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Deliverable 4.1

Demonstration of Kaumera Extraction Installation (KEI) plant operation

Date: 06 January 2024

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Acknowledgements

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Disclaimer

The information included herein is legal and true to the best possible knowledge of the authors, as it is the product of the utilization and synthesis of the referenced sources, for which the authors cannot be held accountable.

Keywords

▪ Kaumera Extraction ▪ Case Study ▪ Construction ▪ Optimization ▪ Operation

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Deliverable information

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Name of researcher(s) with roles	Jasper Elgersma (Lead Engineer CS3 - Lenntech)

[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other; **ETHICS**=Ethics requirement, **ORDP**=Open Research Data Pilot

[2] **PU**=Public; **CO**=Confidential, only for members of the consortium (including the Commission Services); **EU-RES** Classified Information: RESTREINT UE (Commission Decision 2005/444/EC); **EU-CON** Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC); **EU-SEC** Classified Information: SECRET UE (Commission Decision 2005/444/EC)

History of changes

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4	07/01/2024	Revision based on comments Violeta Kuzmickaite	Philipp Wilfert (TU Delft)

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Executive Summary

Objective of this deliverable

This deliverable addresses the objectives associated with Task *4.1 Implementation and optimization of the Demonstration Kaumera Extraction Installation (KEI)*. More precisely, it documents the successful achievements of subtasks *4.1.1 Detailed engineering and construction of the Demonstration KEI* and subtask *4.1.2 Testing of the Demonstration KEI at a municipal Nereda wastewater treatment plant in The Netherlands.*

Structure of the report

In the first section, a comprehensive overview of the Water Mining project is given. This is followed by a section outlining the objectives and scope of the deliverable. In section 3, detailed information about case study 3 and the Kaumera production process are given. In section 4, details about the process units, capacity of KEI, operating conditions, process units' dimensions, and energy (and utility) requirements are provided. Visuals of the equipment are also included. In section 5, information on the implementation and successful optimization of KEI, covering steps taken to commission and start-up CS3 are given. The report concludes with final remarks and outlines the next steps, including the transport to and operation at the municipal wastewater treatment plant in Faro/Olhão, Portugal.

Summary

In summary, the deliverable documents the successful engineering, construction, commissioning, and the first-time operation of the KEI demonstration at the municipal wastewater treatment plant in Utrecht. The documentation includes visuals (engineering drawings / photos), detailed explanations, lists of capacities, and dimensions of all process units to illustrate the KEI Demonstration and the Kaumera production technology. It turned out that the batch process was relatively simple to control and could be easily optimized. Within a few batches of operation Kaumera was produced with quality parameters and yield as compared to other locations in The Netherlands. Some process parameters, like KOH and HCl dosing were conveniently established in lab scale experiments before.

Conclusion & Outlook

Overall, the Kaumera extraction technology and KEI proofed to be flexible, and it can be assumed that operation is quickly adjustable to new sludge types/locations. The successful work documented in this deliverable underlines the wide-reaching technology replication potential of Kaumera production.

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Acronyms

CS	Case study
KEI	Kaumera Extraction Installation
MWWT	Municipal Waste Water Treatment Plant
IBC	Intermediate Bulk Container
OPEX	Operational Expenditure
TS	Total Solids

1. Overview of the project

WATER-MINING is a project funded by the European Commission (Horizon 2020 – Grant Agreement No 869474) with a total duration of 48 months (Start date: 01/09/2020 – 31/08/2024) and a total budget of approx € 19 million (EU Contribution: € 16,876,959.59). The project is entitled "Next generation water-smart management systems: large scale demonstrations for a circular economy and society" and it is a project granted under the call topic "CE-SC5-04-2019: Building a water-smart economy and society". Further information about all the sister projects funded under this topic can be found at the CORDIS website here. The WATER-MINING consortium comprises 38 partners from 12 countries, led by the Delft University of Technology (TU Delft). More information about the project can be found at the project website (https://watermining.eu) as well as the dedicated website at CORDIS database (https://cordis.europa.eu/project/id/869474), while an overview is provided below.

The WATER-MINING project aims to provide for real-world implementations of Water Framework Directive (and other water related legislation), as well as the Circular Economy and EU Green Deal packages by showcasing and validating innovative next generation water resource solutions at pre-commercial demonstration scale. These solutions combine WATER management services with the recovery of value-added renewable resources extracted/MINED from alternative water resources ("WATER-MINING").

The project integrates selected innovative technologies that have reached proof of concept levels under previous EU projects. The value-added end-products (water, platform chemicals, energy, nutrients, minerals) are expected to provide regional resource supplies to fuel economic developments within a growing demand for resource security. Different layouts for urban wastewater treatment and seawater desalination are proposed, to demonstrate the wider practical potential to replicate the philosophy of approach in widening circles of water and resource management schemes. Innovative service-based business models (such as chemical leasing) are being introduced to stimulate progressive forms of collaboration between public and private actors and access to private investments, as well as policy measures to make the proposed water solutions relevant and accessible for rolling out commercial projects in the future. The goal is to enable costs for the recovery of the resources to become distributed across the whole value chain in a fair way, promoting business incentives for investments from both suppliers and end-users along the value chain. The demonstration case studies are to be first implemented in five EU countries (NL, ES, CY, PT, IT) where prior successful technical and social steps have already been accomplished. The broader project consortium representation will be an enabler to transferring trans-disciplinary project know-how to the partner countries while motivating and inspiring relevant innovations throughout Europe.

2. Scope of the deliverable

Within WATER-MINING project, Work Package 4 (WP4) is focusing on the "Demonstration of extraction/valorization of Kaumera Nereda Gum".

WP4 is structured in the following five tasks:

- **Task 4.1**: **Implementation and optimization of Demonstration Kaumera Extraction Installation (KEI)**
- **Task 4.2:** Comparison of the properties and quality of the produced Kaumera in the warm and colder climate region
- **Task 4.3**: Investigation of the fermentability at high pH value of the residual sludge from Kaumera extraction process
- **Task 4.4:** Combined phosphate recovery with Kaumera extraction to produce a concentrated phosphate fertilizer raw material
- **Task 4.5**: Coordination of WP4 activities and interrelation with other WPs

The results from the implementation of this work package are presented through eight deliverables

- **Deliverable 4.1: Demonstration plant KEI operation, Utrecht (connected to Task 4.1)**
- **Deliverable 4.2:** Kaumera quality and properties (connected to Task 4.2)
- **Deliverable 4.3:** Fermentability of extraction residue (connected to Task 4.3)
- **Deliverable 4.4:** Phosphate recovery options (connected to Task 4.4)
- **Deliverable 4.5**: Report on the technical results from the implementation of WP4 – input for inter-related WPs (connected to Task 4.5)
- **Deliverable 4.6:** Update of D4.5 (connected to Task 4.5)
- **Deliverable 4.7:** Update of D4.6 (connected to Task 4.5)
- **Deliverable 4.8:** Demonstration plant KEI operation, Faro (connected to Task 4.1)

The current deliverable, D4.1 comprises subtasks *4.1.1 Detailed engineering and construction of the Demonstration KEI* and *4.1.2 Testing of the Demonstration KEI at a municipal Nereda wastewater treatment plant in the Netherlands* of Task 4.1. The work was led by TU Delft. RHDHV was responsible for the basic design and supported the start-up of KEI in Utrecht. Lenntech made the detailed design and assembled and commissioned KEI.

KEI was installed at the facilities of the Nereda MWWTP of Utrecht in the Netherlands, as colder climate region, compared to Faro, Portugal. Hoogheemraadschap De Stichtse Rijnlanden (HDSR), owner of the Utrecht MWWTP, gave access to the site and provided space for the set-up and operation of the KEI. HDSR acquired necessary permits and supplied consumables (water /electricity) for the plant operation. HDSR was supporting some of the works during the installation and operation of the demonstration KEI on site.

On-site TU DELFT took care of the interconnecting piping, cabling, pneumatics and on-site assembly (power and signal cable connections in cabinets and for equipment by HDSR/Lenntech). TU Delft operated / optimized the demo with support by RHDHV.

This deliverable comprises one of the “Demonstrator” deliverables foreseen within WP4 and aims to provide information on the demo systems (and its components) and the optimization measures in form of a report.

This deliverable is also a “Public” deliverable, thus not containing any confidential information.

3. Introduction

The Kaumera production pilot plant is designed to extract Kaumera from excess sludge obtained from Nereda WWTPs. The pilot installation can process sludge with total solid (TS) contents between 3-5%. However, the preferred TS for a full scale system will be 5%. The production capacity is about 0.5-1 m^3 Kaumera / day and 5 m^3 thickened sludge / day. Below a flow scheme of the extraction process (Figure 1). An overview on CS3 plans and intentions is given in Table 1.

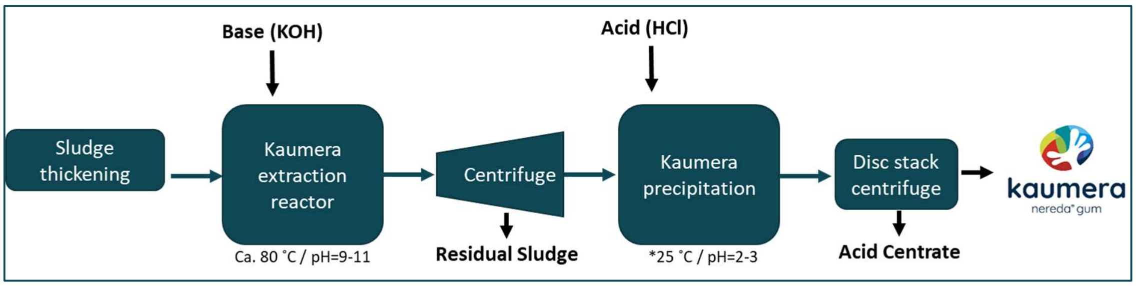


Figure 1: Flow scheme for Kaumera Nereda® Gum extraction from granular sludge.

The sludge from the gravity thickener is pumped to a skid with a 1000 L sludge buffer tank, where it is macerated and pumped from to the reaction tank. This steel reactor has a net volume of 6 m^3 and is equipped with an electrical mixer. During extraction, the sludge is continuously mixed to prevent settling. The reactor is fully covered. Within the reactor the sludge is heated to 80-90 °C to extract the Kaumera and kill pathogens. A steam generator is used for steam injection to introduce heat into the reactor. The sludge in the reactor is continuously mixed while heating. Once the sludge in the reactor has reached a temperature of about 80 - 90 °C, potassium hydroxide is dosed into the reactor until a pre-set pH is reached. Hereafter the content of the reactor will continue to be mixed for some time to kill pathogens.

From the reactor the conditioned sludge is pumped to a decanter centrifuge separation unit where a alkaline sludge pellet is separated from the alkaline centrate containing solubilized Kaumera. The produced alkaline sludge pellet (~10-15% TS) is collected in the alkaline sludge pellet buffer tank. While the alkaline sludge pellet is diluted and returned to the MWWTP for further treatment in the current pilot design, the potential fermentation of this pellet to produce pure methane/green gas in future is investigated in task *D4.3: Fermentability of extraction residue*. The alkaline centrate, containing Kaumera, is collected in the alkaline centrate buffer tank. From the alkaline centrate buffer tank, the centrate is pumped to the cooling tank.

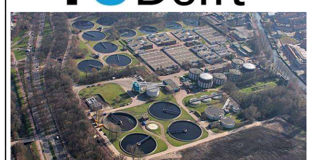
In the cooling tank alkaline centrate is cooled overnight to a temperature of 15-30°C by cooling water in a spiral. Once it has been cooled, hydrochloric acid (HCl) is dosed into the tank, until a pH below 3 is reached. During cooling of the centrate and chemical dosing, the contents of the tank are continuously mixed.

The acidified alkaline centrate is pumped to a disc centrifuge where the precipitated Kaumera is separated. The produced Kaumera is stored in an IBC and can be picked up for processing/application. The acidic centrate is collected and returned to the MWWTP for further treatments.

In addition to the process described above, the Kaumera extraction unit is equipped with a rinse system to cover the needs of flushing water of the centrifuge and of the decanter. This system includes a 1000 L water break tank and a booster pump that can is connected to the different skids/containers of the units.

All the wastewater/washwater streams are collected in the acidic centrate buffer tank, which is used to return the streams to the MWWTP for further treatments.

Table 1: Overview on CS3 intention.

<table>
<tr><td>CS3 Names</td><td colspan="2">Urban WWTP in Utrecht – The Netherlands</td><td>Urban WWTP in Faro/Olhão - Portugal</td></tr>
<tr><td>CS3 Owners</td><td colspan="2">TU Delft (Partner No. 1)</td><td>ADA (Partner No. 26)</td></tr>
<tr><td>Scale & capacity</td><td colspan="3">Large (portable) demo – Capacity: 5 m³/day</td></tr>
<tr><td>Key CE intervention</td><td>□ Recovery of high added value raw materials: Kaumera Nereda® Gum & Phosphate from urban wastewater</td><td rowspan="3">
Faro/Olhão, Portugal</td><td rowspan="3">
Utrecht, Netherlands</td></tr>
<tr><td>Relevant sectors</td><td>Municipal and industrial wastewater treatment /Agriculture /Construction</td></tr>
<tr><td>Special focus</td><td>Improved recovery of resources & creation of new business opportunities</td></tr>
<tr><td colspan="4">Status of the case study today:
<u>Faro/Olhão WWTP</u>: This plant is the first full-scale greenfield Nereda® installation treating complete flow in Southern Europe and represents the largest investment in water sanitation made in the Algarve – and one of the largest in Portugal to date. The Nereda® technology is an innovative method of treating wastewater offering significantly lower OPEX whilst able to achieve very high levels of nutrient removal in a reliable and compact plant. The Faro/Olhão plant also makes use of a Nereda® Controller which forms the heart of the plant’s automatization system where data are continuously monitored and analyzed to optimize and maximize the plant’s efficiency. Thanks to this emerging technology it has been possible to reduce the Faro/Olhão plant’s carbon footprint by 50%, and an energy saving up to 50% is expected. The plant also has solar panels that, with an installed capacity of 50 kW, will produce energy for use by Auxiliary services. The Faro/Olhão WWTP provides a service to a population equivalent of 113,200. The plant has a maximum flow rate of 28,820 cubic metres (m³) per day. The sludge line is designed for production of approximately 8,000 kg d.w./day.

<u>Utrecht MWWTP</u>: Utrecht is the 4th largest city in the Netherlands. Operational since 2018, the award-winning Nereda plant in Utrecht is the largest constructed in the Netherlands, with an average daily flow of 76,271 m³ and a capacity of 450,000 PE. At this site, situated in the center of the city of Utrecht, domestic wastewater treatment using the Nereda technology and sludge handling takes place. There is also a Nereda demonstration unit on site, built a few years ago to test the feasibility of the full scale. The unit, treating 1,500 m³/day (9,000 PE), is still operated by RHDHV for development and optimization purposes.</td></tr>
</table>

Demonstration: The transportable demo unit will extract biopolymers from 1-3% of the wastewater treatment residuals generated.
Ambition at the end of the project and beyond: The Kaumera extraction initiative has been already embraced by the Dutch Foundation for Applied Water Management Research (STOWA). STOWA include water boards, provinces and the Ministry of Public Works and Water Management and supports the implementation of the Nereda/Kaumera concept for national adoption in the Netherlands (see also Letter of Support by HDSR). This project will comprise the stepping stone to provide the necessary body of evidence that the Water Boards in the Netherlands (and abroad) would require for doing so.

4. Demo system used in CS3

4.1. Introduction to chapter 4

Details about the capacity, the operating conditions, the dimensions and energy (and utility) requirements are provided in the following. The demo system from Case Study 3, primary set in Utrecht comprises the following equipment– which serve as structure for this chapter (see also Figure 3).

1. Skid with Feed Buffer Tank, Macerator and Reaction Tank Feed Pump
2. Reactor Tank
3. Container with Steam Generator (10ft container)
4. Container with chemical dosing equipment (20ft container)
5. Container 1 (40ft container)
    - Buffer tanks,
    - Feed and discharge pumps,
    - Break water tank and hydro booster
    - Main control cabinet
6. Container 2 (20ft container)
    - Decanter centrifuge
    - Separator centrifuge
7. Cooling Tank

Figure 2 gives an overview over the process steps. In the following each process unit will be described.

All waste streams/discharges and gravity safety overflows are combined in one central discharge pipe which is brought back to the inflow of the MWWTP.

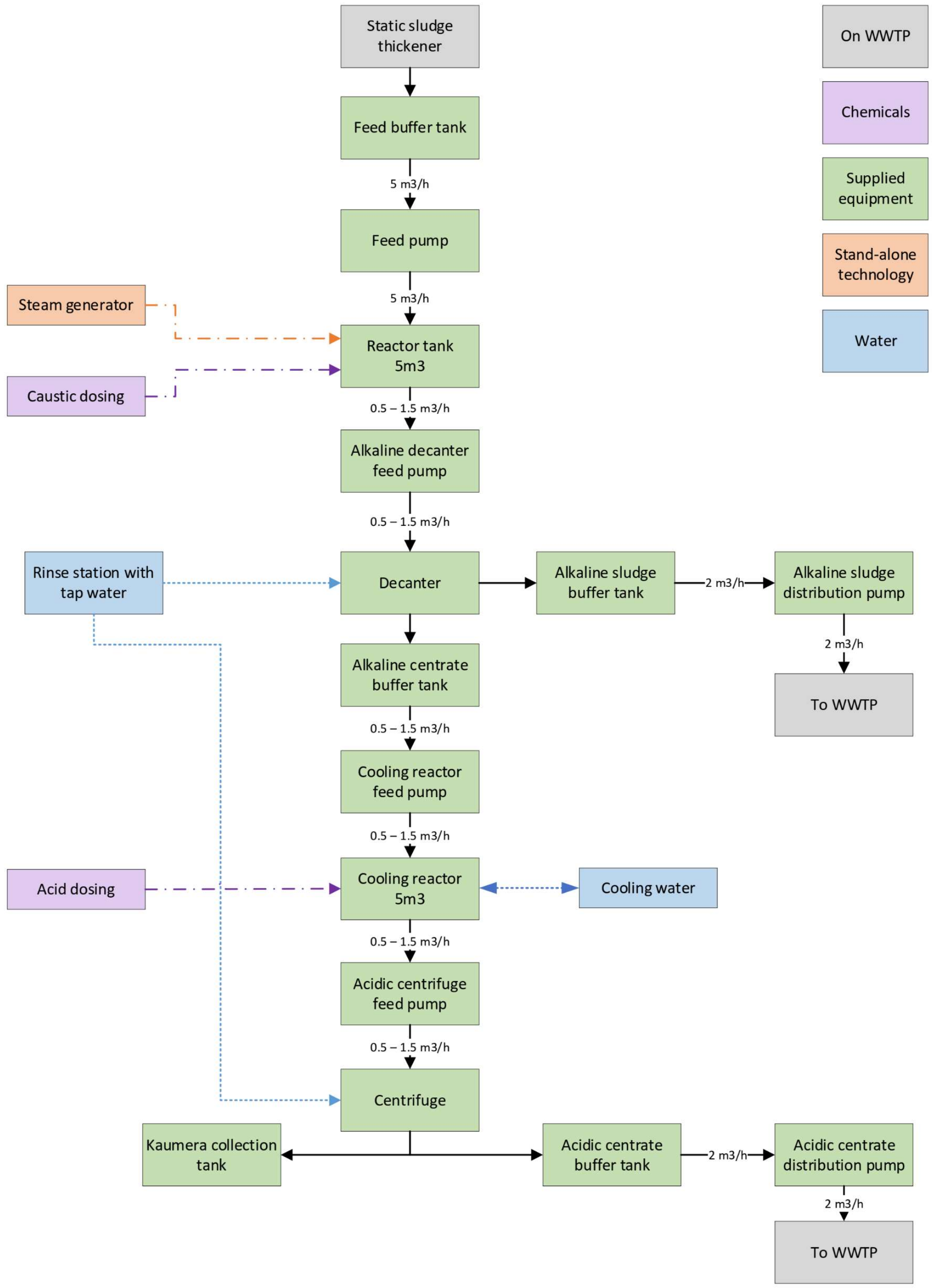


Figure 2: Simplified process diagram over the Kaumera extraction process (provided by Lenntech).

For automation the process is divided into the following sequences. Numbers in brackets indicate which equipment/container is involved:

(A) Reactor tank filling (1 & 2)
(B) Reactor tank heating (2 & 3)
(C) Alkalinisation (2 & 4)
(D) Separation with decanter and cooling reactor filling (2, 5, 6 & 7)

(E) Cooling sequence (7)
(F) Acidification sequence (4 & 7)
(G) Kaumera separation sequence using disc centrifuge (5, 6 & 7)

All images and drawings are provided by Lenntech. With the exception of images from the steam generator (BKS Verkoop & Advies BV) and the drawings from the chemical dosing unit (Chemflow Doseertechniek BV.), reactor tank (PFS-Process BV) and the cooling tank (KWB Kunststoftechniek)

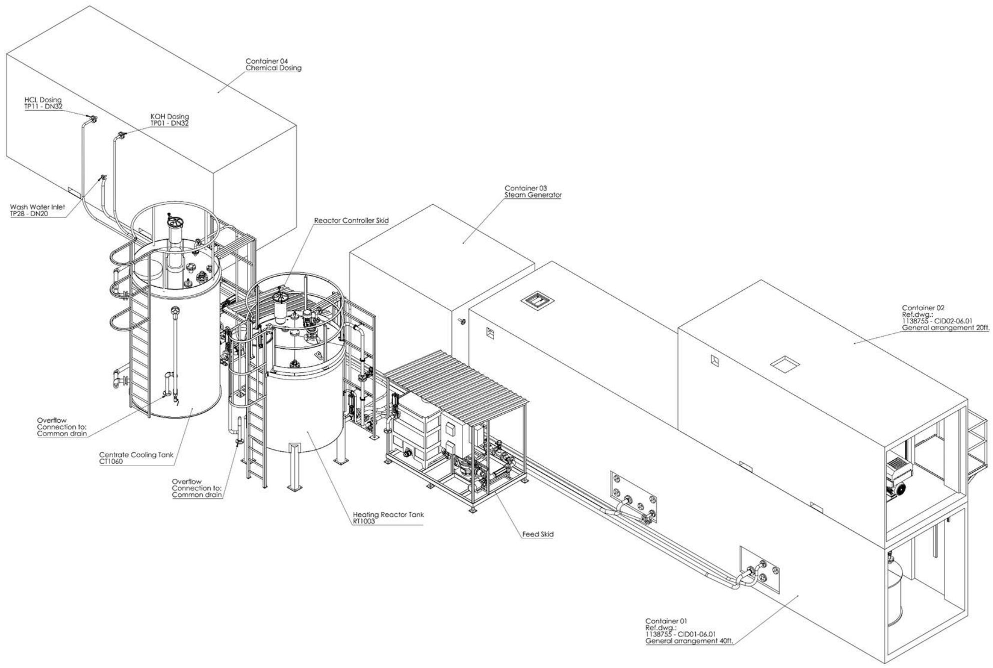


Figure 3: Engineering drawings of the pilot installation (by Lenntech).

4.2. Skid with Feed Buffer Tank, Macerator and Reaction Tank Feed Pump

All equipment described in the following is placed on a roofed transportable steel skid (Figure 4) The feed buffer tank is used as bumper tank between the gravity thickener and the Kaumera production pilot unit. The tank is filled automatically via gravity (Faro) or using a cavity pump (Utrecht), the supply can be stopped using an automatic valve as controlled by the level measurement in the reaction and feed buffer tank respectively. The sludge from the feed buffer tank passes through the macerator and is pumped by a cavity feed pump into the reactor. This pump is directly turned on when enough sludge is available in the feed buffer tank, flowrate is controlled by a variable frequency drive and the pressure is monitored by a pressure transmitter. The whole unit has a capacity of 5 m^3/h, it is mainly built of stainless steel with stainless steel piping. The feed tank is a 1000 L plastic tank with level measurements. A freshwater connection is needed (ca. 2-3 m^3/L -> supplied by the hydrophore system in the 40ft container, to be described in subsection 6) for the periodic macerator flashing. As well pneumatics for the automatic valves are needed (supplied from a compressor in the 40ft container). The operating pressure is about 1 bar (max. 4 bar).

Figure 4:. The feed skid with a 1000 L feed buffer tank, a macerator and cavity pump.

4.3. Reactor Tank

The macerated sludge is collected into a 6 m³ isolated steel reactor , depicted in Figure 5. A mixer mounted on top of the reactor tank is operating when enough sludge is collected in the reactor tank for mixing and to avoid settling. The mixer is equipped with a frequency controller in order to work at a dedicated speed. The reactor tank is also equipped with a level transmitter to determine when the tank is full. When the sequence is over, the mixer keeps operating until the next sequence is enabled by the operator. The reactor tank is furthermore equipped with a temperature sensor and a pH probe. A manhole enables maintenance work inside the tank.

The system works in a sequential mode: filling-heating up-alkalinisation-emptying. Once the minimum level is achieved. The mixer operates until all the sequences are done.

Within the reactor the sludge is heated to about 80-90 °C to extract the Kaumera and to kill pathogenic bacteria. For that, the steam generator is used for steam injection to introduce heat via a stainless-steel steam injection lance into the reactor. Once the sludge in the reactor has reached a temperature of 80-90 °C, potassium hydroxide is dosed into the reactor until a set pH is reached. Hereafter the content of the reactor will continue to be mixed for a pre-set time.

Figure 5: The reactor tank for alkalinsation and heating up the excess sludge.

4.4. Container with Steam Generator (10ft container)

The steam generator is diesel propelled (ca. 20-50 L Diesel/batch) and connected via a silicone isolated hosing to the reactor tank. It has a steam capacity of up to 260 kg/h, with a thermal load of up to 175 kW and a max. operating pressure of 13 bar. All equipment is placed in a 10ft container, Figure 6.

The boiler is a not forced flow boiler. There is no excess water. Common fault sources, such as piston pump, transmission, suction and pressure valves, usually required with regular evaporator coil, do not exist. Instead, the steam generator works on the same principle as a water room boiler. The burner switches on and off automatically depending on the steam pressure. The boiler feed pump, a maintenance-free rotatory pump, feeds water automatically based on the water level.

The water supply module in the container has a volume of 330 L. Water is automatically supplied from the hydrobooster system in the 40 ft container (supply ca. 1 m^3/h). The feed-water condensate tank has fresh water / tap water pre-heating and automatic dosing pump.

In order to avoid the build-up of deposits and materials with high consistency in the boiler vaporisation system, the steam generator is clarified under pressure, and thus under high temperature. Clarification and continuous removal of first condensate are performed in a water seal. Using an integrated heat exchanger the energy of the clarification water and of the first condensate are transferred to fresh feed water. If the water seal temperature exceeds a certain value, the water will be collected. Water softener with filter material: 2 x 30 L and a nom. capacity of 1.25 m3 per hour are used. The pressure loss is 0.22 bar.

A double-walled solid 400 L safety tank for the diesel is installed directly in the boiler room. This system can even be used in water protection areas.

The steam injection is automatically induced via the PLC in the 40ft container.

Figure 6: The 10ft transport container with the steam generator.

4.5. Container with chemical dosing equipment (20ft container)

The 20ft dosing container includes two IBC drip trays with (1300 L buffer volume) with day tanks (200L). KOH, 25% will be used to adjust the pH of the heated sludge in the reactor tank and HCL, 30% or H_2SO_4, 50% will be used to adjust the pH of the alkaline centrate in the cooling tank. Depending on the type of sludge roughly 50-100 L of acid or base are added respectively. The transport container has two opening doors on each short side and two wicket doors on the long side, as depicted in Figure 7. The container is equipped with a partition between the acid and base section. With a forklift truck an IBC can be placed on the drip tray. The container is supplied with a ribbed pipe heater on both the acid and caustic side to prevent frost damage to the water pipes. AirCos are installed as a backup for the heating system and to prevent high temperatures in the containers which can lead to evaporation of HCl, H_2SO_4 or KOH.

A so-called IBC day tank system for the storage of the chemicals is foreseen. This means that there is a 1000 L IBC supply at a time and we have a free outlet in the day tank. The dosing units with pumps are placed on a separate frame in the container – protected with PVC glass. These dosing cabinets harbour pumps with a capacity of 375 L/h each.

Acid and base respectively are pumped over double-walled traced tubing in the cooling and reactor tank respectively.

An emergency shower including eye shower is installed outside, on the side of the container next to a door. This emergency shower is insulated and traced to -15 ˚C.

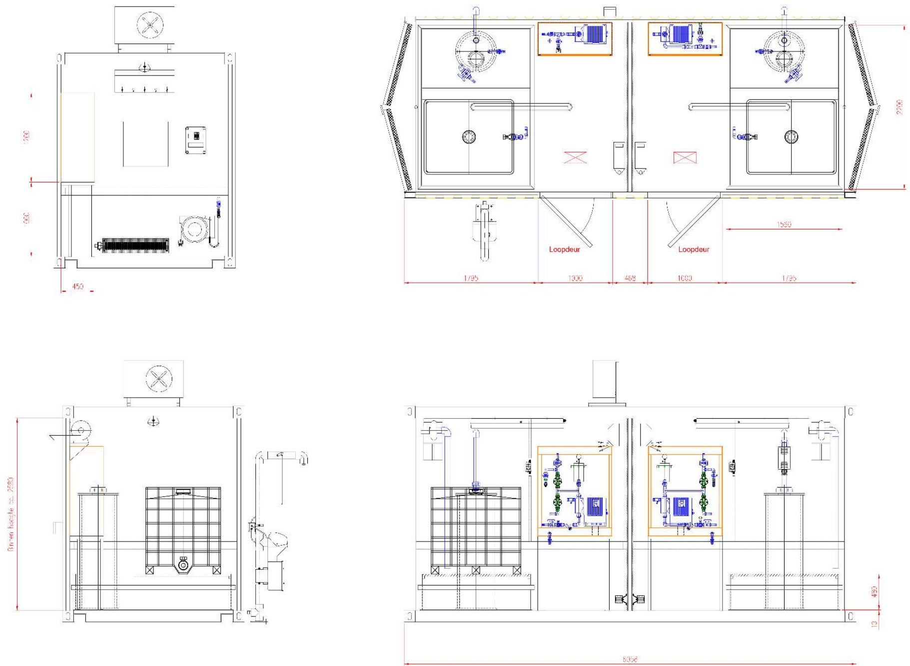


Figure 7: Schematic overview on the chemical dosing system placed in a 20ft container.

4.6. Container 1 (40ft container)

The container harbours the water break tank (1000 L) with a hydro booster pump, the main control / power supply cabinet, buffer tanks for alkaline waste sludge and Kaumera (1000 L) and buffer tanks for alkaline and acid centrate (200 L). Pumps for discharging the waste steams (acid centrate / alkaline sludge pellet), pumps for feeding the disc and decanter centrifuges and for pumping Kaumera to collection IBCs are installed.

The water break tank is fed with fresh or tap water supplied from external source. A water supply to the 40ft container from the MWWTP with about 2 bar and 2-3 m^3/h is needed. The hydrophore / hydro booster system creates a pressurised network with max. 5 m^3/h supplying the steam generator, the chemical dosing container, the macerator, the decanter and disc centrifuge (washing) with water. The pressure of this line is monitored by a pressure transmitter and can be adjusted from 2 to 5 bar directly on the hydrophore system.

The heated and alkalinised sludge flows through heat and base resistant hosing from the reactor tank via gravity to the 40ft container. The decanter centrifuge in the stacked 20ft container is fed with this sludge using a cavity pump (max. 1.5 m^3/h). After separation the alkaline sludge pellet from the decanter centrifuge is collected in the alkaline sludge pellet buffer tank (1000 L), diluted with water and pumped with a cavity pump (1.5 m^3/h) via pressure hoses to a discharge pit outside the container. The alkaline centrate from the decanter centrifuge (containing solubilized Kaumera) is collected in the alkaline centrate buffer (200 L) and pumped with a cavity pump (2m^3/h) to the cooling tank.

After cooling overnight and addition of acid the acidified alkaline centrate flows via gravity through PVC hoses into the 40ft tank to a peristatic pump which is the feed pump of the disc centrifuge (1.5 m^3/h). After separation the acidic centrate is collected in the acid centrate buffer (200 L) and discharged via a peristaltic pump (2 m^3/h) to a sewer pit outside the container. The acid sludge (a.k.a. Kaumera) is collected in a 1000 L collection tank. From there it can be pumped to an IBC outside the container for either collection and further usage or it can be recirculated to the influent of the MWWTP via a sewer pit.

The container harbours the control cabinet which is equipped with a HDMI surface to follow and control all process steps (Figure 8). All data is recorded. Remote operation and observation of operation is possible. All containers are connected via an emergency stop circuit. All operation steps can be initiated from this HDMI surface.

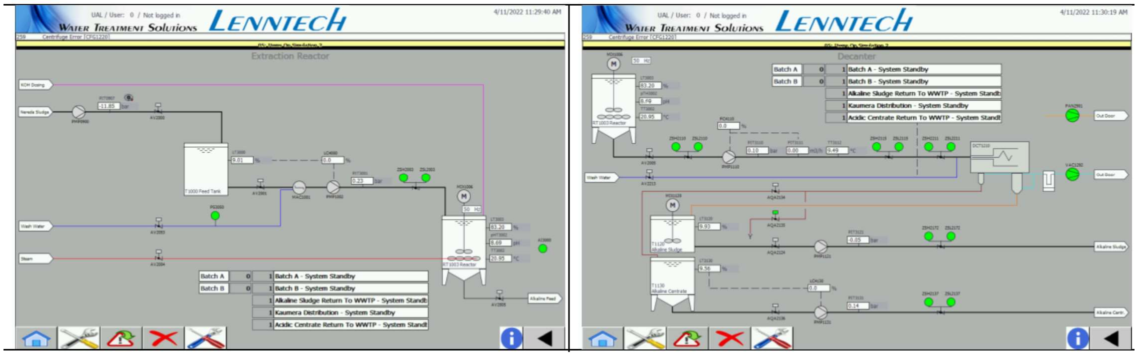


Figure 8: Screenshot from the HDMI to control the pilot operation (outdoor equipment and decanter P&ID are illustrated).

The power supply for the whole pilot (160 A and 80 kW) is brought from the MWWTP into the power cabinet of the 40ft container and from there distributed to the steam generator, the feed skid, the 20ft container, the chemical dosing container and a skid with the electrical cabinet for the reactor and cooling tanks

Furthermore, a pressure generator is installed for the pneumatic system. This system is needed to automatically open / close the valves in the whole installation.

The container is equipped with forced ventilation and AirCos.

Figure 9 shows the internals for the 40ft container and how the stacking of the 20ft and 40ft looks like. Figure 10 and Figure 11 depict different views of the container.

Figure 9: View inside the 40ft container (left) and an impression on the stacked on containers during loading of trucks for transport of KEI to Utrecht. The bottom container is the 40ft container.

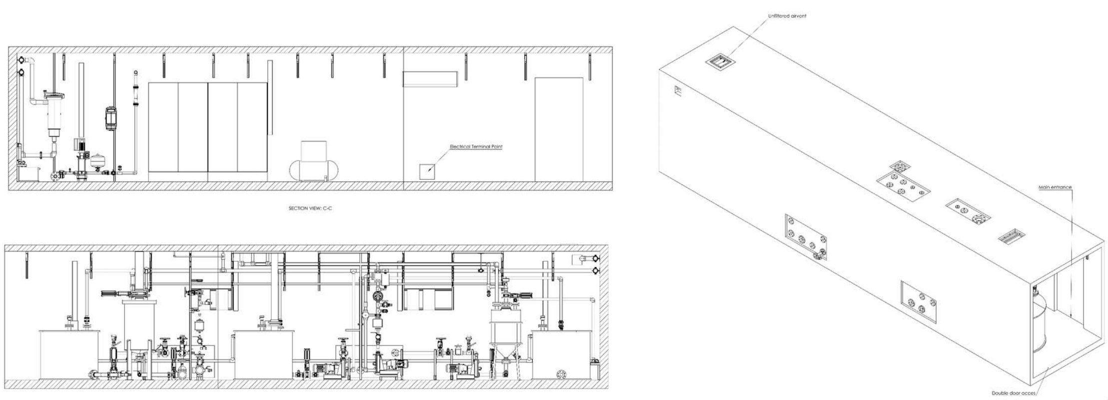


Figure 10: Section and bird view of the 40ft container.

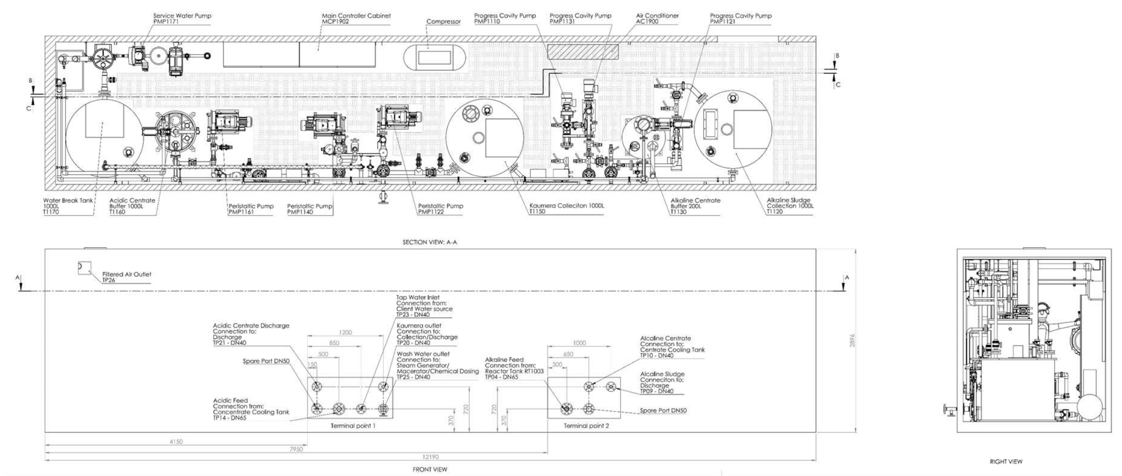


Figure 11: Different views on the 40ft container.

4.7. Container 2 (20ft container)

The container is stacked on the 40ft container, Figure 9. It contains the decanter centrifuge, disc centrifuge including local control cabinets for the separation equipment and an odour filter with forced ventilation from the alkaline discharges (pellet and centrate) and a crane for maintenance work on the separation equipment, Figure 12.

The decanter centrifuge is used for solid / liquid separation after the alkaline Kaumera extraction step. The disc centrifuge is separating the gelled Kaumera after acidification from the liquid phase.

The capacity of the machines is indicated in Figure 2. General arrangements inside the container can be seen at Figure 13.

Figure 12: Decanter centrifuge (left) and disc centrifuge –a.k.a. separator (right).

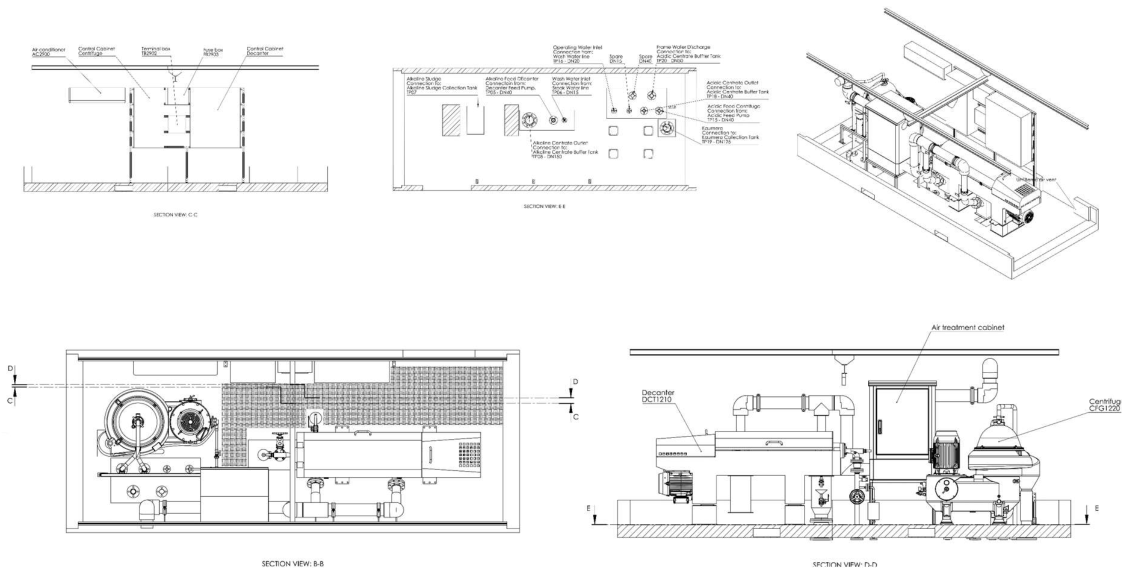


Figure 13: General arrangement of equipment in the 20ft container.

4.8. Cooling Tank

The alkaline centrate is collected in a 6 m³ isolated PP-H / PE-100 cooling reactor tank , section and top view are depicted in Figure 14. A mixer with frequency drive is mounted on top of the reactor tank and is operating when enough centrate is collected in the tank. The reactor tank is equipped with a level transmitter to determine when the tank is full. When the sequence is over, the mixer operates until the next sequence is enabled by the operator. The cooling tank is furthermore equipped with a temperature sensor and a pH probe. A gravity safety overflow with swan neck prevents overflowing of the reactor. The tank is single-walled with sloping bottom and a flat and reinforced roof. A manhole enables maintenance work inside the tank.

The centrate is cooled from about 80-90 °C down to approximately 15-30 °C within 10-12 hours using available process water with 10-25°C (10-25 m³/h). Cooling spirals (150 m PE Slang) are installed inside the tank After cooling, acid is added until a pH<3 is reached to precipitate Kaumera. In Faro, brackish process water (i.e., treated effluent) can be used for cooling to minimize the tap water consumption for the installation. N.B. for a full scale system heat exchangers would be used for sludge cooling and heating to minimize energy / water consumption for heating and cooling of streams.

The tank material is resistant to chemical aggressive substances (concentrated hydrochloric acid, high salinity process water / alkaline centrate) and high temperatures (80 - 90 ˚C). The tank is transportable, as it can be seen in Figure 15. It has to withstand extreme weather conditions (operation in winter times in Netherlands and in summer times in Portugal).

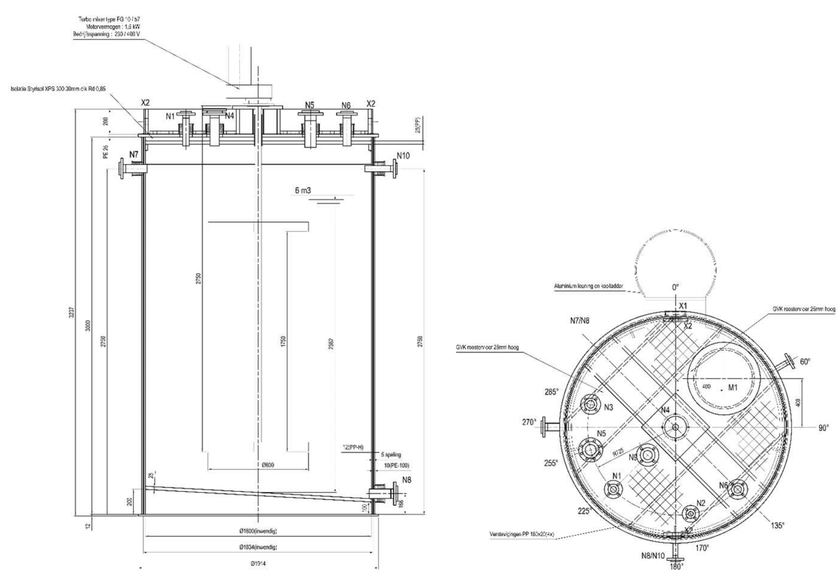


Figure 14: Section and top view on the cooling reactor.

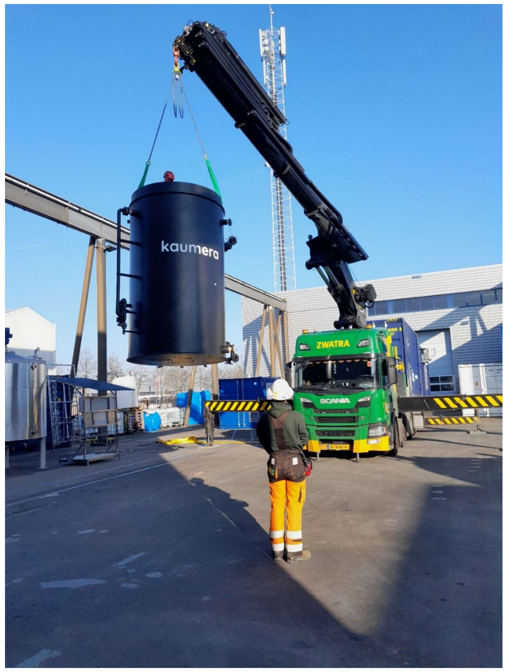


Figure 15: Transport of the cooling tank. On the left the swan neck and on the right the inlets for the cooling water are visible.

5. Implementation and Optimization KEI

The pilot was successfully started-up and commissioned with the support of Lenntech in April 2022. This comprised water testing of the installation, I/O testing and testing of the automation software.

RHDHV and GEA supported the optimization of the pilot operation with sludge afterwards. The goal was to obtain a Kaumera quality that is comparable with the one of the existing facilities to extract Kaumera in Epe and Zutphen.

The main process parameters, like KOH and HCl dosing required for an optimal extraction, were established by TUD in lab scale experiments. The batch process was relatively simple to control and optimize and within a few batches of operation Kaumera was produced with identical gelling properties, total solid and volatile solid contents as in Epe and Zutphen. The pilot proofed to be flexible and is can be assumed that operation is quickly adjustable to new sludge types/locations.

Some optimization steps were done by changing decanter centrifuge and disc centrifuge settings. GEA and RHDHV have plenty of experience from the operation and optimization of the extraction processes in Epe / Zutphen. Parameters that were i.a. modified: bowl speed and torque (decanter centrifuge) and back pressure using a pressure retaining valve in the disc centrifuge.

On the 6^{th} of June 2022 the pilot was officially opened with about 50 guests from industry, academia and Dutch Waterboards. A press released was published.

After the successful start-up, mass balances (energy, chemicals, Kaumera yield/sludge reduction) are currently established to give HDSR an impression on the technology and what can be expected when building a full scale installation. Additionally, horizontal WPs will be provided with this information.

It is expected that disassembly/assembly takes 2-3 people and around 2 weeks' time. A plan in this regard will be immediately established, starting in August, for the transport to Faro. The pilot should be in operation for the second CoP meeting at the end of October in Faro.

WATER MINING released a press communication describing CS3 which included an schematic representation of all the elements of the KEI installation and CS as depicted in Figure 16. In addition, all horizontal WPs will be provided with all the information contained in this report.

6. Concluding remarks

The objectives of subtasks *4.1.1 Detailed engineering and construction of the Demonstration KEI* and *4.1.2 Testing of the Demonstration KEI at a municipal Nereda wastewater treatment plant in the Netherlands* have successfully been achieved.

The components from the demo systems, as described in this report have been successfully commissioned and optimization steps are complete. Mass balances are yet to be established over the process for further Water Mining activities (for LCAs, business cases/models, social impact studies).

In August disassembling of CS3 starts and it is planned to bring the pilot to Faro, Portugal at the beginning of September.

The pilot should be in operation for the second CoP meeting at the end of October in Faro.

Figure 16: Overview on the main CS3 equipment and the location of CS3 in Faro, Portugal

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