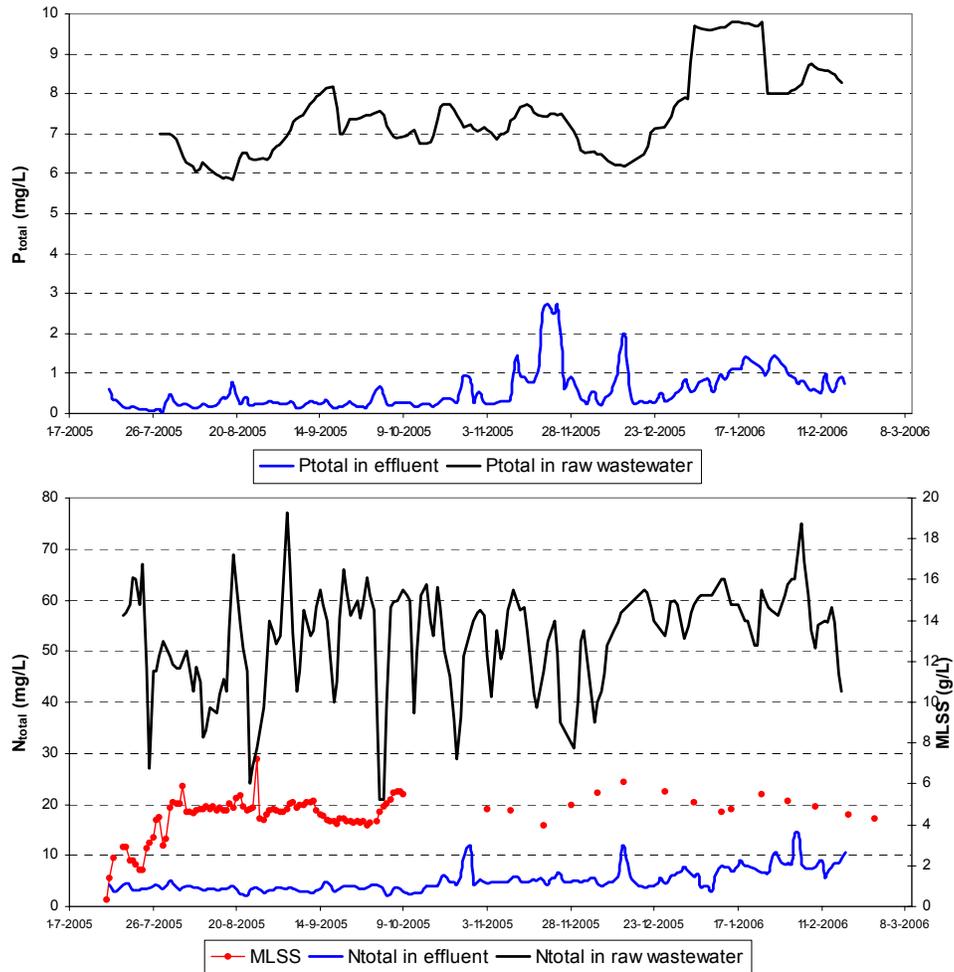
**Figure 1.4** Aerial picture of the WWTP Amsterdam West. In front: digestion tanks with office buildings and sludge treatment, in the background: the wastewater treatment lines, and on the right side: the AEB.

Besides the primary and surplus sludge produced by the WWTP Amsterdam itself, the sludge treatment is fed with liquid sludge transported by pipeline from the nearby WWTP Westpoort and with thickened sludge from several WTPs within the AGV area. To accommodate the internal and imported sludge flows, the sludge processing installations at WWTP Amsterdam West have a capacity of app. 1.8 million p.e. The sludge is dewatered by means of centrifuge decanters to approximately 24 % dry solids. The dewatered sludge is stored in sludge cake silos and transported to the AEB (see incineration buildings with two chimneys at the right side of the aerial picture). There it is injected into the high-efficiency furnaces and incinerated together with municipal waste.

Electric energy generated by the gas engines is transferred back to the treatment plant. In addition, the digestion tanks, workshops and offices at WWTP Amsterdam West are heated by a hot water circuit, which is fed with heat from the biogas engines and furnaces of the AEB. In the future the heat exchange may also be used to raise the temperature of the wastewater during winter times to increase treatment activity.

### Operational Results

The WWTP Amsterdam West has performed very well from the first day of start-up until today (Mulder *et al.*, 2005; Reitsma *et al.*, 2006). The wastewater treatment process produces effluent with yearly average nutrient concentrations of < 6.7 mg total nitrogen/l and < 0.81 mg total phosphorous/l (see figure 1.5).



**Figure 1.5** Treatment efficiencies over the first year of operation of WWTP Amsterdam West for total phosphorous (above) and total nitrogen and MSL (below), resulting in yearly average concentrations in the effluent of < 6.7 mg N<sub>total</sub> /l and < 0.8 mg P<sub>total</sub> /l

## Conclusions

The new wastewater treatment plant Amsterdam-west has been successfully designed, constructed and taken into operation, within the limits of available space, time and budget.

The applied technology, based on the mUCT process, is sustainable in terms of low energy and chemical consumption and effluent quality. Sustainability is implemented in daily operation by the co-operation with the neighbouring Waste and Energy Enterprise Amsterdam. This combined effort has led to a very energy-efficient energy exchange, with biogas and dewatered sludge going in one direction and electricity and heat in the other.

From the first start-up phase the process has produced effluent with  $< 6.7 \text{ mg N}_{\text{total}} / \text{l}$  and  $< 0.8 \text{ mg P}_{\text{total}} / \text{l}$ , fully compliant with the EU Municipal Wastewater Act.

## References

- ATV (2000) Design of one-step activated sludge treatment plants (in German). Arbeitsblatt, ATV-DVWK A131.
- Kruit, J, Huilsbeek, J., Visser (2001). Bulking sludge solved? Proceedings of the Third IWA Activated Sludge Population Dynamics Specialist Conference, 13-15 June, Rome, 2001, pp 344-352.
- Mulder M., Van Nieuwenhuijzen A., and Reitsma B. (2005). Start-up of the first treatment units of the remarkable "small" WWTP in Amsterdam (in Dutch). *H<sub>2</sub>O*, 2005, vol. 11.
- Reitsma B., Van Nieuwenhuijzen A. and Mulder M. (2006). Start-up of the new WWTP Amsterdam-West (in Dutch). *H<sub>2</sub>O*, 2006, vol. 10.
- Reitsma, B. (2001a). Implementation of the mUCT-process at the new WWTP Amsterdam-West (in Dutch). *H<sub>2</sub>O*, 2001, vol. 18.
- Reitsma, B., et al (2001b). Increased surface load secondary sedimentation tanks WWTP Amsterdam-West (in Dutch). *H<sub>2</sub>O*, 2001, vol. 19.
- Reitsma, B.A. and Kramer, J.F, (2004). New guidelines for deep secondary sedimentation tanks (in Dutch). *H<sub>2</sub>O*, 2004, vol. 11.
- STOWA (2001). Bulking sludge control at nutrient removal WWTPs (in Dutch), STOWA report 2001-02. Utrecht, the Netherlands.
- STOWA (2002). Optimisation of round secondary sedimentation tanks (in Dutch). STOWA report 2002-21, Utrecht, The Netherlands.