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Construction of an Automatic Flushing System for Retention Tanks, Including Rainwater Retention Tanks in Urban Stormwater Drainage Systems using Sluice Gate Devices

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Abstract

Application of an autonomous flushing system for retention tanks using sluice gate systems that enable automated release of the stored energy of the water column in the impoundment chamber to achieve highly effective flushing of sedimentary contaminants accumulated in the tank during operation. The system operates automatically through sluice gate arrangements equipped with pneumatic drives and liquid level sensors, allowing precise control of the process. Compared to traditional methods (tilting gates, ejectors, pumps), the proposed system is characterized by low energy consumption, approximately 0.05 kWh per flushing cycle, and a simple configuration consisting of channel sluice gates and their drives, which reduces the risk of failure and simplifies routine maintenance of the tank. Additionally, the proposed solution is cost-effective in operation, with readily available spare parts on the domestic market. The flushing system consisted of valves installed on the front wall of the water damming tank. The facilities, including the installation, were verified by conducting tests to determine the hydraulic and technological conditions (sediment leaching efficiency) during the tank flushing process.

1. INTRODUCTION

The discharge of rainwater through the sewer system, especially the so-called intensive (short-term) ones, causes its flow to be overloaded. Due to the limited possibilities of designing cross-sections of pipes for such incidental events, when they occur, the system is overloaded and flooding occurs (Edel 2009). Given the existing and ongoing climate change (Wibig 2000; Słyś 2008), such situations are on the rise, which makes the use of technical solutions to reduce the

occurrence of flooding as well as floods by lowering maximum rainfall flows even necessary. Therefore, a key solution in rainwater drainage systems, but also in combined sewer systems, is the need for technical solutions in the form of retention tanks for periodic collection and retention of rainwater. This allows for proper water management, reduction of flood risk (during intense rainfall), use of stored water for economic purposes (irrigation of green areas) and the indirect function of reducing water pollution (mechanical pretreatment from suspended solids) (Królikowska and Królikowski 2012) or their gradual discharge into the sewer system or directly into a receiver (e.g., a watercourse) (Kaca and Kubrak 2020).

2. TECHNOLOGICAL TESTS OF THE RETENTION TANK

Rainwater flowing into the reservoir contains highly variable values of suspended solids concentrations over time. Therefore, it becomes very difficult to establish a suspended solids (granular) composition that can be unambiguously taken as a reference composition and used in modeling studies. Knowledge on this subject is not systematized. Therefore, after analyzing the necessary literature study and available research (Królikowska 2011; Ociepa 2011), a suitable granulometric composition was adopted and a mixture called substrate in the description was prepared to mimic the sludge in the retention tank under test (see, Fig. 1). The prepared substrate mixture was spread over the length of the reservoir $L = 17$ m and the width from the wall to the installed supports in the tank $B = 2.91$ m. As a result, the total area (A = area of the assumed substrate deposit) was about 46 m^2 per tank track), where the substrate was spread to a height (thickness) of about $m = 0.015$ m. For each part of the tank (per tank track), 750 kg of substrate was used. For the flushing process (one test), there was 1500 kg of substrate in the entire tank. Next, experiments were performed for the adopted criteria, namely: the flushing process with three valves installed per tank track, without walls and with walls separating the tank tracks (Fig. 1), for two actual fills in the damming tank $T_{max} = 2.4$ m, $T_{min} = 1.5$ m, and with a fixed opening of the valves $a = 0.1$ m and opening $a = 0.2$ m. Technological studies from the flushing process shown in Fig. 2 (selected material illustrating the effect of the flushing process), which illustrates the stages of the test performed. Decomposed substrate with the valves closed and thus accumulated flushing water in the flushing chamber $T = 2.4$ m and the subsequent programmed raising of the gates $a = 0.2$ m and the moving flushing wave can be seen, as well as the completely washed out deposited substrate in the next shot (Fig. 2). On the basis of the experiments carried out at the site, the efficiency of removal of sediment-mimicking

Fig. 1. A reservoir with a system of installed sluice gates to flush the tank. Visible line of installed supports for wide tanks (without walls). On the right, installed walls separating the recipient track from the supports.

Fig. 2. Effectiveness of substrate leaching on the real model at the preset filling T = 2.4 m in the reservoir damming chamber and the assumed opening of the sluice gates a = 0.2 m. Sediment flushed out at 100%. View of one track without applied walls.

substrate in fixed amounts and over the adopted area was determined using a quantitative method (see Table 1). Comparing the amount lined on the bottom to the amount of substrate remaining after the leaching process, collected and measured.

Table 1

Results of the calculated leakage efficiency of the decomposed substrate on the bottom of the retention tank model (weight per test for two tracks is 1500 kg). Flushing wave efficiency

Lp.	Flow q [m^3/ms]	Water level in tank T [m]	Opening of the sluice gates a [m]	Determined parameters to determine the effect of the flushing wave	
				Substrate volume Ms [kg]	Flushing wave efficiency EF [%]
Without the use of walls					
1	0.79	2.4	0.2	**16.59**	**99**
2	0.41	2.4	0.1	**219.51**	**85**
3	0.62	1.5	0.2	**599.05**	**60**
4	0.32	1.5	0.1	**755.12**	**50**

3. SUMMARY

The obtained results of the leaching efficiency on the real facility summarized above in Table 1, evidently show that the increase in the damming vessel T (height of the water column) is very important and affects the effect of gravitational flushing (leaching) of the accumulated deposit (prepared substrate). The selected opening of the sluice gates $a = 0.2$ m at the analyzed water fill T in the damming tank also allowed to obtain the most favorable technological parameters during the process of flushing the tank. The conducted experiments showed that the use of three sluice gates is the right for the flushing process in the tank.

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