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Model supported design and operation of a wastewater treatment pilot plant

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ABSTRACT

Wastewater treatment plants (WWTPs) are actually designed and in a very static way. They are designed for an assumed maximum load and hard limits according the water quality of at their effluent. Their operation parameter often are not changed much form the design parameters. In reality the loads at the inlet of the WWTP are changing hourly and may also change in their average over a longer period of time. Also the ecological needs for the water quality at the effluent may change over the time.

During a project on integrated water resource management (IWRM), Fraunhofer AST analyzed the WWTP of the City of Darkhan in Mongolia according to its design and operation. To support this analysis a mathematical model of the WWTP has been developed. Unfortunately the analysis showed it is preferable to build a new WWTP over changing the old one. Therefore, for a second stage of the project a pilot plant of a new WWTP will be built.

The new WWTP will be of a sequencing batch reactor type. The planning and test operation will be supported by model based simulations for better integrating the dynamic nature of the processes into the design and operation procedure.

Index Terms **–** Wastewater treatment, WWTP, Modeling, IWRM

1. INTRODUCTION

Integrated Water Resource Management (IWRM) is about concerning the whole water cycle, all economical, social and environmental problems as well as all involved parities. Therefore this integrated approach can only be done by different research areas working together. One of these projects, called MoMo took part in the “Model Region Mongolia”, in the catchment area of the river Khara. Darkhan is the biggest city in this area by far. The following paper will mainly discuss the wastewater treatment aspect of IWRM.

WWTPs are very important facilities in today’s water cycle. They are needed to efficiently bring used water back to a state that is not harmful to nature and human beings and can be reused for different tasks. In fulfilling this task they should be as efficient and cost effective as possible. To achieve this goal, the wastewater purification has only to be “as good as needed”.

The WWTP in Darkhan was commissioned in 1968 and is using mechanical, biological, chemical sewage treatment. It has been designed mainly for COD removal. Some biological processes become very slowly or not functioning at all under low temperature. The equipment for mechanical treatment is sewage screens as well as primary and secondary sedimentation tanks. A chemical treatment of the outflowing water by chlorination is out of order but should not be reactivated. Extremely polluted water from industries and mining is flowing into the WWTP and leads to a degradation of control and a reduction of the level of purification to around 70%. Most waste water collectors are not being maintained or repaired and need to be expanded or replaced. Due to many years of utilization of the sewer network, joint caulks and pipes have already been overused, tree roots have penetrated pipelines and the resulting line blockages cause serious operational problems. The pressing waste water problems in Industry and Ger areas have not been solved. This is the most important challenge that needs to be addressed over the next few years.

The WWTP of Darkhan currently is in operation for more than 40 years and in a state that will not provide a sustainable water treatment for the near future.

The purpose of the water supply strategic master plan of Darkhan with an assumed population of around 120,000 inhabitants is to define the development and management policy of the waste water treatment facilities of the city in order to meet the expected requirements until 2025, including those likely to arise from the progressive urbanization of the Ger areas. A specificity of city Darkhan is the existence, beside a conventional urban area commonly referred to as the core area and equipped with all the facilities of modern cities, of large informal housing areas combining small houses and Ger areas. These Ger areas regroup more than one half of the population of Darkhan, mainly the traditional and newly settled families and are not connected to the WWTP.

The WWTP currently utilizes only a third of its capacity. It is operated very inefficiently and therefore costly. Due to the cold climate the polishing pond can not be utilized in winter time. The purification provides no de-nitrification. Due to the under-utilization various ponds are not in use and deteriorate. The ponds in use and the service buildings are in a condition that allows actual operation, but provides no long term sustainability.

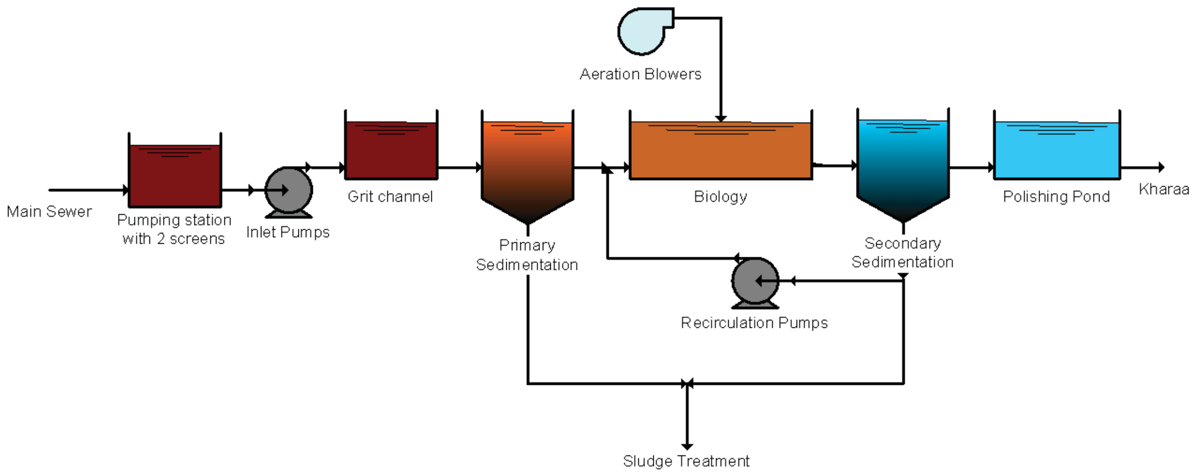

Figure 1 – Model structure of the actual WWTP of Darkhan

2. THE EXISTING WWTP

In a first stage, the existing WWTP and its inflow characteristics have been analyzed. This analysis revealed the drawbacks of the design and operation of the existing WWTP. It included approaches to improve the operation of the WWTP as well as long term structural and economical considerations.

2.1. Simulation of the existing WWTP

By using a computer model of the WWTP Darkhan (Figure 1) different variants of operation have been simulated. The simulation software models all parts of the WWTP that are important for purification. Therefore the simulation program mainly uses ASM 1 and 3 type models [1][4][5][6][9][10] for dynamically modeling the biological processes of the WWTP and the polishing ponds. There are also models for the sedimentation processes in the sedimentation tanks.

By analyzing the inflow data average daily trends of the important parameters are generated (Figure 2). The computer model is calibrated using self-measured two-hourly data. Unfortunately the quality of the available data is only mediocre which leads to only fairly adapted models.

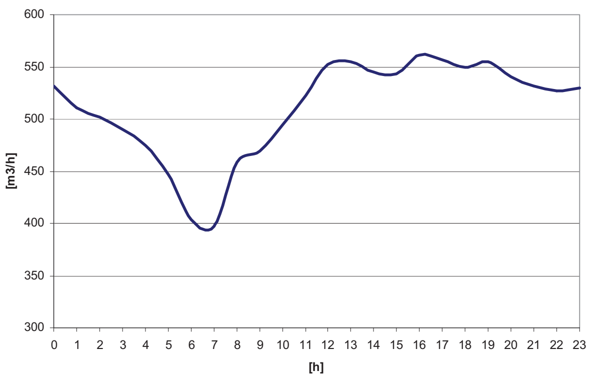

Figure 2 – Averaged daily inflow

The most important action will be to make the operation of the CWWTP more stable and sustainable (e.g. installed pumps have high maintenance times and often there is no replacement available during maintenance).

The actual oxygen concentration within the biological tank is up to 6 mg/l. Keeping this level of aeration consumes a high level of electrical energy. The long term simulations of the treatment processes have shown it is possible to reduce the aeration to a level of less then 2.5 mg/l and consequently the consumption of electrical energy used for the aeration of the biological tank without sacrificing the treatment efficiency. As visible in Figure 4 the change of oxygen concentration in the aerated tank (first chart) has no significant influence on the concentration of NO_3, NH_4 and COD concentrations in the effluent. A stable operation of the WWTP with reduced oxygen concentration is possible but clogging of the aerators may be possible due to reduced air flow.

2.2. Structural and economical analysis of the existing WWTP

Besides analyzing the operational efficiency of the WWTP the analysis of structural and economical problem was another important task during the project. The following significant problems have been localized:

Technical problems:

- Equipment is broken and needs very high electrical consumption (pumps and air compressor),
- The technical situation does not meet the requirements and standards,
- The CWWTP is in a state that will not provide a sustainable water treatment for the near future.
- No control and no SCADA systems,
- Rehabilitation and service works are bad,
- Online measurements are necessary,
- Self-monitoring is insufficiently,

- The existing laboratory at USAG can not analyze all required elements,
- The wastewater treatment in the small cities and villages in the Kharaa River catchment area is mostly out of operation,
- The existing laboratory equipment is old.

Environment problems: The environmental problems caused by wastewater from industries, mining and urban (slaughter houses, wool factories, bakeries, pharmaceutical companies, hospitals, power stations, printing houses, vehicle repair) and tanneries (cleaning and producing leather, coats) in Darkhan are serious. With more than 40 years in operation the CWWTP in Darkhan currently is in a state that will not provide a sustainable water treatment for the near future. An accident in the village Khongor Sum in year 2005, only 29 km upstream of Darkhan, shows the high risk for the population caused by illegally operating mining companies and practically nonexistent monitoring.

The MoMo project is realizing major contributions to improve the critical environmental situation in the urban and rural area of the city Darkhan of Mongolia by

- Determining the potential impact that can be realized through the adoption of state-of-the-art wastewater management strategies and advanced processing technology and
- Contributing to the protection of drinking water source areas, surface water, groundwater, and the river Kharaa from pollution by waste and wastewater.

Hygienic problems: In Ger areas the hygienic situation is similar as in DWSS. There is no wastewater collection, treatment and removal system. Diseases originate from unsanitary conditions, caused by untreated drinking water, open sewage in the pit-latrines coupled with unhygienic habits. Self-built not tight traditional pit latrines without cleanout are in use at every family's compound. Urine and faeces leak from the pit latrines into the ground.

Financial problems: The USAG has not enough investment possibilities for the reconstruction of the CWWTP. The USAG has increased the water tariff since January 2009 more than twice. Nearly 50% of the income from water fees are going to the covering the electrical consumption of the pumps and other electrical equipments.

Instead of simply installing advanced wastewater treatment technology and control methods only the consideration of these structural and economical problems during implementation will lead to sustainable IWRM strategies. Especially financial constraints will lead to a solution "as good as necessary" instead of "as good as possible".

3. THE PILOT PLANT FOR A NEW WWTP

Based on the experiences of the first part of the MoMo project it has been planned to build a pilot plant to test possible treatment methods of a future large scale WWTP for the city of Darkhan.

The main goal for this pilot plant is to be robust in handling varying loads, cost effective to build and operate. When scaled up, a large scale plant based on the pilot plant should have the same characteristics and should be easily adaptable to the unpredictable development of the population of Darkhan and the produced wastewater.

Modern technologies as sludge digestion and energy production shall be integrated into the pilot plant as well as the future large scale plant. The effect of the very low temperatures in Mongolia in winter time on the biological processes of the plant has to be considered.

Based on those considerations it was decided to build the pilot plant as a Sequencing Batch Reactor (SBR) type plant (Figure 3). This type or WWTP is characterized by a great flexibility in operation [2][3].The problem with this type of plant will be to achieve sustainable sludge stabilization under very low temperatures, as the temperatures may go as low as -40 °C in winter time.

To achieve this goal, the design and operation of the pilot plant will be based on offline and later online simulations and model predictive control [7][8] to reduce costs for construction of the plant as well as operation. The simulation model will be based on the same ASM models as the model of the old plant but adapted to the specifications of the SBR processes.

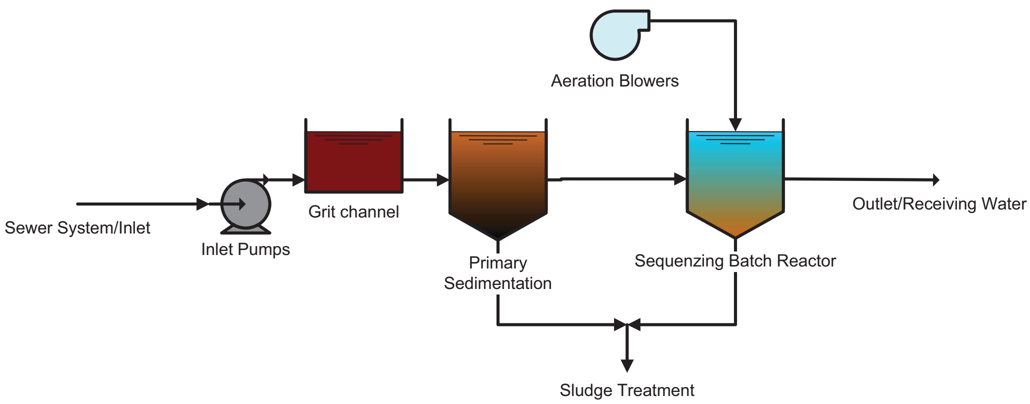

Figure 3 – Possible SBR pilot plant

4. CONCLUSION

Improving the operation of WWTPs by model based simulations can lead to significantly reduced operational costs even if the available measurements are unsatisfying. The lower calibration quality of the model still can be sufficient for impovements of the plant operation.

Especially WWTPs which have been designed long ago can benefit from model based simulations to

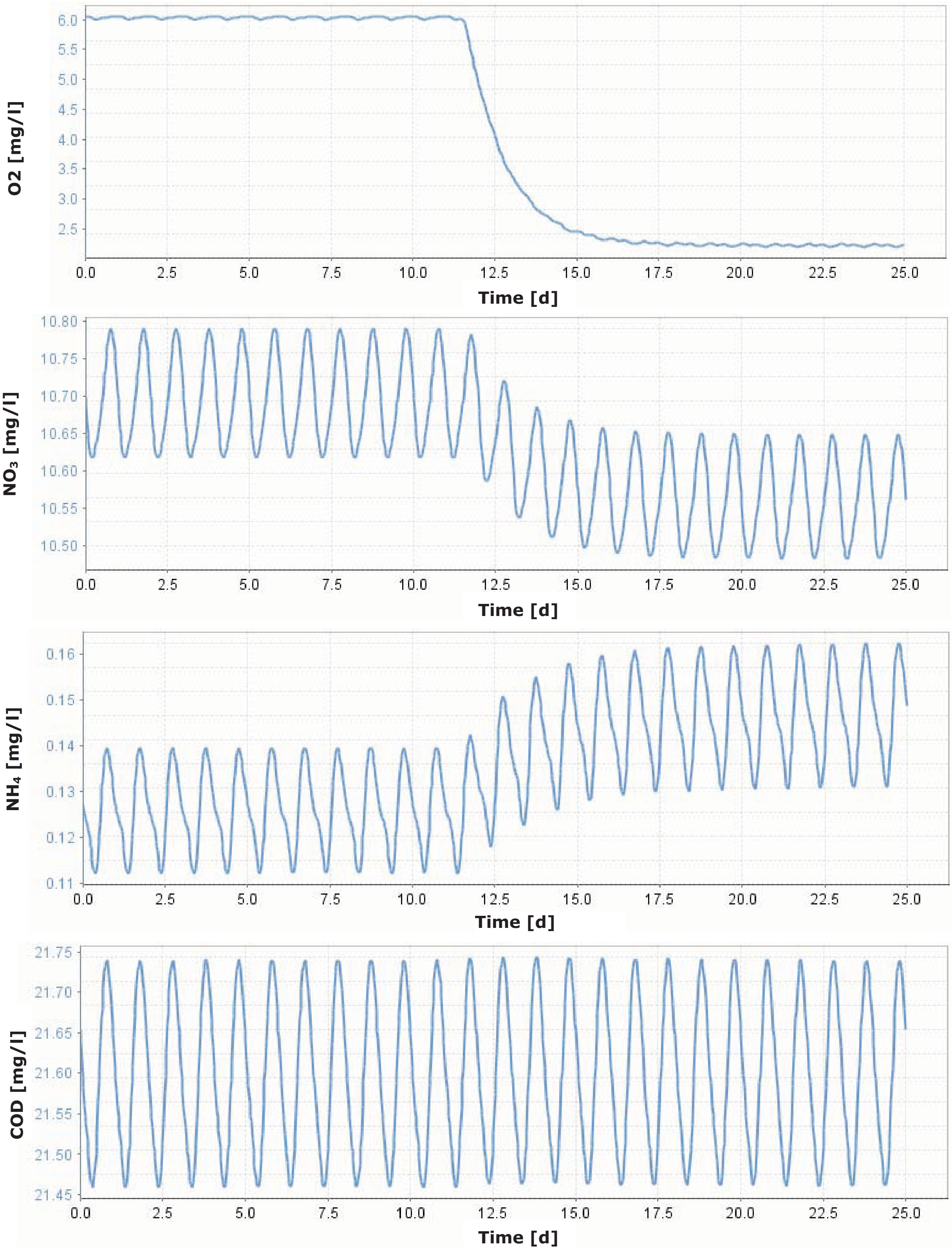

Figure 4 – Effects of changing oxygen concentration on effluent concentrations

adapt their operation procedures to the actual loads. This is often possible without structural changes to the plant.

To improve plant operation above a certain level, structural changes of the plant are necessary. For these changes a strategy strongly considering the local ecological and economical needs is desirable. Such a strategy may differ from what is commonly known as the best solutions in wastewater treatment. The pilot plant in Darkhan may help to find a possible solution for the existing problems.

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