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EVALUATION OF EFFICIENCY OF HYDRODYNAMIC TREATMENT ON SEWAGE SLUDGE

ABSTRACT

The advanced treatment of sewage sludge is a very important task of the 21st century. To convert the sewage sludge into valuable fertiliser or renewable fuel, first of all an intensive, additional to the main biological stage, aerobic degradation is needed. Such a treatment can be carried out by ultrasonic or hydrodynamic effect. An industrial scale hydrodynamic text rig with a specially designed pump had been built and preliminary laboratory and industrial on-site systematic tests had been carried out. Based upon the industrial experimental results, several quality parameters were measured on the real sewage sludge before and after the hydrodynamic treatment combined with the adsorption process. The conclusions were drawn.

INTRODUCTION

Sewage sludge is the residue resulted from the wastewater treatment processes. Sludge, as the largest in volume by-product, still consists of valuable nutrients and has a significant calorific value, its treatment and disposal methods are of significant concern. Once it has been realized that sewage sludge components can be recycled, it led to the idea of making products from sewage sludge. Valuable products from sludge can be recycled as materials for the purpose of the land application or as secondary energy source [1]. This idea of the recycling of sewage sludge has initiated innovations in technologies and techniques. The new technologies aim at the effective and efficient treatment of sewage sludge ensuring its safe applications. Although there are many different new methods for sludge treatment, the common goal of all of them is a partial or complete bacterial cell rupture, i.e., disruption of the cell wall and the release of intercellular organic substances into the liquid phase to facilitate the biodegradation processes. One of these new methods is the disintegration by hydrodynamic cavitation, which has a positive effect on the degree and rate of anaerobic sludge digestion [2]. The secondary aerobic degradation can be enhanced too by a hydrodynamic treatment. To prove that a R&D project was generated with the title „Development of bio raw materials products range with a special regard to the local technology – research on the possibility of utilisation by technological optimization" (GINOP-2.2.1-15-2017-00069) with the consortium consisting of Transdanubian Regional Water Works LTD and the Institute of Raw Materials Preparation and Environmental Processing, University of Miskolc.

Hydrodynamic cavitation results in the formation of cavities filled with vapour – gas mixture inside the flowing liquid, due to rapid local pressure drop. This local pressure drop subsequently recovers causing cavities to collapse. There are two types of effects caused by the cavitation occurrence: mechanical and physicochemical. These two effects arise due to changes happening inside the cavitation bubble itself during the implosion. The physicochemical effects are represented in pressure and temperature increase, which accounts for a thermal shift. A second consequence is the chemical effect taking place due to the creation of ozone, hydroxyl radicals, and the initiation of a chain of chemical reactions. Hydrodynamic disintegration can activate the biological hydrolysis process and, therefore, significantly increase the biodegradation [3]. Although there are some studies on hydrodynamic cavitation effects on sewage sludge, more experiments with various operation scales should be conducted to understand and address scale-up issues.

Our research is going to tackle the experimental work on an industrial scale set-up to establish pathways for transferring the fundamental technique into practice. Our idea is to combine hydrodynamic treatment with the addition of solid seeds having adsorbing capacity from one hand, as well as cell rupturing ability from another. Fossil coal with high humic acid content was chosen as a potential seed material, it can contribute the value of the fertilising and energetic recycled products as well. Another seed material chosen was natural zeolite having adsorbing capacity but no calorific value.

MATERIALS AND METHODS

A hydrodynamic test rig had been developed. The experimental set-up applied consisted of an open storage tank with a volume of 1.86 m^3, centrifugal pump, cavitation chamber (slurry pump) and pipelines that have different cross-sections, which is used for connecting the storage tank with the cavitation chamber for the purpose of circulating the working fluid, a discharge valve and recirculation point. The working principle of the set-up is based on recirculating the fluid from the tank through the cavitation chamber, and re-feeding it back to the tank. After specific recirculation time, the content of the tank can be discharged through a discharge point. The scheme of the experimental set-up is presented in Fig. 1 and a photo is shown on Fig. 2.

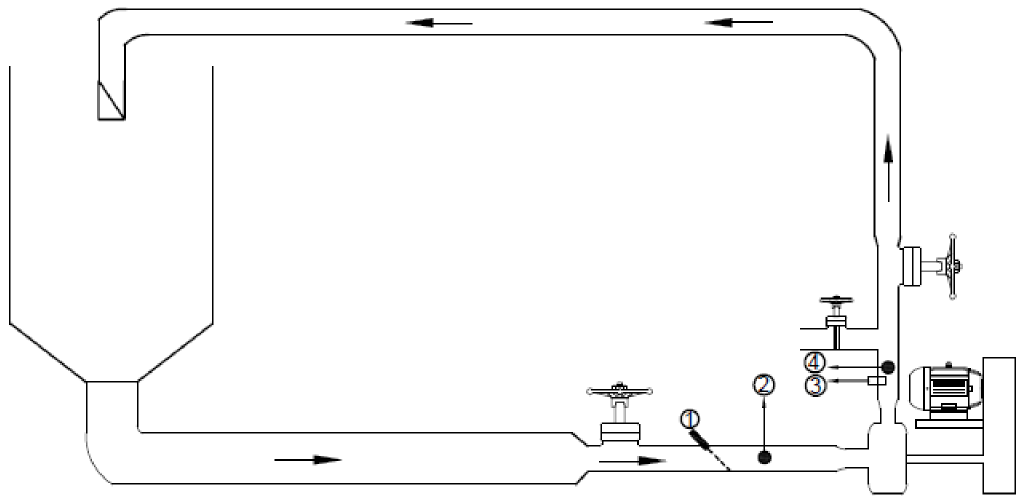

Fig.1: The scheme of the experimental set-up.

1- Tank. 2- Valves. 3- Transducers and their positioning. 4- Cavitation chamber. 5- Centrifugal pump. 6- Discharge point. 7- Recirculation pipe.

Fig. 2: Photo about the hydrodynamic experimental rig.

First fluid dynamics parameters were measured in the laboratory and the pump characteristic curve was determined [5, 6] as it is shown in Fig. 3.

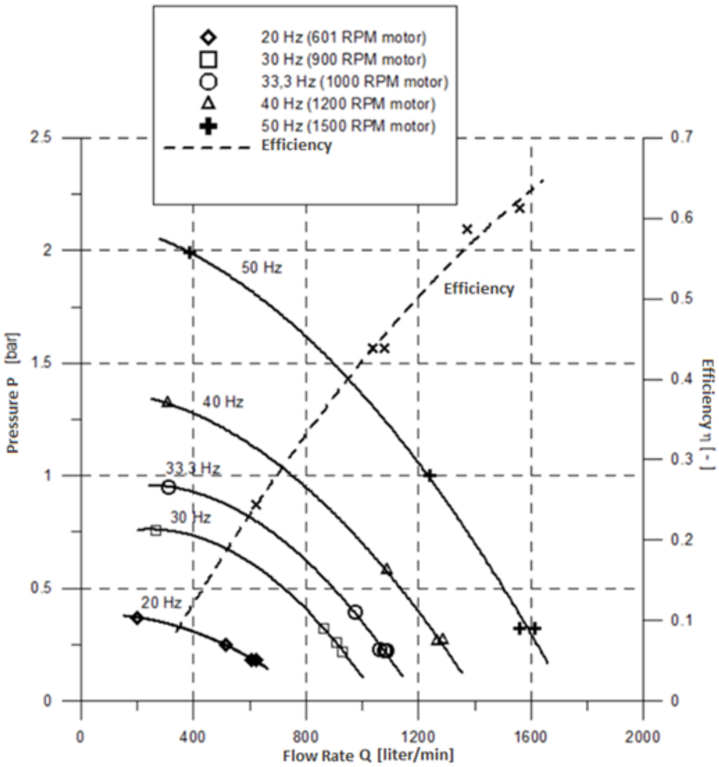

Fig. 3: Pump characteristic curve [4].

Several laboratory experimental runs were carried out with tap water and addition of fossil coal seeds. The promising results were obtained concerning the pH and dissolved oxygen concentration change.

After the preliminary laboratory work the test rig was transported and industrial experiments were carried out on the site of Waste Water Treatment Plant in Siófok. The real sewage sludge was used, several parameters like pH, dissolved oxygen concentration (DO), chemical oxygen demand (COD), biological oxygen demand (BOD) and total organic carbon (TOC) were measured at different dosages of seeds as additives, as well as the revolution number of pump.

RESULTS AND DISCUSSION

Fig. 4 shows the pH values at different revolution numbers after 30 min retention time of hydrodynamic treatment. It can be seen that at fossil coal used as seed additive the pH drop after the hydrodynamic treatment as compared with pH before that is much higher than in case of zeolite. The pH drop increases with the increasing dosage of fossil coal, but almost indifferent to the revolution number. The pH phenomenon is related to the cavitation, as well as adsorption on the seeds surface. The latter seems to be weaker in case of zeolite.

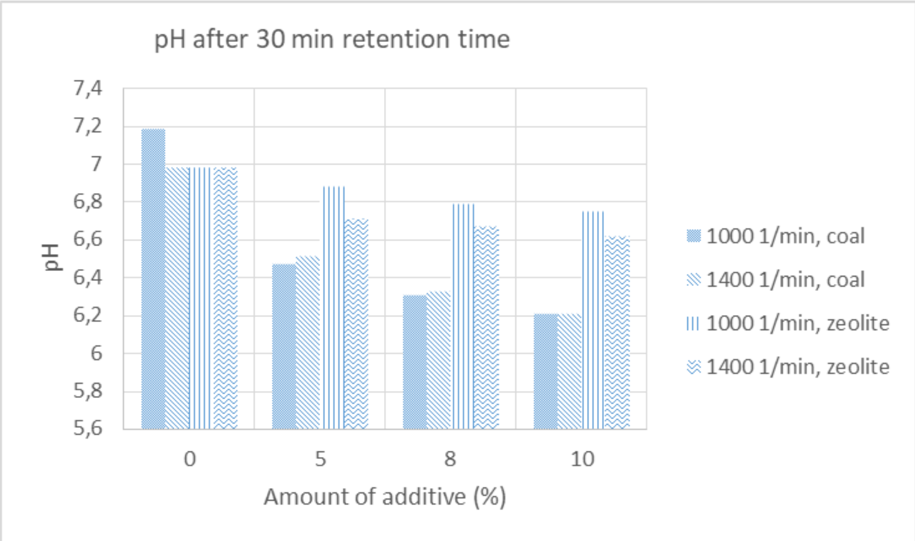

Fig.4: pH at different revolution numbers after 30 min retention time of hydrodynamic treatment.

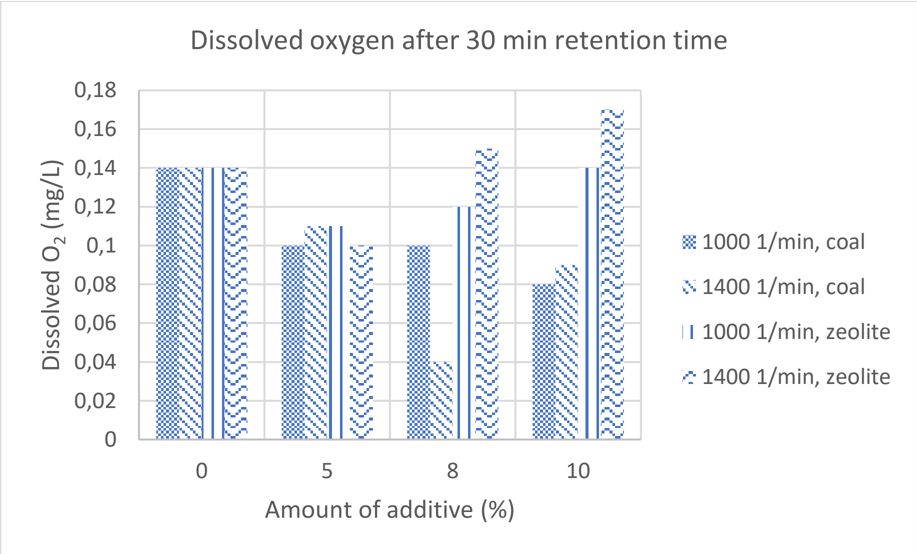

Fig. 5: The change in the dissolved oxygen concentration (DO) due to the hydrodynamic treatment and using additives at various dosages, after 30 min retention time at different revolution numbers.

The change in the dissolved oxygen concentration (DO) due to the hydrodynamic treatment and using additives at various dosages, after 30 min retention time at different revolution numbers is illustrated by Fig. 5. It can be seen that the DO in case of the fossil coal as seed decreases with its growing dosage and lower as compared with the case without additive. In the meantime the revolution number dependence is obliged by a minimum function. The minimum was found at 8% dosage and 1400 1/min revolution number.

Nevertheless, in case of zeolite the DO first decreases, then increases with the increasing dosage, finally above 8% and higher revolution number it becomes even higher than that without it.

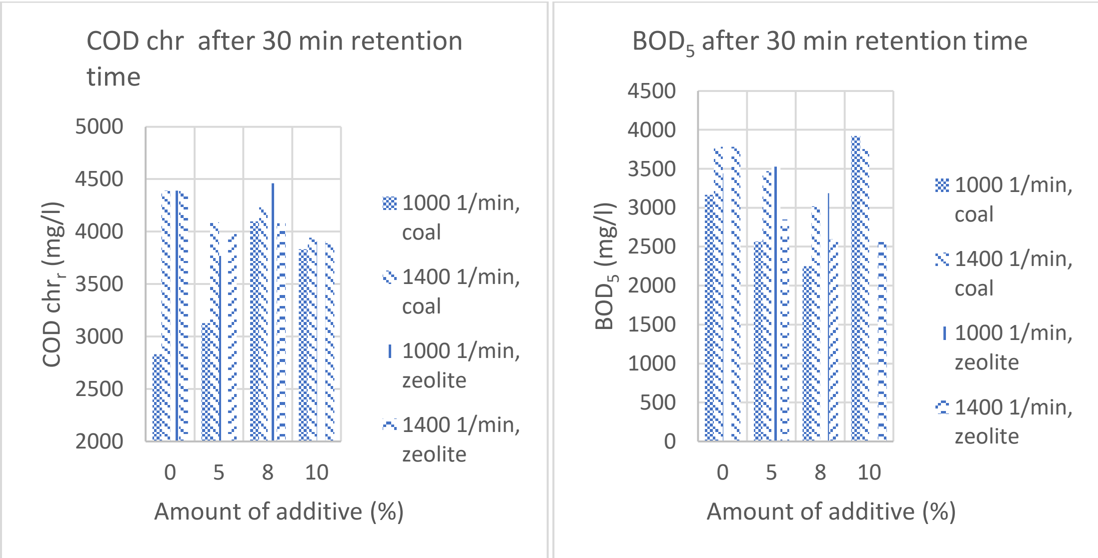

Fig.6: Change in chemical oxygen demand (COD, left side diagram) and biological oxygen demand (BOD, right side diagram)) due to the hydrodynamic treatment and using additives at various dosages, after 30 min retention time at different revolution numbers.

Fig. 6 shows the change in chemical oxygen demand (COD, left side diagram) and biological oxygen demand (BOD, right side diagram)) due to the hydrodynamic treatment and using additives at various dosages, after 30 min retention time at different revolution numbers. It can be easily seen that at 1000 1/min, and somehow less markedly, but still at 1400 1/min revolution number with the increasing dosage of fossil coal the COD increases, while the BOD decreases until 8% dosage, then the former decreases and the latter increases. It means that below 8% there is no significant cell rupture and the dissolution of colloid particles. Anyway, it is quite a job to reveal all the reasons of behaviour because in our system the cell rupture due to the cavitation is accompanied by the adsorption process making the whole system a very complex.

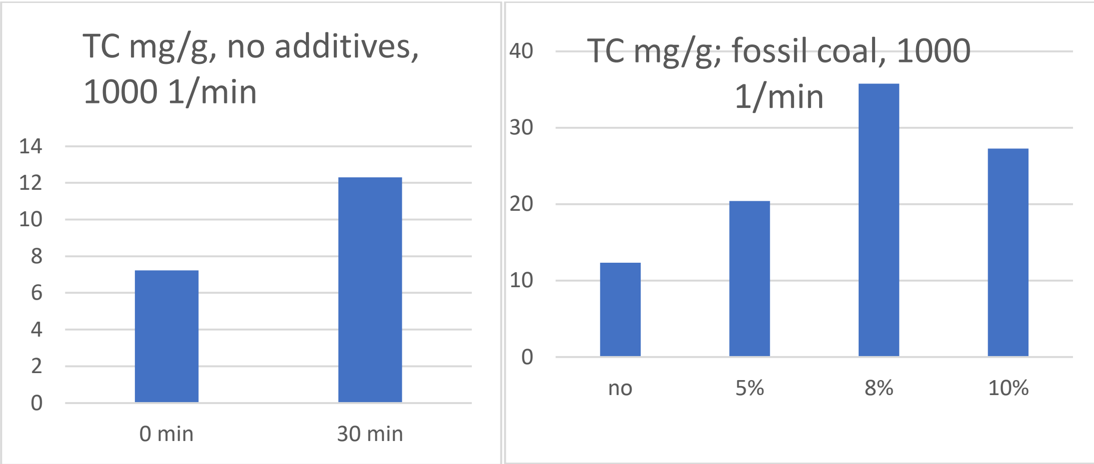

Fig.7: Total carbon without and with fossil coal seeds at 1000 1/min revolution number

Fig. 7 illustrates the total carbon specific value without and with the fossil coal seeds at 1000 1/min revolution number of pump. It is prominent that the value increases with the hydrodynamic treatment until 8% dosage, then decreases. It means that the rupture of the microbial cells definitely took place and there is an optimum of operational parameters.

CONCLUSIONS

Based upon the industrial experiments carried out at the WWTP in Siófok and results obtained by measuring several quality parameters on the real sewage sludge before and after the hydrodynamic treatment at various operational conditions the following conclusions were drawn.

- The proposed innovative hydrodynamic treatment combined with the adsorption on the surface of solid seeds like fossil coal and zeolite does work.
- The pH, DO, COD, BOD and TC change due to the cavitation combined with adsorption are in agreement and indicate the rupture of the microbial cells and the dissolution of colloidal particles in water, with their further fast aerobic degradation.
- The dependence of the above quality parameters with the operational parameters like revolution number and dosage of additives was also revealed.

ACKNOWLEDGEMENT

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