INTEGRATION OF INNOVATIVE URBAN WATER INFRASTRUCTURE IN REGIONAL CIRCULAR ECONOMY SYSTEMS MODEL PROJECT DONGTAN, CHONGMING ISLAND, SHANGHAI, CHINA

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ABSTRACT

Urban wastewater disposal has been developed through the ages particularly in Europe. Its development originated in the basic hygiene problems of the cities. There followed concerns to protect the waters from inflows of nutrients. The systems are established and have proved effective, but in times of increasing costs of energy, fossil energy shortages, climate change and in regions where water and nutrients are scarce it is becoming necessary to review these systems.

Hamburg Public Sewage Company (HSE), part of Hamburg Water Group (HW), has developed an innovative water, waste infrastructure for a model project named Eco City Dongtan, situated on Chongming Island, Shanghai, China. The planning includes agriculture operating on ecological principles. The concept, the selection of the technical components from a large number of possibilities and the combination of individual elements in a system take into consideration the particular local parameters on Chongming Island. It is planned to realise a cyclical management system in which the possibilities provided by part streams are consistently realised.

In accordance with the global aim of increased efficiency, the resources necessary for life in the Dongtan project on Chongming Island, water, energy and nutrients, will be completely recycled. This innovative water infrastructure concept is suitable as a module when cities with large populations are to be created with structures that are future-oriented. The principle of this concept can be applied worldwide in the selection of technical components, in dry areas and in water-rich areas.

Key words: urban wastewater infrastructure, vacuum systems, anaerobic digestion, hydrothermal carbonization, circular economy

1. INTRODUCTION

Life and survival on earth require water, energy and nutrients. These three resources cannot be replaced neither in the necessary quality nor quantity. Today resource efficiency becomes inevitable on a global scale. Resource efficiency problems have occurred during the industrialization age while planning of fast growing cities. 2007 cities are at the heart of the climate change debate as half of the world's population lives in urban areas and cities account for 50% of the greenhouse gas emissions. Logically, cities are the ideal places for promoting innovative solutions to reduce the carbon footprint without reducing quality of place. There is a real good chance to solve problems with a sustainable future design of coming cities.

The earth's population is growing and accumulating more and more in mega cities. For example the urban population in China is to reach 1,1 billion by 2050, this is a shift of more than 600 million people from rural to urban. Several hundreds of new cities have to be build in the near future. China is facing their coming up urban infrastructure problems. In the framework of a Hamburg-Shanghai sister city project, Hamburg Water, HW, was asked to give advice about advanced sustainable urban water infrastructure design. Within the valid masterplan area of more than 80 square kilometres on Chongming Island, Shanghai, a new eco city named Dongtan will be build soon. 10 000 residents will live in Dongtan by 2010 the year of the world EXPO Shanghai. The catchment area shall rise to more than 8 hectares. The main Chinese goal of the Dongtan eco city planning is to minimise the total amount of carbon dioxide emission within the regional boarders. With priority renewable energy will be implemented in Dongtan. – In this paper you will find the advices of Hamburg Water we gave to our sister city partners in Shanghai.

Will low value biomass from houses, gardens, settlements, cities and regional agriculture become more dominant in the future? The answer is “yes”, because biomass is not only an everlasting sustainable primary energy carrier. Locally grown biomass and its products can ideally be integrated into a regional circular economy. It can substitute fossil fuels and other raw materials. Renewable biomass from the region is a key factor for a sustainable future. Nevertheless, the economical use of energy in urban development is of essential importance. The available stocks of coal, oil and natural gas with its long routes of transport from the deposits to the users will be short in the coming decades.

As mentioned before the world gets more and more urban. This is a prime reason to integrate the supply and disposal of urban agglomerations into regional material flow systems. Organic waste disposal, water supply, communal sewerage collection and treatment of tomorrow will be integrated into the manufacturing process of different kinds of biomass. This process will lead to the reduction of resource consumption, less environmental pollution and will furthermore deliver recyclable products from biomass that are necessary for a new growing cycle of biomass.

Biomass needs water, nutrients and solar energy to grow. With new energy autarkic urban water infrastructure systems – we call it Hamburg Water Cycle, HWC - Hamburg Water delivers recyclable water and the needed nutrients for the growth of biomass for regional material flow systems.

Today, in September 2007, the people of the world are confronted with the results of their own inappropriate behaviour, the excessive and inefficient use of water, primary energy and nutrients, which have led to the well-known problems:

- On the world scale, there is neither enough water so necessary to life, nor is the quality of the available water adequate.
- Essential raw materials, such as the nutrient phosphorous, are no longer available in sufficient quantities all over the world.
- The primary energies oil, gas and coal will be exhausted in the foreseeable future.

The common factor of all these problems is that they vary in their intensity in different parts of the world. Human behaviour produces excessive emissions which cause climatic changes which are proved to aggravate the existing problems. As a result of the climatic changes, the place at which the problem is acute and the place responsible for the problem are no longer identical. However it should be mentioned in this paper that there are available tools for the sequestration of atmospheric carbon dioxide.

A further common factor of these problems is that the continuing migration of people away from the land means that in the near future people will mostly live in megacities. This is where the solutions for global problems will have to be found. The Hamburg Public Sewage Company is involved in the further development of the existing urban sewage and rainwater drainage infrastructures and is one of the first stakeholders which deals with new disposal concepts in conurbations including eco-sanitation in Hamburg as well as abroad.

2. ANALYSIS

The end-of-pipe wastewater disposal systems currently in operation today are technical highly optimised and have the following characteristics:

- An apparently unavoidable consumption of primary energy with moderate purification standards.
- Unavoidable residual pollution of the waters and seas into which the cleaned wastewater is discharged with possible eutrophic effects.
- Unavoidable pollution of waters and seas with micro-pollutants.
- The waste of high-quality tap water, mostly of drinking water quality, through the flushing wastewater sewer system.

- Destruction of nutrients due to the current wastewater treatment methods resulting indirectly in waste of primary energy resources due to the need to produce nitrogenous fertilisers.
- High-quality rainwater is allowed to flow away unused via nearby waters.

Neither the Hamburg Public Sewage Company, nor any other company which is successfully operating an urban water-infrastructure-system within the industrialized world has a blueprint answer to the world-wide problems of wastewater disposal facing us in the future, or in developing countries and those in transition today. In addition, the characteristic factors of different locations are decisive for the planning and decision-making of a sewage company, too.

Moreover, infrastructures – the lifelines of a city – are subject to dynamic and characteristic changes of growing cities, for example in the form of new industrial areas and housing estates, or the change from indirect to direct discharge.

In the future, global constraints will contribute increasingly to the essential changes in urban sewage infrastructures. The driving forces of development are already foreseeable today, i.e. the efficient use of water, the protection of resources and the saving of energy. If we focus on the climate change it would be desirable to not only slow down further greenhouse emissions, but also to invert the current development by sequestering the atmospheric CO_2. Low value biomass can be transformed into an efficient deposited form of carbon, i.e. hardly degradable carbonaceous soil.

3. POSSIBLE SOLUTIONS TO FORESEEABLE PROBLEMS

Today all new supply and disposal systems for cities have a common feature: streams of substances are kept separate near to their sources. With management of streams of substances (material-flow-management), individual parts of the streams are collected, treated according to specific requirements and then returned to a production process. The aim is to create processes which are almost complete cycles, whereby 100% efficiency can never be achieved (circular-economy). In the case of new communal supply and disposal concepts, the resources water, energy and nutrients are made available again for a new production cycle. This recycling enables substitution to be used instead of primary resources. Primary energy sources are replaced by renewable raw materials and this results in a general reduction in the consumption of resources.

4. MODEL PROJECT ON CHONGMING ISLAND

Hamburg Public Sewage Company, part of Hamburg Water Group, HW, has developed an innovative urban water infrastructure for the growing City of Dongtan, Chongming Island. The planning for Dongtan includes regional agriculture operating on ecological principles. Farming is a necessary part of our circular economy system. Material flow management will admit to deliver almost the whole regional demand of nutrients in agriculture as well as for food production in greenhouses.

Greenhouses are profligate users of energy. In temperate climates the energy is used to heat the house in the winter, and in tropical climates energy is used to keep the greenhouse cool. By using a fully insulated light proof growing factory it should be possible to recirculate CO_2 and water and nutrients within the system and thus reduce energy requirements. Existing artificial light sources produce too much heat, but light emitting diodes (LED's) may provide a possible solution because of their low heat production characteristics.

Using LED's and a hydroponics crop production system, air can be recirculated and any excess heat and water vapour removed. CO_2 could be recycled by the digesting process of low valuable biomass while soluble components of the biomass could be incorporated back into the nutrient solution.

The energy source for the lights may come from solar panels on the roof of the building. Electrical energy can be efficiently converted into photosynthetically active radiation and into plant material. The plants could be photosynthesising for up to 24 hours per day and the marketable yield managed by the spectral balance. The level of CO_2 in the house could be up to 1500 ppm so it is postulated that yield is fare more that in best current commercial yields could be achieved, anywhere in the world.

The concept, the selection of the technical components from a large number of possibilities and the combination of individual elements in a system take into consideration the particular local parameters on Chongming Island. It is planned to realise a cyclical management system in a small area in which the possibilities provided by part streams are consistently realised:

- Domestic greywater (wastewater without water from toilets) is channelled downhill to constructed wetlands treatment plants and, after successful purification is added to the rainwater collected in the settlement for irrigation purposes.
- Domestic blackwater (wastewater from toilets) is channelled by vacuum technology to a biogas reactor, an anaerobic digester.
- Domestic organic waste and organic residues from agriculture and liquid manure are also channelled to the biogas reactor.
- It is planned to include part of the harvest of entire plants, such as maize, in the biogas process.
- The biogas gained from these renewable raw materials is to be utilised. Electricity produced via a combined heating plant, CHP, and also heat/cold will be used for the conditioning process and in the settlement of Dongtan.
- The fermented residues from the biogas reactor will all be returned as fertiliser to the fields.

The resources used in the settlement, water, energy and nutrients, will thus for the most part be recycled in the Chongming Island cyclical process. The operational consumption of all the buildings constructed has been designed for optimal energy utilisation. On Chongming Island this is an important component in the cyclical management concept.

If the Chinese primary aim is to focus on climate change problems which means the reduction of CO_2 emissions and the possibility to invert the current development by sequestering the atmospheric CO_2, the hydrothermal carbonization (HTC) is a promising stand alone process as well as a supplement for the anaerobic digesting treatment of biomass. With HTC processing the carbon content in organic substances can be transformed into a stable form of biomass char near 100%, which means with almost no loss via CO_2 emissions.

At present Hamburg Wasser is investigating in the HTC process because the carbonization of blackwater, organic waste and low valuable biomass can be an efficient procedure for removing atmospheric CO_2 with several additional advantages:

- HTC is a chemical process that is found in nature.
- The process can convert low valuable biomass into a valuable fertilizing soil additive.
- It is known that black soil not only stores carbon, it also boosts crop yields in a spectacular manner. Pure nutrient soils can be transformed into black nutrient rich earth. Certainly further research and development has to be done.
- HTC is a herald of another natural transformation of “waste” into resources.

For imagination of the sustainable innovative water, waste and wastewater infrastructure concept designed for the eco city of Dongtan see figure 1.

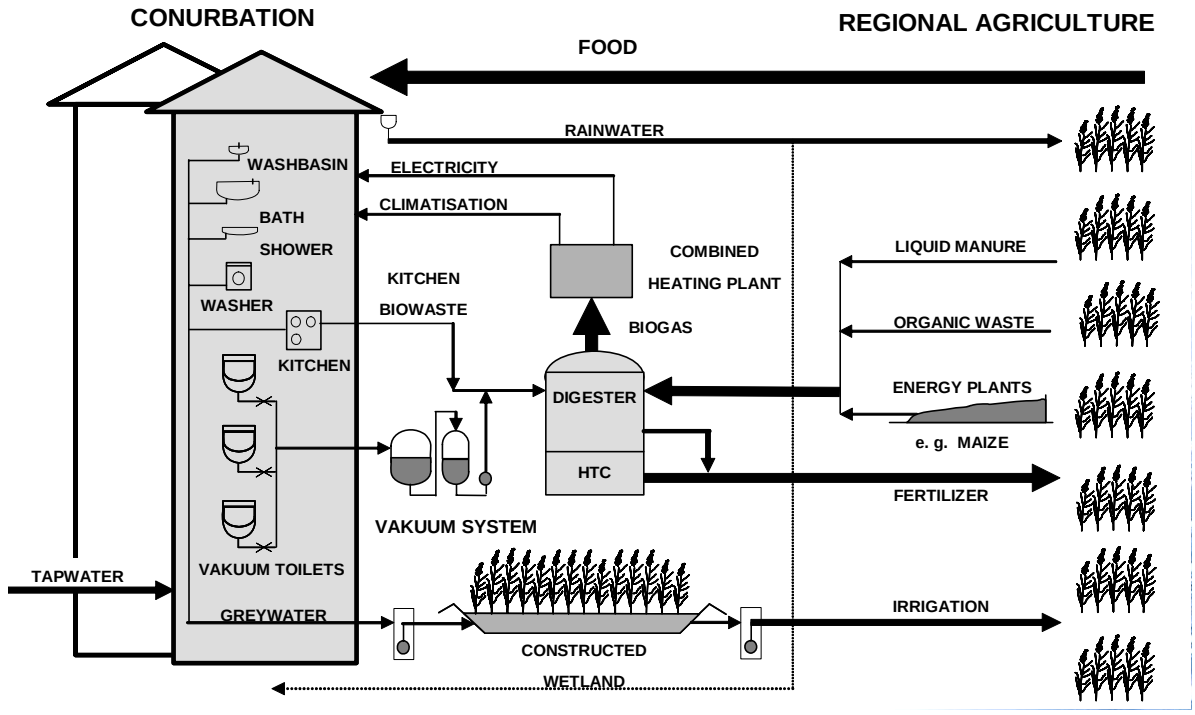

Figure 1: Innovative urban water and organic waste infrastructure in regional economy systems. Model project Dongtan, Chongming Island, Shanghai, China. Concept: Hamburg Public Sewage Company, HAMBURG WASSER

5. ADVANTAGES OF THE MODEL PROJECT

Some of the excellent advantages connected with this model project on Chongming Island are summed up in the following:

- The traditional wastewater disposal system is abandoned for this model project and is integrated completely in other processes. Here there will be no pollution of the China Sea from wastewater.
- Tap water consumption of under 90 l / P*d will be possible. All water which has been used will be used again for irrigation after it has been treated in the greywater treatment plant (constructed wetland).
- The constructed wetland will be perfectly integrated in the natural landscape of Chongming Island as elements of the design. The harvest of plants can be included in the biogas process.
- The primary energy consumption necessary for traditional wastewater disposal will be replaced by a process of energy production from renewable raw materials. The energy requirements of the settlement on Chongming Island can be covered when additional renewable raw materials are included in the biogas process.
- Emissions having a negative effect on the climate will be almost totally avoided in the functioning of the settlement including the farm.
- The urban water- and organic waste infrastructure of Dongtan can be designed as a carbon sink with a minimum of CO_2 emissions.
- The fertilisers required for the regional agricultural processes will be recycled from the biogas process. Phosphate fertiliser which cannot be replaced and nitrogen fertilisers created with considerable quantities of primary energy will be substituted in this way.

6. SUMMARY

In accordance with the global aim of increased efficiency, the resources necessary for life in the Dongtan project on Chongming Island, water, energy and nutrients, will be almost completely recycled within the regional boarders. The city supply and disposal system can be outlined as a carbon sink.

This innovative waste and water infrastructure concept is suitable as a module when cities with large populations are to be created with structures that are future-oriented. The principle of this concept can be applied worldwide in the selection of technical components, in dry areas as well as in water-rich areas.

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