Executive summary

The SANBOX idea refers to a novel source separating sanitation approach for remote tourist facilities in Europe. The SANBOX system aims to reach high treatment performance, recycle water and nutrients and use solar power as energy source. The vision is to come close to a self sustaining zero effluent treatment system. The project has developed an innovative modular system consisting of six modules that can be assembled depending on the specific climatic and social conditions at a particular target site. The project implemented and tested three different modular combinations of the SANBOX at three climatically different sites.

SANBOX Scandinavia is adapted to the Nordic region taking into account the cold temperatures with little solar radiation during winter-time. It refers to an extreme compact wastewater treatment system having a total footprint of only 8 m^2. The main feature of the Scandinavian modification is a novel integration of a new developed SANBOX particle separation unit and proven MBR technology. The system reaches treatment performance of more than 90% in terms of COD and pathogens resulting in an effluent that is fulfilling bathing water quality.

The SANBOX Alps is a novel integration of greenhouse and wastewater technology. It refers to an innovative solar driven compact wastewater treatment system with recycling option for the greywater stream. The system has been tested at Britannia lodge in Saas Fee, Switzerland on 3030 meter altitude. The results show, that the extremely small blackwater volume obtained using Jets^{TM} vaccuum toilets opens up for novel solar-based treatment and hygienization opportunities. The unit reached very high reduction rates for organic matter and pathogens even at extreme high loading rates, which is an important issue regarding the vulnerable environment in high alpine locations as the Alps.

SANBOX Mediterranean is adapted to the special requirements of the Mediterranean region. An innovative combination of SANBOX components and cheap natural based treatment systems meets the challenges related to the combination high treatment requirements and relatively low price level. With the solar-based SANBOX evaporation and hygienization module developed it was possible to reach zero effluent for blackwater during the testing period in spring of 2011.

The test results show that all three SANBOX modifications have a high market potential. This has been confirmed by the large attention the prototype at Britannia lodge met among the local media in Switzerland. For a market implementation, most of the components need some additional research and improvements, the SANBOX consortium hopes to conduct this within the next two years.

Summary description of project context and objectives

In the SANBOX project a group of 5 European SMEs, all active in the market for decentralised wastewater systems, joined to develop an innovative, compact wastewater treatment system to serve the growing market for upgrading of sanitation facilities for remote located tourist enterprises such as mountain lodges or buildings in sensitive coastal and carst areas. The increasing interest of potential customers as Alpine Clubs, agro-tourism or hotels arise from more demanding regulations, the tourists' increasing comfort expectations and the enterprises own interest in protecting and keeping the local environment attractive for tourists.

The project objectives are related to development of a novel compact wastewater treatment system that utilize source separation, solar based energy supply and recycling of water and nutrients. On locations with high availability of solar radiation, the project aimed to reach the ambitious goal of zero effluent emission.

Main results from the SANBOX system

The project have developed different treatment units, the so called SANBOX modules, that can be combined into a compact source separating wastewater treatment system meeting the specific requirements of a particular target market. The SANBOX modules are:

- SANBOX greywater module: an innovative biofilter system with a novel compact design for greywater treatment and recycling for toilet flushing. The test results from a farmhouse in Tartu in Estonia and Britannia lodge in Switzerland show, that the system reached high treatment performance and is at the same time extremely robust and resilient in terms of handling variable and peak loading.
- SANBOX particle separation module: a novel solid removal system, that is considerably more compact than a traditional sedimentation tank. The system has been successfully tested for loading rates up to 60 PE (person equivalents), four times above the SANBOX target size. The SANBOX team also developed a modified version of this module that can be used for removal of grease in kitchen wastewater.
- SANBOX hygienization and evaporation module: The core component of this unit is a hygienization tank having a footprint of only 1 m^2. For locations with sufficient solar radiation a cascade evaporation unit is available as a supplementary option. The evaporation unit enables to reach zero effluent emission.
- SANBOX MBR unit for blackwater liquid fraction: For locations with little solar radiation, the project team developed an alternative post treatment unit for the blackwater liquid fraction. This novel integration of the SANBOX particle separation module and MBR technology reached an extremely good effluent quality, which fulfills the requirements for bathing water.
- SANBOX solid fraction treatment module: The project came up with two potential solutions for handling the blackwater solid fraction. The most promising is a novel solar-based drying unit, that has been tested at Britannia lodge in Switzerland. The second option, a composting unit, can have a high potential in warmer regions, such as the Mediterranean area. Both units need some further development.

- SANBOX greenhouse box: This SANBOX module has been developed to meet the challenge related to very cold conditions on high alpine locations having limited energy availability. The application of novel of greenhouse technology ensured a sufficient temperature range for the biological processes at Britannia lodge on 3030 meter altitude with help of the sun.

Considering different climatic conditions and solar energy availability in Europe, the project produced and tested three SANBOX system options.

- SANBOX Scandinavia is adapted to the Nordic region in taking into account the cold temperatures with little solar radiation during winter time.
- SANBOX Alps has been specially designed for high alpine tourist facilities such as mountain lodges. This SANBOX modification works with solar power and handles the strong freezing conditions with help of an innovative greenhouse box.
- SANBOX Mediterranean is adapted to the special requirements for the Mediterranean region. An innovative combination of SANBOX components and cheap natural based treatment systems meets the challenges related to the combination high effluent requirements and relatively low price level.

All three modifications have been tested under real conditions at relevant end-user sites. The following three sections provide an overview of the three SANBOX systems options and the corresponding testing results

Testing results from the prototype of the SANBOX Scandinavian modification

The SANBOX Scandinavian modification integrates a novel approach for separation of particles with proven MBR technology. The innovative particle separation unit enables to remove high amounts of particulate organic matter and phosphorous on a substantially smaller footprint than a traditional sedimentation tank. This enables an extremely compact system design. It is possible to integrate a whole blackwater system for 15 PE on a total footprint of only $6m^2$.

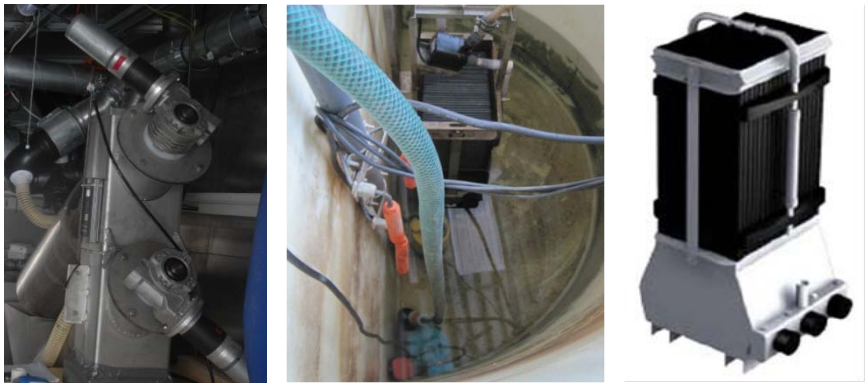

Figure 1: SANBOX Scandinavian modification refers to an innovative combination of the SANBOX particle separation unit with SiClaro™ MBR technology

The system has been tested at Kaja student dormitories in Ås, Norway. During the 5 months of testing in the spring of 2011, the system reached excellent treatment performance. The effluent system reached bathing water quality with respect to indicator bacteria which opens new opportunities for reuse for irrigation of green areas or agriculture. The latter is especially of interest regarding nitrogen and phosphorus that both are valuable nutrients for crop plants. Reuse for irrigation therefore requires lower treatment performance in terms of phosphorous and nitrogen reduction, which allows a simpler system design and saving of energy.

Table 1: Effluent concentration ranges that have been obtained with the SANBOX Scandinavian modification during the prototype testing at Kaja student dormitories

Parameter	Effluent concentration	Reduction rate
BOD_5	10-20 mg/L	>99%
N	250-300 mg/L	20-30%
P_{tot}	20-30 mg/L	80-90%
E-coli	<10 U/mL	>99%

The system has a high potential, especially regarding water and nutrient reuse. However, for a market implementation, some additional research is needed in terms of process control and nitrogen reduction. The SANBOX consortium therefore needs time for development work before the system is ready for a broader dissemination.

Testing results from the prototype for the SANBOX Alps modification

The SANBOX Alps modification refers to an innovative solar driven compact wastewater treatment system with recycling option for the greywater stream. The testing results from Britannia lodge have proven that it is possible to run the whole system on solar energy and reach high removal rates also under the extremely challenging conditions related to mountain lodge.

Figure 2: The SANBOX Alps system: a novel integration of wastewater and greenhouse technology ensuring a smooth operation also at the strong freezing conditions of high alpine locations.

The testing conditions at Britannia were extremely demanding. The prototype setup has been tested for two seasons in summer 2010 and spring 2011. Not only the high altitude of 3030 meter above sea level and strong freezing conditions, but also extreme peaks with up to 130 guests in one day (the SANBOX is designed for an average of 15 – 25 PE) challenged the SANBOX system.

Due to the highly insulated greenhouse box the system handled the low temperatures conditions without any problems. The season peaks, however, resulted in challenges, for the greywater recycling especially. The very concentrated kitchen wastewater, which comprised more than 90% of the total greywater volume, resulted in up to 10 times higher COD mass loading rates than the system was designed for during peak loads. The system handled

these extreme overloads without technical problems and even reached COD reduction rates of 30-50%. However, the effluent quality was not acceptable for reuse for toilet flushing, due to the content of emulsified grease particles causing both odour and depositions in the toilet bowl.

Figure 3: The greywater module was struggling with the high grease content of the kitchen wastewater at Britannia lodge. Despite extremely high loading rates, the system worked for more than 6 months without technical problems and reached a remarkable COD reduction of up to 50%.

The blackwater system was also challenged with extremely high loading rates during the season peaks. However, considerable reduction rates could be reached in terms of COD and pathogens, the most critical parameters in a high alpine environment. COD or organic matter was reduced by 80% which is mainly a result of the good performance of the particle separation unit, which managed the extreme peak loading rates without problems. The experiences from Britannia lodge show that the SANBOX particle separation unit can handle loads up to 300 toilet flushes/day, corresponding to 60PE, which is substantially higher than the target size of 15-25 PE. The results also show, that the low blackwater volume generated using Jets^{TM} vaccum toilets opens for novel solar-based hygienisation opportunities. The latter are resulting in substantial pathogen reduction, which is an important issue regarding the vulnerable drinking water sources in the high Alps.

Figure 4: SANBOX blackwater system: A novel combination of Jets VOD^{TM} vacuum sanitation and solar driven SANBOX technology

Despite this good performance in terms of COD and pathogens, the effluent of the blackwater system still is relatively high concentrated and do need some post-treatment. However, this can at most locations be done with a simple natural based system such as soil infiltration or constructed wetland.

Despite the remaining challenge, the prototype testing at Britannia lodge was an important experience for the SANBOX consortium. The data generated comprise an important database for a further development of the system for this particular marked segment. Especially the kitchen wastewater, which substantially differs from normal greywater, is a challenge that will be encountered at many tourist facilities, not only high mountain lodges.

The results from Britannia lodge indicate that the system has a high potential for improving the sanitation facilities on mountain lodges and other remote tourist facilities in the Alps. At the same time shows the experiences from the two testing seasons, that the system needs an additional development work for a proper implementation. The experiences and data from the onsite testing at Britannia lodge was an essential step in the development work, but it is more appropriate to conduct the required improvement of the system components at the R&D facilities of the related companies. The SANBOX consortium therefore decided in compliance with the Swiss Alpine Club to return the SANBOX components for further development and re-establish the previous dry toilets at Britannia lodge while waiting for an improved system to be installed.

The SANBOX consortium will thank the Swiss Alpine Club for its great engagement that enabled this important onsite testing in the high Alps. Many thanks also to local companies Anthamatten Bau AG, Heriwan AG and Viessmann Schweiz AG for the great support in the construction work and establishing the solar heating system. A special thank goes to Therese Andenmatten and her team for the great hospitality the SANBOX team could enjoy at Britannia lodge and the patience regarding the deficiencies of the SANBOX system.

Figure 5: It was always a great pleasure to enjoy the great hospitality from the Britannia team, especially the legendary Britannia Rösti and Cafe Britannia.

SANBOX system in Mediterranean area-overview

In south-eastern Europe sanitary systems at tourist sites without connection to centralized sewage infrastructure seldom meet contemporary environmental requirements. In addition many rural tourist enterprises are facing challenges regarding technical and legal requirements, extreme climatic conditions, limited energy and water supplies and large variation in activity depending on season. The SANBOX provide users with comfort comparable to traditional water toilet systems. The vision for SANBOX is to come close to a self sustaining zero effluent treatment system by following the main principles of ecological sanitation: source separation, water and energy saving, and nutrient recycling.

In 2010 SANBOX system was constructed in Mediterranean area in the frame of 7OP; “Capacities; Reserach for the benefit of SMEs”. The location for the SANBOX technology prototype was selected on Adriatic coast at Sečovlje Saline Natural Park in Slovenia in Mediterranean climate conditions. The selected area is defined as an area of natural value with habitats of the rare, endangered and characteristic vegetal and animal species, where, due to the long-lasting human action, a typical saltpans ecosystem came into existence.

Figure 6 Natural park Soline, Sečovlje, Slovenia.

Figure 7: SANBOX prototype at Natural park Soline, Sečovlje, Slovenia in 2011.

The main goal of SANBOX system in Mediterranean area (Soline) was to reach zero water emissions of valuable end products. The wastewater from the toilets (blackwater) is separated to liquid and soild fraction. The liquid fraction of blackwater is treated in bio filters to remove solids and nutrients. A solar evaporator uses solar radiation to disinfect and evaporate the liquid part of the blackwater. The evaporation module as such should ensure safe release of final emissions into the environment. The solid part of blackwater is composted to obtain a safe end-product for agricultural purposes. Grey water from sinks is treated in a hybrid constructed wetland system to a quality that it can be used for toilet flushing.

The SANBOX system aims to reach satisfied treatment performance, recycle water and nutrients and use solar power as its energy source. The benefit of source separation is that nutrients are not sent to sea or fresh water but are recycled and reused.

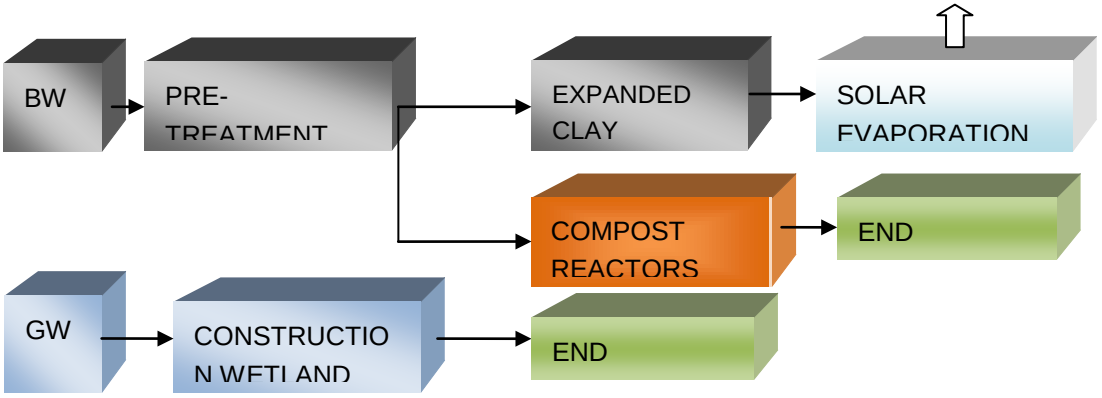

Figure 8: A scheme of the Sanbox sanitary unite. BW-blackwater, GW-greywater.

Benefits: (1) reduction of water pollution/eutrophication, (2) reduction of water consumption, (3) water reuse, (4) nutrients reuse on the fields.

The specific steps of the SANBOX are: (1) pre-treatment filters for separation/dewatering, (2) expanded clay based biofilter for treatment of blackwater liquid phase, (3) solar evaporation module for evaporation of blackwater liquid phase, (4) self heating with organic material compost reactors, and (5) hybrid constructed wetland. Blackwater is pre-treated by filtration with organic filters, solids are recycled into sanitized and nutrient-rich compost, and the liquid fraction is treated by recirculation through an expanded clay-based biofilter and evaporated. Roots of plants in association with microbial biofilm stabilize and enhance the treatment process in the constructed wetland.

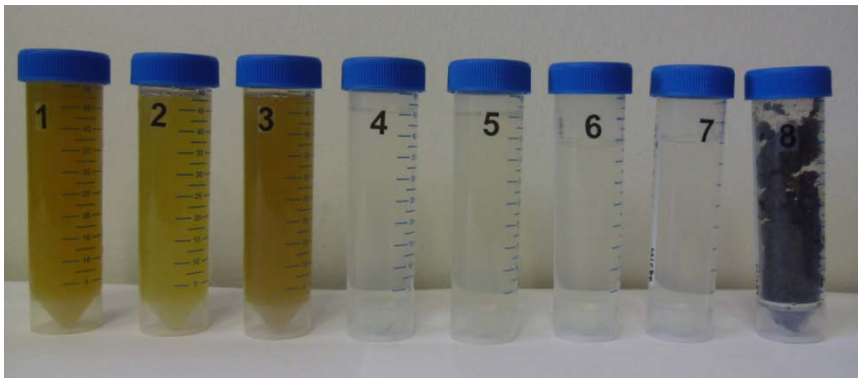

Figure 9: Wastewater at different treatment segments in SANBOX sanitary unit at Soline. 1-raw blackwater, 2-blackwater from pre-treatment filters, 3-blackwater from expanded-clay biofilter, 4-greywater at inflow into the constructed wetland, 5-greywater at outflow from horizontal constructed wetland, 6-greywater at outflow from vertical constructed wetland, 7-blackwater from Solar evaporator, 8-compost.

Greywater treatment results from the SANBOX Mediterranean prototype at Natural park Soline, Sečovlje, Slovenia have proven that it is possible to reach substantial removal rates under the extreme challenging conditions that are related to a Mediterranean climate. Blackwater liquid phase reached zero water emission, while compost could be used as fertilizer on agricultural area.

Impacts and wider implementation of the SANBOX system

The test results from the tree SANBOX prototypes indicate a high potential to improve sanitation systems of remote tourist facilities among Europe and reduce its impact to the local environment. The consortium expects that the key components of SANBOX will soon be available as commercial products so that the system can be implemented on a broader level.

The SANBOX Scandinavian modification shows a high potential towards water reuse for crop irrigation. Important nutrients such as nitrogen and phosphorous can be recycled which can result in a substantial reduction of synthetically fertilizer and consumption of fossil energy for its production. The present prototype needs some further development in terms of process control. It is planned to conduct further R&D work with the goal to have a first commercially available system in 2.3 years.

The SANBOX Alps modification obtained a remarkable treatment performance during the prototype testing period at Britannia lodge despite of the extreme challenging conditions. The system showed clearly a high resilience to extreme freezing conditions and critical overloading that can occur during season peaks, both factors that are important for reaching a broader implementation in this market segment. The results also prove that it is possible to run a wastewater system on solar power and reduce the use of fossil energy. The experiences from Britannia comprise an excellent basis for a smooth and target-orientated product development so that the first commercial system can be available within few years.

The SANBOX Mediterranean modification reached the extreme ambitious goal of zero effluent in terms of blackwater. Considering the numerous tourist facilities along the vulnerable Mediterranean coast line the system has a substantial potential for reducing negative impacts of currently untreated wastewater discharges. The SANBOX consortium plans to continue with the prototype testing at SOLINE for 1-2 years to gather additional experiences as a basis for a proper product development and market implementation.

For the participating companies, the SANBOX project resulted in ideas for new products in young and rapidly emerging market of source separating wastewater technology. The consortium expects a substantial business potential related to the project outcomes, also outside the European continent. The project was therefore an important milestone in order to strengthen the leading position of Europe in terms of sustainable and source separating wastewater technology.