DANISH APPROACH TO HANDLING OF HOSPITAL WASTEWATER - FROM A POLLUTION PROBLEM TO NEW WATER RESOURCES

KRISTINA BUUS KJÆR[1]

Abstract

Significant quantities of specialized pharmaceuticals are used in hospitals. These pharmaceuticals are excreted by patients via urine and faeces and end up in the wastewater, which also contains a mix of chemicals, viruses and resistant bacteria. For these reasons, the Danish environmental authorities want wastewater from hospitals with significant discharges of harmful substances to be treated at the source.

Keywords: environmental and health risk, hospital wastewater, public sewer, wastewater treatment plant.

1. INTRODUCTION

Many pharmaceuticals, such as antibiotics and cancer drugs, are toxic to aquatic organisms. Municipal treatment plants are not designed to remove these types of substances, which results in discharges to the aquatic environment. Also, harmful bacteria and viruses from patients can be spread via combined sewer overflows and flooding during heavy rainfall. Sewage workers as well as bathing visitors in the water areas may be infected.

For these reasons, the Danish environmental authorities want wastewater from hospitals with significant discharges of harmful substances to be treated at the source. But hospitals as well as municipalities need documentation of how hospital wastewater can be treated and whether it is technically/economically feasible.

1 Kristina Buus Kjær, MSc, DHI A/S, Danska

2. OBJECTIVE

Pre-tests in laboratory scale on possible innovative technologies were carried out by DHI for the Danish Environmental Protection Agency (EPA) in 2010-2011. These pre-tests were followed by targeted pilot and laboratory tests of the wastewater from Herlev Hospital. The laboratory tests showed that membrane bio-reactor (MBR) technology combined with activated carbon, ozonation and UV was efficient in relation to the critical pharmaceuticals and pathogens in the hospital wastewater.

But the pre-tests did not show how the technologies should be combined and adjusted to the continuous flow of hospital wastewater in full scale. At the same time, the treatment efficiency needed to be tested for the removal of a large number of pharmaceuticals and xenobiotics, toxic effects on algae, daphnia, fish as well as hormone effects. Furthermore, the effectiveness of the treatment needed to be tested in relation to viruses and antibiotic-resistant bacteria.

On this background, the Capital Region of Denmark and Herlev Hospital decided in 2012 to initiate a private-public innovation project with the first full scale test of treatment of hospital wastewater in Denmark. Herlev Hospital is the plant owner and Grundfos BioBooster A/S has been responsible for the overall project. DHI has been responsible for the tests, development, evaluation, and reporting.

The overall objective of the project was to provide in-depth knowledge to Danish hospitals and environmental authorities, offering them a more solid basis for deciding whether hospital wastewater treatment is a viable solution in their local area. At the same time, the intention was to create a complete solution with treatment of wastewater, air emissions and sludge (drying) on site, having the potential to be exported worldwide.

3. METHOD

3.1 Working Area

Herlev Hospital is a large scale university hospital with 700 beds and a yearly wastewater volume of 150,000 m^3. The hospital is now under expansion and in 2020, the hospital will have 900 beds and discharge 200,000 m^3 per year. The hospital serves 700,000 citizens within a large variety of medical specialities. Within cancer treatment, the hospital treats patients from all Zealand.

3.2 The Herlev Hospital wastewater treatment plant

The Herlev Hospital wastewater treatment plant (WWTP) was constructed from 2013 to 2014 and has been operated since May 2014. The test period covered a period of 1.5 years from May 2014 to November 2015. The plant consists of a membrane bioreactor (MBR) with nitrogen and phosphorus removal, followed by a combination of polishing technologies. During the test period, the polishing step was split into two separate lines with different configurations, Line 1 and Line 2, which were operated in parallel. Line 1 consisted of granular activated carbon (GAC) treatment, followed by ozone and UV. Line 2 consisted of ozone, followed by GAC treatment and UV. Operation of the different setup of the two lines allowed for comparison of GAC and ozone treatment. After the test period, Line 1 was reconstructed to the same setup as Line 2, because the evaluation showed that Line 2 performed most efficiently on removal efficiency as well as on GAC consumption.

All solid waste streams (screenings, sludge and spent GAC) are sent to incineration at the local household waste incineration plant (850-1,200 ºC), where 80 % of the energy produced is turned into district heating while 20 % is used for power supply.

A central air treatment unit with a photoionization process based on UV-light treats all vent air from the plant (vacuum in the building). Microbiological risk investigations of the air emissions showed that treatment worked efficiently. No complaints from neighbors or others concerning odour problems were registered.

4. RESULTS OF ANALYSIS

4.1 Effluent discharge criteria

The wastewater treatment performance was evaluated in-depth through a monitoring and testing programme. 118 samples were analysed for active pharmaceutical substances and in total, 122 substances were analysed. In addition, tests were performed for bacteria, virus and toxicity on water living organisms. An overview of analyse and test results from raw wastewater to final treated effluent is presented in Table 1.

Table 1: Overview of treatment performance. From raw hospital wastewater to final treated effluent.

Parameters	Raw untreated wastewater	Treated wastewater
Toxic and persistent antibiotics (e.g. ciprofloxacin, clarithromycin and sulfamethoxazole), painkillers (diclofenac) and cytostatics (e.g. capecitabine)	Factor 10-300 exceeding of effect limits PNECFreshwater) for water living organisms	99.9 % removal and no exceeding of effect limits PNECFreshwater) for water living organisms
Contrast media (e.g. iomeprol)	High concentration (2,5-7 mg/l)	99 % removal
Antibiotic resistant bacteria	High occurrence of antibiotic resistant bacteria	No fecal or antibiotic resistant bacteria
Water born viruses (norovirus)	High concentration (1.7·10^5)	Under limit of detection (<26 GC/l)
Fish fry (zebra fish)	100 % mortality within 96 hours	0 % mortality within 96 hours
Crustacean (daphnies)	No offspring (all test animals died)	Offspring survives as in clean control water
Estrogenic activity (A-YES)	Estrogen effects	No estrogen effects

Table 1 shows that the load of pharmaceutical substances were removed by 99.9 % and that the substances still measurable in the effluent were below the effect concentrations for freshwater living organisms (PNECFreshwater) without dilution. The highly persistent, but less toxic, contrast media were removed by 99 %. Fecal and antibiotic resistant bacteria were removed and viruses, represented by norovirus, could not be detected. Ecotoxicity effects on fish and daphnies as well as estrogenic effects could not be measured in the final treated effluent.

Treatment performance in relation to general organic substances and nutrients was high compared to typical emission requirements. At the end of the test period, where the biological and chemical processes were optimized, COD, Total-N and Total-P were measured to respectively 10-20, 2-3 and 0.2 mg/l in the effluent.

The evaluation of the treatment setup showed that the MBR-ozone-GAC setup was the most efficient setup compared to MBR-GAC-ozone. The tests showed that the ozonation had a higher pharmaceutical removal efficiency when it was applied before GAC and at the same time, it made the GAC more efficient. The MBR-ozone-GAC was also observed to result in less GAC usage, most likely because the general organic matter is transformed into more water soluble compounds by the ozonation. No critical formation of ozone by-products, such as bromate or NDMA, was observed.

4.2 Investment and Environmental costs

The assessment of the overall economy was based on a registration of all operational expenditures. This included consumption of energy, chemicals, GAC and the costs for handling of by-products as well as man-hours for service. In addition, there is also maintenance costs for general maintenance of the plant. This was calculated as 2-3 % of the investment cost per year.

The investment cost of a fully operational WWTP is assumed to 25-35 million DKK. The investment depends highly on the construction of the building for the WWTP. The actual investment at Herlev Hospital was high due to a wish to construct a building for the WWTP with special architectural features. The economical key figures are presented in Table 2.

Table 2: Overall economical key figures for the Herlev Hospital WWTP.

Type of cost	DKK	EUR
Investment cost	25 - 35 mill. DKK	3.3 - 4.7 mill EUR
Operation & Maintenance costs	10.87 DKK/m^3	1.45 EUR/m^3
Fee for discharge to public sewer	25.54 DKK/m^3	3.41 EUR/m^3

Herlev Hospital is presently paying a discharge fee of 25.54 DKK/m^3 for discharge of wastewater to public sewer. If, in the future, th e wastewater is discharged directly to the nearby local stream (Kagså), this fee will no longer be applied, which will result in possible savings of running costs of 15 DKK/m^3 (25.54 - 10.87 = 15 DKK/m^3). A win-win situation can be achieved, where pollutants are removed, the treated water is used for conservation of the local stream and overall wastewater costs are saved. It should be noted that depending on the specific future solution, there will be other costs related to the direct discharge, such as construction of a dedicated pipeline or costs for using the rainwater pipeline of the water company.

5. CONCLUSION

If the treated water is released directly to the local stream (Kagså) and from here further on to the marine bathing water area (Lodsparken), possible environmental and health risks have to be assessed. Therefore, risk assessments were carried out in the local water areas based on hydrodynamic modelling of spreading and fate of chemical and microbiological parameters. The results showed that the estimated risks were negligible during normal operation of the WWTP.

The high water quality of the final effluent opens up many options for reuse. Presently, reuse of the treated water in the existing cooling towers at the hospital is planned. Around 10,000 m^3/y are expected to be reused here. Practical planning for the implementation of the direct release to Kagså is being carried out at the time of writing.