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Experimental verification of tertiary treatment process in achieving effluent quality required by wastewater reuse standards

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ABSTRACT

Modern technologies in wastewater treatment can produce high quality effluents, therefore wastewater is now considered a valuable product suitable for reuse. However, water reuse needs to be regulated based on applicable and legally binding guidelines, therefore the lack of a regulatory framework hampers this practice and its benefits. The Czech Republic, as many other countries, has an absent water reuse legislation. In this study, a pilot-scale tertiary treatment was installed at Milevsko Waste Water Treatment Plant (WWTP) in South Bohemia (20,000 P.E.) to demonstrate the effluent quality that can be achieved and evaluate the reuse potential, especially on non-potable applications, such as industry and irrigation. WWTP secondary effluent was treated by three separated technologies: Dissolved Air Flotation (DAF), sand filter and Filtra-lite® filter; followed by ultraviolet (UV) disinfection. Results on water quality were compared to Czech standards for drinking and non-drinking water, and to some international benchmark regulations for water reuse. Our results have led us to initiate the introduction of legislation regulating wastewater reuse in the Czech water management framework.

1. Introduction

Wastewater reuse has become a desirable manner of dealing with this product due to its fairly high quality and the sustainable use of the urban water resources. Applications for reuse are quite diverse, but an essential part in this process is the implementation of valid and binding legislation that sets clear policy for wastewater reuse. Often, effluent quality not only ensures adequate protection of recipient waters but, in some cases, exceeds the requirements of environmental protection. An extending shortage of drinking and fresh water coupled with steadily increasing potable water prices is leading to widespread investigation of WWTP effluent reuse options [1]. Various modifications to WWTP technology can produce different qualities of treated wastewater to suit particular reuse requirements [2,3]. For each application of treated wastewater reuse, safety criteria must be established and the potential risks associated with these processes must be defined according to World Health Organisation guidelines (WHO) [4,5]. In Europe, treated wastewater has to comply with both EU and national water law, and depending on the final use of the treated water, it would have to comply with many other EU directives. Applicable legislation must consist of several fundamental components which can be divided into basic parts: defined terms based on guidelines of the WHO, specified wastewater reuse areas, raw material quality for specific applications and regions, and processes able to achieve the required quality.

To facilitate this process, a pilot plant project assessing three different simple tertiary treatment devices was installed in a WWTP with a capacity of 20,000 PE located in South Bohemia, Czech Republic. To ensure hygienization of the effluent, an UV unit was used downstream of all devices under evaluation. Data from these experiments were compared with existing legislative requirements from the Czech Republic as well as the U.S. and European Guidelines for Wastewater Reuse. The main aim of this project is to demonstrate the achievable quality of real WWTP effluent and evaluate its potential for reuse in the industrial sector, mainly. Additionally we aspired to characterize and compare the removal efficiency of water quality indicator parameters of the three simple tertiary treatment devices employed.

Water reuse is not a current practice in the Czech Republic although the technologies to produce clean effluents are available. Up to now, the effluent of WWTPs are discharged into recipient waters, usually rivers or streams nearby the plant, only applying extra measurements to improve the quality of the effluent when the discharge is made on protected or sensitive areas [7,8].

In this pilot plant project we tested three devices for removal of residual pollution from WWTP effluent, including a separation process by DAF unit, a Sand Filter and a Filtra-lite® filter containing expanded crushed clay material. The performance of these devices was improved

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with a downstream UV reactor to provide hygienization [9–15]. The reason for filtration's dominance in the pilot systems is the maturity of this technology along with the low price in comparison with newer technologies like membranes [16–18], although membrane technologies were not in the scope of our research. The particular three devices in the study were chosen because DAF is commonly used in early stages of wastewater treatment but, to the best of our knowledge, has not been used as a tertiary treatment, especially in the Czech Republic. Filtra-lite® is a more recent technology that is not widely spread yet, however it is promoted as a safe and reliable filtration system that was created 20 years ago in cooperation with technical institutes and water experts, having now many successful case studies. Sand filter is a common and widespread tertiary treatment technology, so it was important to compare its results with the more innovative technologies. The experiments were adapted to water treatment standards in the Czech Republic and results obtained were compared to the requirements for industrial and irrigation use, as well as drinking water, despite the fact that achieving drinking water quality was not the aim of the experiment neither was expected. Lastly, the comparison was also made to examples of wastewater reuse guidelines abroad.

2. Methods

A pilot plant of tertiary treatment was installed in the facilities of the WWTP of Milevsko in South Bohemia region in the Czech Republic. The three treatments tested were: (1) separation after coagulation by DAF, (2) sand filtration and (3) Filtra-lite® filtration. All processes used secondary clarifier effluent as influent, which had already passed through a coagulation-flocculation process according to Fig. 1.

For the coagulation-flotation stage, 100 mg/L of 40% water solution of ferric sulphate (PIX-113) was dosed as a coagulant. Rapid homogenization was achieved in the first mixing area while the subsequent mixing area promoted floc formation with a slow mixing gradient. The flotation unit's coagulant dosing and mixing area was utilized as a common pre-treatment for all devices. A majority of the mixture (7.5 m^3) remained in the coagulation area for further separation by DAF unit; however 0.5 m^3 were diverted to feed each of the experimental filtration units.

The sand filter was composed of fine FP1 sand (0.5–1 mm diameter particles), the sand layer was 1.6 m thick and the filters had a Leopold® type S® gravitational drainage system to ensure uniform water flow and minimize channelling. Inflow entered the filtration unit 40 cm above the packed filtration material and was regulated by a floating flowmeter system.

The Filtra-lite® filtration is based on clay material expanded at 1200 °C and subsequently crushed into specifically sized particles. The filter applied in this project employed two layers: the lower one of higher density particles (0.8–1.6 mm diameter), and the upper one of lower density particles (1.5–2.5 mm diameter). Each layer was 0.8 m thick.

The three processes were not working parallelly at the same time, but were working with few hours difference always using the same water as influent. The processes were applied alternately using working cycles. The secondary clarifier effluent of the WWTP was stored in an exchange vessel of 30 m^3 at 16–18 °C and water quality was tested and proven to be consistent when supplied to each one of the three processes. From there, the pilot plant was fed on 5-h cycles for each treatment, with sampling performed every 30 min. For each device 13 cycles were run, meaning 130 samples were taken, analysed and considered for the results here presented. UV radiation was applied after each process as disinfection method using a low-pressure LifeUVL01xxSP-II lamp of 254 nm wavelength. The pilot-study was performed during spring-summer 2016, on a timespan of 4 months.

2.1. Physico-chemical analysis

Samples taken were analysed on site for turbidity, colour and total iron using mobile colorimeter, and for pH and temperature using mobile probes. These parameters were measured again in laboratory under more controlled circumstances to monitor their stability and accuracy. Physical and chemical parameters, such as orthophosphate, chemical oxygen demand (COD), and ammonia nitrogen, were analysed in the laboratory. On site, the measurements were done with DR/890 Colorimeter HACH® and pH/oximeter WTW Multiline P3.The analyses carried on in the laboratory were based on standard methods [19]. Results are reported in the superior part of Table 1.

2.2. Microbiological analysis

The organisms used as indicators of contamination were total coliforms, Escherichia Coli, Intestinal enterococci and colonies at 22 °C. As shown on Fig. 1, quality analyses were made on samples of the influent, labelled as sampling point 1; samples of the effluent of each tertiary process, labelled as 2a, 2b, 2c; and samples of each of the previous effluents after the UV disinfection had taken place, labelled as 3a, 3b and 3c respectively.

For total coliforms the count was done in UFC/100 ml performed by membrane filtration technique [20]. A 100 ml portion of the water sample with its appropriate dilutions passed through a 0.45 μm membrane filter and was placed in a plate with lactose-containing agar medium (m-FC agar). The plates were incubated for 18–24 h at temperature of 44 ± 2 °C and after that the colonies could be counted.

For *E. coli*, 100 ml samples with their appropriate dilutions were filtrated trough a 0.45 μm membrane and then kept for liquid cultivation in a medium with MUG (4-methylumbelliferyl-β-D-glucuronide) during 2–4 h at a temperature of 36 ± 2 °C. The count was made exposing the cultivated filter to an UV lamp with a wavelenght of 365 nm, where the colonies were confirmed as *E. coli* because of their fluorescence [20].

Intestinal enterococci count were also made by membrane filtration of the diluted sample, and later cultivated in a solid medium (sodium azide and 2,3,5-tri-phenyltetrazole chloride). The cultivation takes place at a temperature of 36 ± 2 °C for 44 ± 2 h. Enterococci are counted as presumptive enterococci, as typical colonies are considered

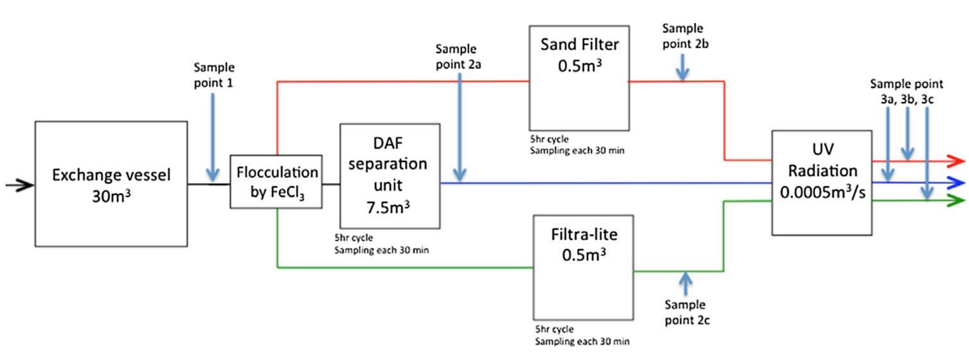

Fig. 1. Scheme of pilot plant of tertiary treatments with sampling points.