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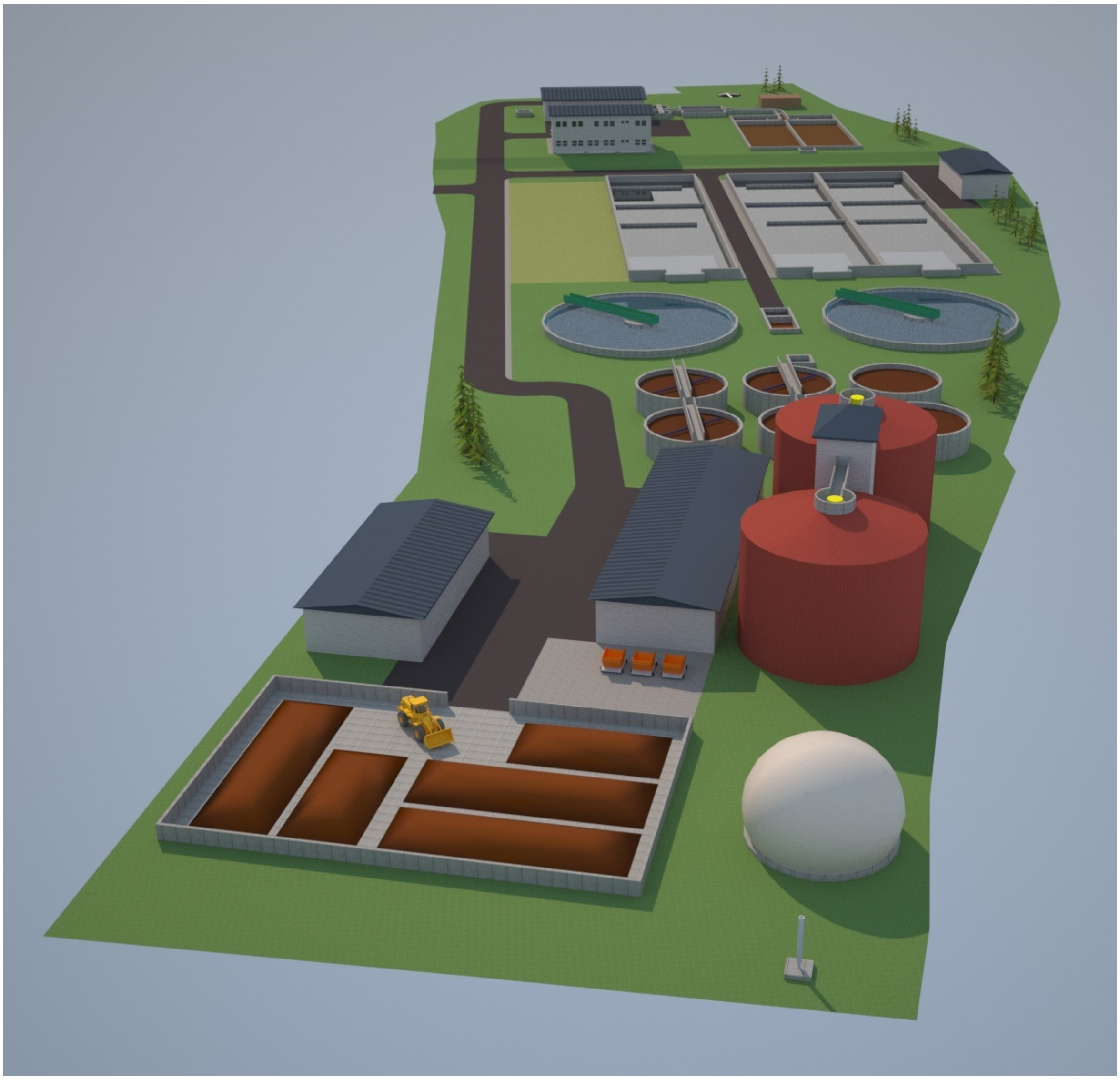

Modern WWTP Design

SLUDGE PRODUCTION & ENERGY EFFICIENCY

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Table of Content

Figures and Tables

1 Future Requirements for Wastewater Treatment Plant Design

The enforced implementation of Council Directive 91/271/EEC for Urban Waste Water Treatment (UWWTD) sets out additional requirements for future WWTP design in order to comply with state of the art process technology, regarding:

- Advanced sludge treatment for reduced sludge production;
- Phosphorous recovery;
- Energy efficiency.

It should be noted that these requirements are closely related and may be realized step by step during the life-cycle of newly designed and completed WWTP's and shall be considered for upgrade and rehabilitation of existing WWTP's.

1.1 Reduce Sludge Production

Sludge production (primary sludge + waste activated sludge) is chiefly dependant on the adopted wastewater and sludge treatment process technology of a WWTP.

- Primary sludge (PS) production depends on the required wastewater treatment efficiency, i.e. whether primary treatment is applied for secondary treatment or tertiary treatment at big WWP's;
- Secondary or WAS production depends on the biological treatment process, i.e. application of the attached growth or suspended growth process, or combinations thereof;
- Digested sludge production depends on the degradation efficiency of the sludge stabilization process and potential process optimisations.

For the purpose of *minimized primary sludge production* primary sedimentation (PS) shall be applied only in case anaerobic digestion is planned for sludge treatment. In such case it should be planned for maximized separation efficiency (SRT ≥ 2,5 h) in case of secondary treatment and as coarse Sedimentation (SRT ≤ 0,5 h) or COD-exfiltration[1] in case of tertiary wastewater treatment in order to maintain the readily, soluble COD fraction for biological treatment.

Reduction of *secondary* & tertiary *sludge production* (WAS) can be achieved by consideration of the attached growth process for secondary wastewater treatment (TF[2], RBC[3]) and by combinations of the suspended growth process (such as CAS[4]) with the attached growth process in case of tertiary wastewater treatment.

Such combinations include advanced wastewater treatment process variants of MBBR[5], IFAS[6] or Nereda[7]. In addition, it should be highlighted that multi-stage treatment processes, such as step-

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[1] Exfiltration of the inert, non-dissolved COD-fraction by micro-sieves (http://www.huber.de/huber-report/ablage-berichte/screens/huber-supplies-a-process-system-as-replacement-for-the-primary-settling-tank.html)
[2] TF = Trickling Filter
[3] RBC = Rotation Biological Contactors
[4] CAS = Conventional Activated Sludge (System)
[5] MBBR = Moving Bed Biofilm Reactor
[6] IFAS = Integrated Fixed-Film Activated Sludge (CAS + MBBR)
[7] Nereda® = modified CAS based on aerobic granulation, Mark van Loosdrecht of Delft, University

feed (cascade) or the modified multiple step Bardenpho process are more efficient at lower WAS production, compared with CAS, due to the cascade effect.

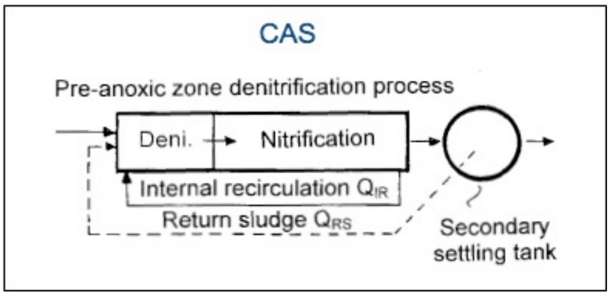


Fig. 1-1 Flow chart for CAS for BNR in accordance DWA-A 131

Review of many feasibility studies for on-going WWTP designs shows that in many cases the simple process of conventional, single stage activated sludge (CAS) for BNR, in acc. with the “plug flow” or A^2O process or SBR process, are adopted for BNR (biological nutrient removal, acc. Art. 4 of the UWWD).

More advanced wastewater-treatment options for reduced WAS-production are presented by the following flow-charts, based on the activated sludge process or combinations of the suspended growth and attached growth process applications.

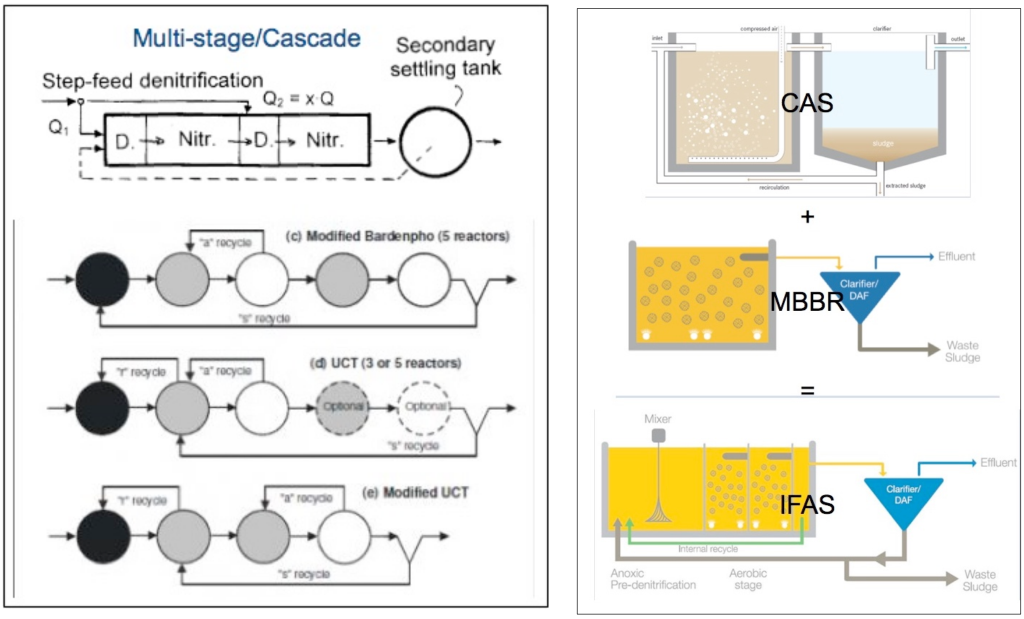


Fig. 1-2 Flow chart for multi-stage process for BNR and IFAS process

The specific WAS production will be reduced due to the adapted biocenosis of multi-stage treatment processes or due to attached growth at MBBR and IFAS. Compared with single-stage CAS an overall reduction of the WAS production in a range of 5-20 % can be assumed[8], depending on the adopted process variant.

The principles for *digested sludge reduction* are mainly targeting on *disintegration* of WAS and/or DS (digested sludge) in order to enhance hydrolysis of nutrients and organic carbon (COD) which are enclosed in the cell membranes of the organic matter (VDS). Thus, increasing the efficiency of VDS-decomposition by some 10-30 % which results in reduced SRT (HRT, digestion time) and

8 https://www.iwapublishing.com/news/reduction-sludge-production-wastewater-treatment-plants

increased digester gas production. However, sludge disintegration may increase the power demand of the activated sludge system due to increased back-charge from sludge water and supernatant which is balanced by the increased digester gas production.

More advanced processes options may consider hydrothermal oxidation (HTC) or combinations of mesophil anaerobic digestion with thermophilic aerobic digestion as well as 2-phase (high-rate) anaerobic digestion.

In addition, the final sludge quantity could be reduced by post-degradation of residual organic matter by sludge humification and composting. Sludge humification in reed beds shall be considered as additional process stage for small WWTP's because long-term storage will furthermore reduce the organic matter of digested sludge and significantly reduce the sludge volume.

The reduction potential of the overall specific digested sludge production by application of modern, commonly approved process technology can be achieved by combinations of the attached & suspended growth process variants for biological wastewater treatment as well as far reaching application of anaerobic sludge digestion combined with sludge disintegration.

The following graph illustrates the recommended range of application of different sludge treatment technologies:

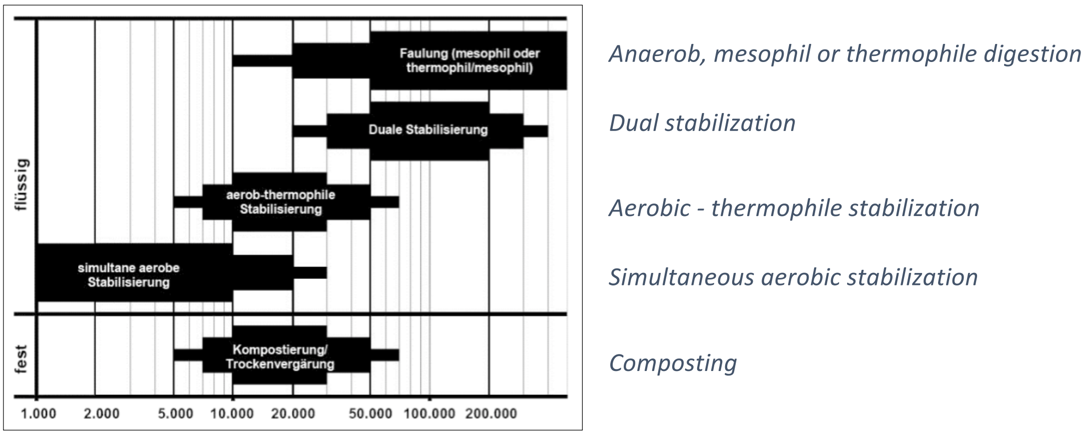


Fig. 1-3 Recommended applications for sewage sludge stabilization, acc. DWA-M368[9]

The review many feasibility studies for ongoing WWTP designs shows that mainly conventional sludge treatment process options for simultaneous aerobic sludge stabilization by extended aeration and single-stage anaerobic sludge digestion (with biogas utilization by CHP) are adopted.

Consultants and designers shall be encouraged to consider modern, state of the art process technologies for both, wastewater and sludge treatment in order to reduce the specific sludge production as far as possible.

1.2 Phosphorous Recovery

The main potential sources for P-reclamation from sewerage sludge are raw secondary & tertiary sludge (WAS), digested liquid sludge (DS), dewatered sludge and its supernatant as well as dry sludge and sludge-ash (in case of mono-incineration).

[9] Advisory leaflet DWA-M 368 „Biological Stabilisation of Sewage Sludge“, 2014 • DWA Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V. • D 53773 Hennef • ISBN: 978-3-944328-60-7

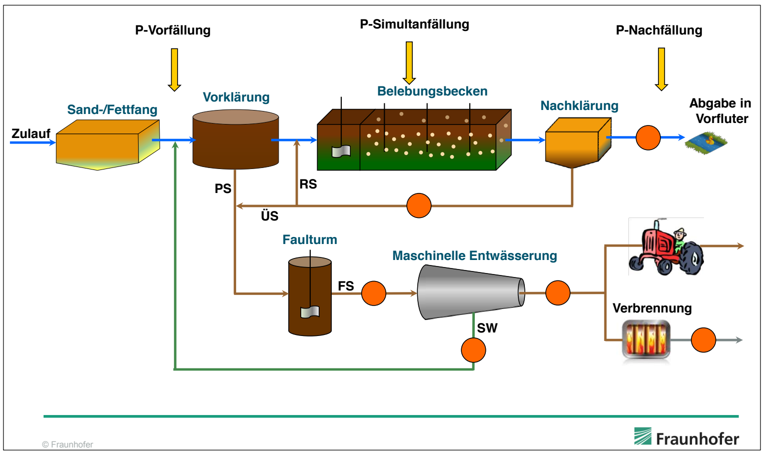


Fig. 1-4 Potential reclamation sources

Various process technologies have been evolved in recent years which are in the commercial phase, now. Two main technologies are available:

- P-extraction from the liquid phase, and
- P-recycling from sludge ash.

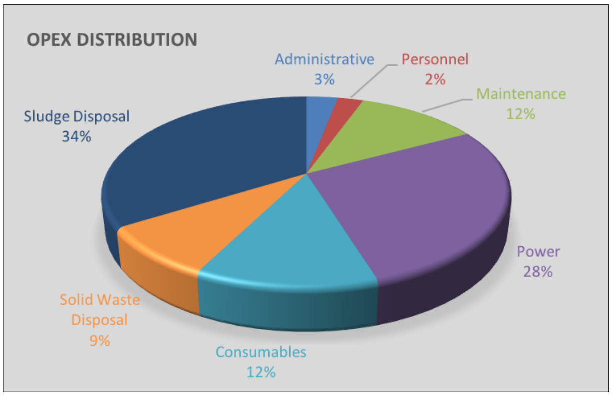
Phosphorus recovery shall be included in WWTP design shall be due to the fact that the access to this resource, which is most essential for future agricultural production, must be assured for the next generation!

- The wastewater treatment process options shall consider P-removal (EBPR + CPR);
- Sludge treatment shall consider future process options for P-reclamation from liquid sludge (i.e. space reservations and possibility to be included into the process);
- Sludge management and disposal shall avoid the loss of Phosphorous requiring mono-landfill of dried sludge or sludge ash;
- Inter-regional (inter-communal) sludge incineration facilities with P-recovery from ash shall be considered on the long term.

Phosphorous recovery at the WWTP will reduce the final sludge quantities accordingly (by some 5 %) and is ultimately required for the next generation in order to make sure todays crop rates!

1.3 Energy Efficiency and OPEX

Power consumption for wastewater and sludge treatment as well as sludge disposal costs are the driving cost factors of OPEX for individual WWTP's.



In most cases the annual costs for sludge disposal are almost equal to annual power costs and may reach 50-60 % of the total WWTP-Opex.

(Example 235.000 P.E.: CAS with anaerobic digestion and CCHP; dewatered sludge to mono-incineration at WWTP with ash-disposal to landfill).

Fig. 1-5 OPEX Distribution

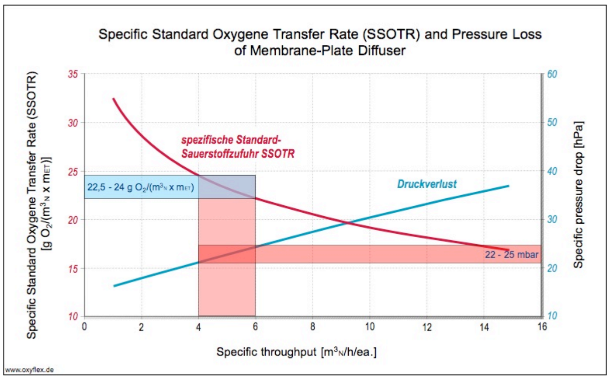
Power costs are depending on the specific power consumption of the wastewater treatment process whereas sludge treatment and disposal costs are depending on the specific sludge production of the individual WWTP.

In many EU accession states, the power market has been fully liberalized but future privatization should be taken into consideration with regard on the enormous investments necessary for network modernization and replacement of outdated power plants. On EU average the average industrial power costs increased by approx. 20 %d during an 8-year horizon.

It can be assumed that in many South-Eastern EU Member States and Western Balkan States current power tariffs for both private households and industrial consumers will increase accordingly, which justifies consideration of energy efficiency measures for WWTP design.

Improvement of energy efficiency targets on the efficiency of the aeration systems as well as on the benefit of self-generated (electrical) power after anaerobic, mesophilic sludge digestion.

At a conventional WWTP (CAS/SBR) the aeration system of the activated sludge system (blowers with membrane aerators or surface aerators) is the biggest consumer which causes approx. 60-70 % of the total power consumption.



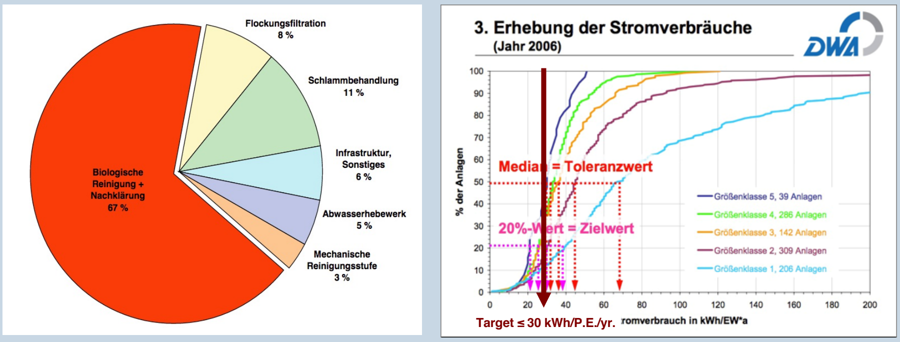
Optimization shall consider multiple stage process variants and application of high efficient aeration systems (OTE ≥ 3,5 - 4,2 kg O_2/kWh).
Plate-type aerators with a specific oxygen intake capacity of SSOTR ≥ 22-25 g O_2/m^3_N x m_{ET} [at 4-8 m^3_N/h/ea.) shall be applied in order to increase the efficiency of the aeration system.

Fig. 1-6 SSOTR (Supratec)

Optimised specific digester gas production (gas yield) is required for high efficient utilization of digester gas reuse for energy & heat recovery by CHP/CCHP[10]. The average specific power potential for conventional biogas reuse is approx. 15 kWh/P.E./yr. for conventional sludge digestion plants and up to 22,5 kWh/P.E./yr. for future, optimized conception of WWTP's.

As an example, it should be noted that during summer month excess heat, which is neither used for raw sludge heating or thermal sludge drying, and which is usually wasted by the emergency coolers of the CHP-engines, might be utilized for cold production by absorption chillers (*CCHP, trigeneration*) in order to provide cooling energy for the entire air-conditioning system of the WWTP (PLC/MCC'S and buildings).

The following graph illustrates the average power demand for wastewater treatment and provides an overview about the specific power consumption based on DWA-benchmarking.



Average Distribution of Power Demand for WWTP's

Benchmarking of Specific Power Demand

Approx. 60 - 70 % Power Demand for Aeration System ← **High Efficient Aeration System**

Target Value for the Specific Power Demand below 30 kWh/P.E./yr. ← Sludge Digestion & CCHP

Fig. 1-7 Average power demand for wastewater treatment and specific power consumption

The specific power demand for new WWTP's shall target on less than 25-30 kWh/P.E./yr. (Germany ≤ 23,5 kWh/P.E./yr.).

Current developments in the process engineering industry promote the application of separate anaerobic digestion more widely, also for small WWTP's (≥ 10.000 P.E.). The DWA themed edition T1/2015[11] provides in deep technological and economic assessment of the topic as well as case studies from recent years.

Besides increased treatment performance and optimized energy efficiency OPEX are significantly reduced, furthermore the carbon footprint of wastewater treatment could be minimized. In comparison with the process of anaerobic digestion the process of aerobic sludge stabilization requires a higher sludge age[12] and additional aeration capacity[13] for separate or simultaneous aerobic sludge stabilization. By application of anaerobic digestion, the bioreactor volume and power consumption (for aeration) will be significantly reduced.

Self-generated power from digester gas utilization (CHP/CCHP) might reduce the overall specific power demand from some 60 kWh/P.E./yr. to less than 30 kWh/P.E./yr.

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[10] CCHP - Trigeneration (https://www.clarke-energy.com/gas-engines/trigeneration)

[11] DWA T1/2015 Sludge Digestion or Simultaneous Stabilization for Small & Middle Sized WWTP's

[12] SRT_{aerob} = 22-25 days instead of $SRT_{anaerob}$ = 10-15 days

[13] BOD_{Load} appr. 2,5 kg DO/kg BOD_5 instead of 1,2 kg DO/kg BOD_5

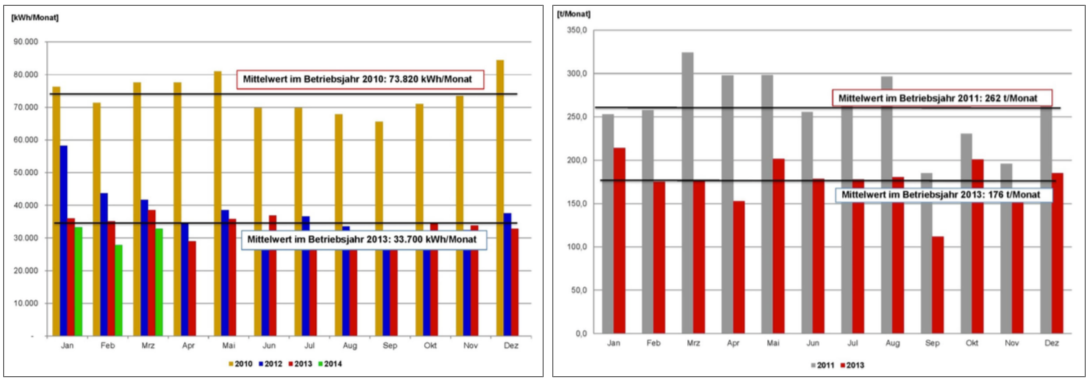


Fig. 1-8 Drop of annual power consumption and sludge cake production after change from aerobic to anaerobic digestion for 28.800 P.E. design capacity, acc. DWA T1/2015, A.1.

For case study A.2 from DWA T1/2015 the total power demand could be reduced by more than 50 % after the process modifications in 2010.

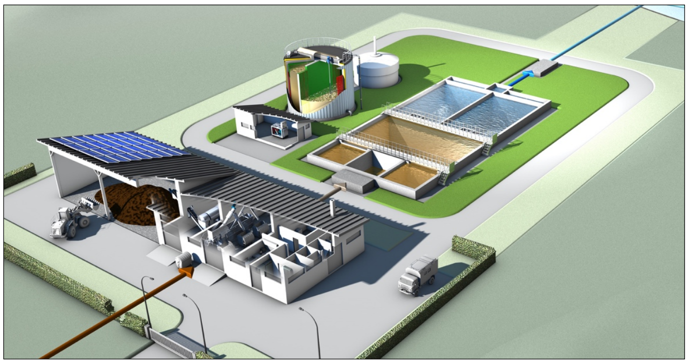
The spec. sludge production decreased from 70 g DS/P.E./d to 45 g DS/P.E./d improving the dewaterability of the digested sludge at reduced flocculation aid consumption, reducing the transportation and disposal costs, accordingly.

The following pictures are showing compact solutions comprising ready-made digesters with integrated gas-storage:

Fig. 1-9 Anaerobic digester with integrated gas holder (www.lipp-system.de/www.mifratis.de)

WWTP design for new wastewater treatment plants or refurbishment and upgrade of existing facilities shall consider application of anaerobic digestion with digester gas utilization for design capacities above 20.000 P.E. Commonly approved technology is available at competitive market price.

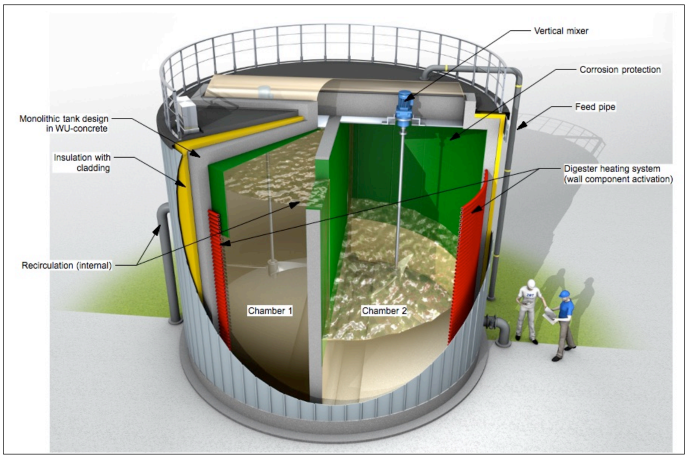
The following presents an example of a modern WWTP (10.000 P.E.) designed for tertiary wastewater treatment, using the well-established Biocos® process[14] (modified SBR) and separate anaerobic sludge digestion with digester gas storage and power recovery by CHP.



Animation of a Biocos® WWTP design proposal.

Fig. 1-10 Layout WWTP 10.000 P.E. with separate anaerobic digestion

The operation building, comprising administrative areas, mechanical treatment and sludge dewatering with lateral sludge storage area can be seen in the foreground. The blower house with generator room and the anaerobic sludge digester with gasholder are seen in the upper background, whereas the Biocos® bioreactors with sludge storage, intermediate pumping station and batch operated clarifiers are seen in the center background.



Anaerobic digester with twin-chamber, slow motion mixers and thermal wall component activation for digester heating.

Fig. 1-11 Compact digester system design (Source: www.zwt.de)

The specific power consumption of the WWTP is calculated with less than 20 kWh/P.E./yr. and the specific digested sludge production is approx. 45 g DS/P.E./d.

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[14] http://www.zwt.de and http://www.hafi-group.com/en/technologies/overview.html

2 Wastewater Treatment Plant of the Future

The carbon footprint (GHG) of wastewater and sludge treatment can be minimized be reduction of the specific power consumption which requires far reaching self-supply of electricity and heat produced by CHP and/or CCHP from digester gas utilization.

Besides various options for wastewater treatment process optimization concerning raw *sludge production* and far reaching application of *anaerobic sludge treatment* processes an additional process for pre-treatment of feed sludge or recirculation sludge by *sludge disintegration* shall be applied for middle sized and big WWTP's. Such type of WWTP's will have a higher power demand due to future sludge drying requirements.

Current research for future and advanced WWTP conception[15] targets on digester gas yield optimization due to side stream reject water (supernatant) treatment by deammonification[16] with MAP[17] precipitation, or stripping of Ammonia (NH_3) which significantly reduces the power requirement of biological wastewater treatment. Ongoing research concerns substitution of Ammonia removal from the conventional process of Nitrification/Denitrification with the process of Deammonification in order to minimize the WWTP footprint, overall power consumption at reduced WAS production (IFAS, MBBR, Nereda) but increased digester gas production for high energy recovery. However, full-scale implementation of such advanced process variants is not expected in the near future but should be taken into consideration for big WWTP's which might be subject to phased implementation.

The following shall be considered for future WWTP design:

- Anaerobic selector for WAS sludge feed (digester) plus separate WAS thickening;
- Intensified, anaerobic, mesophil sludge digestion for WWTP's ≥ 20.000[18] P.E. with digester gas utilization by CHP;
- Intensified, anaerobic, mesophil (or thermophile) sludge digestion for WWTP's ≥ 60.000[18] P.E. with sludge disintegration (ultrasound) and digester gas utilization by CCHP;
- Sludge disintegration for WWTP's ≥ 100.000[18] P.E. by ultrasound, thermal disintegration or thermal hydrolysis and in case sludge disinfection is required;
- Multi-stage, intensified, anaerobic, mesophil (or thermophile) sludge digestion for WWTP's ≥ 250.000[18] P.E. with sludge disintegration and separate supernatant treatment (Anammox[19]) after COD-exfiltration, with digester gas utilization by CCHP.

The following graphs present the COD and mass balance of sludge treatment which illustrates the optimization potential for future WWTP design that shall be considered for the design of big WWTP's ≥ 250.000 P.E.:

[15] Final Report "Wastewater Treatment Plant of the Future", TU München, 2009
[16] https://www.essde.com/en/demon/demon-process
[17] MAP = Magnesia-Ammonium-Phosphate ($NH_4MgPO_4 \cdot 6H_2O$) = Struvite
[18] Proposed design capacities are subject to additional least cost analysis
[19] De-Ammonification: https://www.sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/semi-centralised-wastewater-treatments/anammox

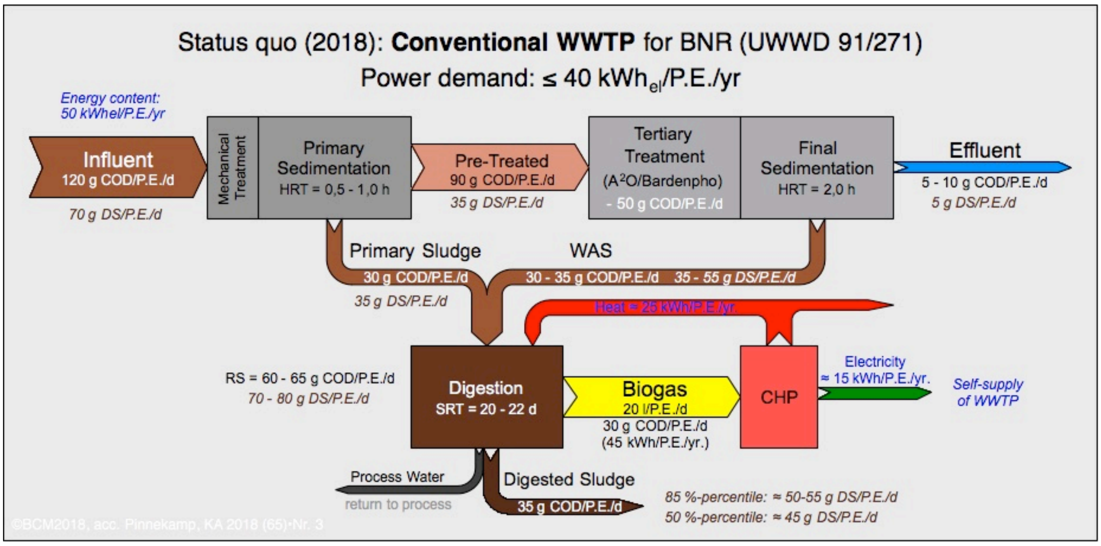

Fig. 2-1 Mass balance for conventional sludge treatment (Pinnekamp, KA 2018 (65), Nr. 3)

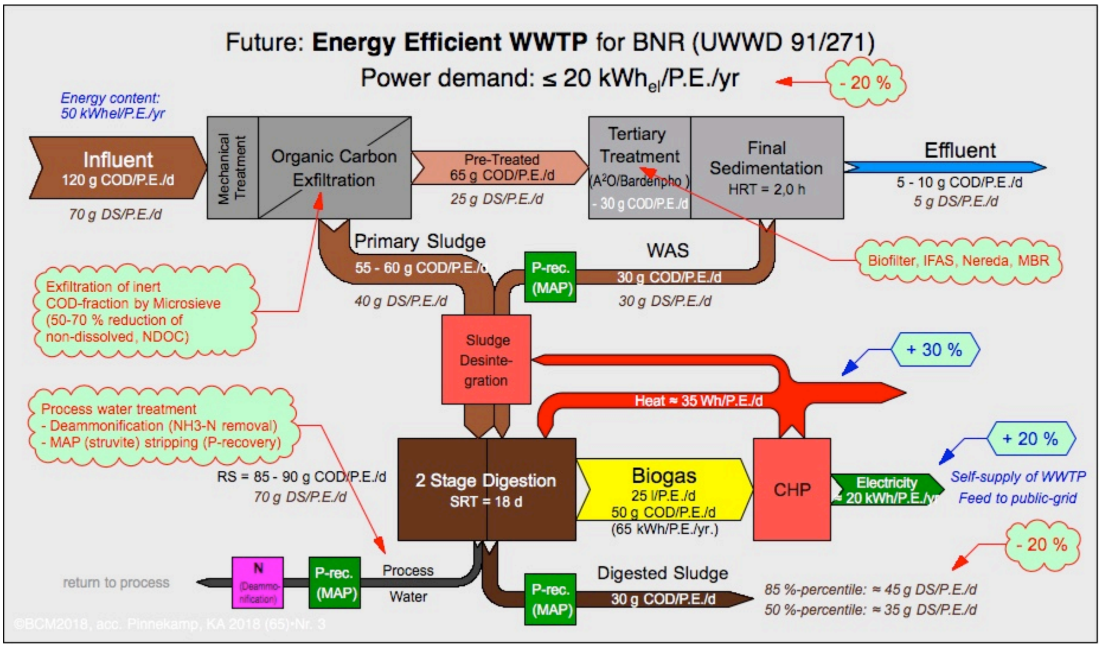

Fig. 2-2 Gross mass balance for optimized sludge treatment (Pinnekamp, KA 2018 (65), Nr. 3)

2.1 Requirements for WWTP Design

Newly designed WWTP's or upgrade of existing WWTP's shall consider state of the art process technology and latest developments and tendencies concerning sludge treatment and sludge management in market leading EU-Member States, which are summarized as follows:

Secondary wastewater treatment (≤ 10.000 P.E.):

- Conservative determination of the design capacity;
- Analyse wastewater composition (long-term) for inhibiting substances/heavy metals/contaminants for sludge quality determination during WWTP construction;
- Primary sedimentation in case of attached growth with anaerobic digestion;
- Attached growth or MBBR for secondary wastewater treatment in multi-lane application;
- High efficient aeration systems (plate type diffusers, SOTE > 3,5-4,2 kg O_2/kWh) for the activated sludge process;
- IT based monitoring of power consumption of individual process steps (energy efficiency, set-point control);
- Disinfection of purified effluent (see multi-resistant-germs);
- Reject aerobic sludge stabilization (separate or extended aeration) ≥ 10.000 P.E.
- Anaerobic, mesophilic sludge digestion with digester gas utilization by CHP (simple commercial system solutions) in case of attached growth (with pre-sedimentation);
- High efficient thermal insulation of digester (high density polyurethane foam, PUR) for optimized heat transition coefficients (slap ≤ 0,25 W/m^2K; wall/roof ≤ 0,16 W/m^2K) and minimized emission losses;
- Extended aeration for simultaneous sludge stabilization (in case of activated sludge);
- Sludge thickening and post treatment in reed beds, if land is available;
- Liquid sludge transport to inter-communal STC[20] for sludge dewatering and advanced sludge treatment (≤ 5.000 P.E.);
- Sludge dewatering and transport to inter-communal STC for advanced sludge treatment (sludge drying, etc.).

Tertiary wastewater treatment (> 10.000 P.E.):

- Conservative determination of the design capacity;
- Analyse wastewater composition (long-term) for inhibiting substances/heavy metals/contaminants for sludge quality determination during WWTP construction;
- Primary sedimentation or COD-exfiltration for tertiary treatment (BNR);
- Bio-P (EBPR), pre-applied (plus CPR);
- Anaerobic selector for return sludge (RAS) feed;
- Multi-lane and multi-stage (step-feed) process for biological wastewater treatment (BNR) by the activated sludge process;

[20] STC - Sludge Treatment Center providing sludge drying plus pyrolysis or mono-incineration.

- Optional upgrade for capacity extension by IFAS/MMBR (approx. + 30 % P.E.);
- High efficient aeration systems (plate type diffusers, SOTE > 3,5 kg O_2/kWh) with fuzzy logic process control;
- IT based monitoring of power consumption of individual process steps (energy efficiency, set-point control);
- Disinfection of purified effluent (multi-resistant-germs);
- Anaerobic selector for WAS sludge feed (digester) plus separate WAS thickening;
- Extended aeration for simultaneous sludge stabilization for design capacities < 10.000 P.E. only; with sludge reed beds for long-term storage (and post-degradation), eventually sludge dewatering and transport to inter-communal STC for advanced sludge treatment;
- Intensified, anaerobic, mesophil sludge digestion for WWTP's ≥ 20.000[18] P.E. with digester gas utilization by CHP at gross-power demand of the WWTP ≤ 30 kWh/P.E./yr. and spec. sludge production ≤ 50 g/P.E./d;
- High efficient thermal insulation of digester (high density polyurethane foam, PUR) for optimized heat transition coefficients (slap ≤ 0,25 W/m^{2}K; wall/roof ≤ 0,16 W/m^{2}K) and minimized emission losses;
- Intensified, anaerobic, mesophil (or thermophile) sludge digestion for WWTP's ≥ 60.000[18] P.E. with sludge disintegration (ultrasound) and digester gas utilization by CCHP[21];
- Sludge disintegration for WWTP's ≥ 150.000[18] P.E. by ultrasound, thermal disintegration or thermal hydrolysis and in case sludge disinfection is required at gross-power demand of the WWTP ≤ 25 kWh/P.E./yr. and spec. sludge production ≤ 50 g/P.E./d (85 %-percentile);
- Solar or thermal sludge drying depending on WWTP design capacity and heat balance for WWTP's ≥ 30.000 P.E. (considered as STC);
- Multi-stage, intensified, anaerobic, mesophil (or thermophile) sludge digestion for WWTP's ≥ 250.000 P.E. with (thermal) sludge disintegration and separate supernatant treatment (Anammox[22]) after COD-exfiltration, with digester gas utilization by CCHP at gross-power demand of the WWTP ≤ 25 kWh/P.E./yr. and spec. sludge production ≤ 45 g/P.E./d (85 %-percentile);
- Advanced sludge treatment by dewatered sludge pyrolysis (or similar) for WWTP's ≥ 60.000[18] P.E. with waste gas and waste heat utilization for sludge drying (STC), granular disposal at mono-landfill (eventually direct side-stream fertilizer application);
- Advanced sludge treatment for dry sludge mono-incineration for WWTP's ≥ 250.000 P.E. with waste gas and waste heat utilization for sludge drying (STC), ash disposal at mono-landfill;
- Dry sludge or ash disposal only to mono-landfill for future P-reclamation by urban mining.

[21] CCHP - Trigeneration(https://www.clarke-energy.com/gas-engines/trigeneration)
[22] De-Ammonification: https://www.sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/semi-centralised-wastewater-treatments/anammox

The aforementioned requirements are targeting on reduced sludge production, and are summarized in the following table considering the different categories and WWTP design capacities:

Cat.	Capacity [P.E.]	Wastewater Treatment	Sludge Treatment	Power Consumption	Sludge Disposal
a	≤ 2.000	*Secondary* Treatment Primary sedimentation (Imhoff tank); Attached growth (TF/RBC); Constructed wetland/reed.	Psychrophilic digestion (Imhoff tank)	≤ 15-20 kWh/P.E./yr.	Liquid sludge transport to STC; Sludge reed bed.
b	≤ 10.000	Secondary Treatment Primary sedimentation in case of attached growth; Attached growth (TF/RBC); CAS or MBBR with extended aeration/without pre-sedimentation.	Mesophilic anaerobic digestion (attached growth) with CHP; Simultaneous aerobic stabilization.	≤ 35-60 kWh/P.E./yr.	Liquid sludge transport to STC; Sludge reed bed for post-stabilization.
c	≤ 50.000	Secondary Treatment Primary sedimentation; Attached growth (TF); CAS or MBBR.	Mesophilic anaerobic digestion with CHP; Mechanical sludge dewatering.	≤ 35-40 kWh/P.E./yr.	Dewatered sludge transport to STC; Sludge reed bed for post-stabilization.
		Tertiary Treatment Coarse Sedimentation; Bio-P (EBPR) with anaerobic selector (plus CPR); Anaerobic selector RAS CAS in multi-lane and single-stage process; Consider IFAS/MMBR.	Anaerobic selector WAS + mechanical WAS thickening; Intensified, anaerobic, mesophilic sludge digestion for WWTP's ≥ 30.000 P.E. with digester gas utilization by CHP; Mechanical sludge dewatering.	≤ 30 kWh/P.E./yr.	Dewatered sludge transport to STC;
d e	≤ 100.000 ≤ 150.000	Coarse Sedimentation or COD-exfiltration; Bio-P (EBPR) with anaerobic selector (plus CPR); Anaerobic selector RAS CAS in multi-lane and multi-stage process; Consider IFAS/MMBR; Consider MBR; Effluent disinfection.	Anaerobic selector WAS + mechanical WAS thickening; Intensified, anaerobic, mesophil sludge digestion with digester gas utilization by CCHP; Sludge disintegration (≥ 100.000 P.E.); Mechanical sludge dewatering; Solar or thermal sludge drying; Sludge pyrolysis (or similar).	≤ 25 kWh/P.E./yr.	STC Dry sludge disposal to mono-landfill; Granular utilization as fertilizer.
f	≤ 250.000	Coarse Sedimentation or COD-exfiltration; Bio-P (EBPR) with anaerobic selector (plus CPR); Anaerobic selector RAS CAS in multi-lane and multi-stage process; Consider IFAS/MMBR; Consider MBR; Effluent disinfection; MAP precipitation; Separate supernatant treatment by Annamox.	Anaerobic selector WAS + mechanical WAS thickening; Intensified, anaerobic, mesophil sludge digestion with digester gas utilization by CCHP; Thermal sludge disintegration or thermal hydrolysis; Mechanical sludge dewatering; Solar or thermal sludge drying.	≤ 25 kWh/P.E./yr.	STC/SMC Dry sludge disposal to mono-landfill; Dry sludge to mono-incineration; Granular utilization as fertilizer.
g	≥ 250.000	Coarse Sedimentation or COD-exfiltration	Anaerobic selector WAS + mechanical WAS thickening;	≤ 25 kWh/P.E./yr.	STC/SMC

Cat.	Capacity [P.E.]	Wastewater Treatment	Sludge Treatment	Power Consumption	Sludge Disposal
		Bio-P (EBPR) with anaerobic selector (plus CPR); Anaerobic selector RAS CAS in multi-lane and multi-stage process; Consider IFAS/MMBR; Consider MBR; Effluent disinfection; MAP precipitation; Separate supernatant treatment by Annamox.	Sludge disintegration for WWTP's ≥ 100.000 P.E. Multi-stage, intensified, anaerobic, mesophil sludge digestion with digester gas utilization by CCHP; Mechanical sludge dewatering; Thermal sludge drying; Dry sludge mono-incineration.		Ash disposal to mono-landfill.

Fig. 2-3 Overview WWTP design requirements, acc. NSMS

Consultants and Contractors working on design for new WWTP's or upgrade and refurbishment of existing WWTP's shall be encouraged to consider modern, state of the art process technology for both, wastewater and sludge treatment in order to reduce the specific sludge production and energy consumption of the WWTP under consideration of provisions for future Phosphorous reclamation.