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Research article

Full-scale effects of addition of sludge from water treatment stations into processes of sewage treatment by conventional activated sludge

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ABSTRACT

An emerging practice for water treatment plant (WTP) sludge is its disposal in wastewater treatment plants (WWTP), an alternative that does not require the installation of sludge treatment facilities in the WTP. This practice can cause both positive and negative impacts in the WWTP processes since the WTP sludge does not have the same characteristics as domestic wastewater. This issue gives plenty of information in laboratory and pilot scales, but lacks data from full-scale studies. The main purpose of this paper is to study the impact of disposing sludge from the Rio Grande conventional WTP into the ABC WWTP, an activated sludge process facility. Both plants are located in São Paulo, Brazil, and are full-scale facilities. The WTP volumetric flow rate (4.5 m^3/s) is almost three times that of WWTP (1.6 m^3/s). The data used in this study came from monitoring the processes at both plants. The WWTP liquid phase treatment analysis included the variables BOD, COD, TSS, VSS, ammonia, total nitrogen, phosphorus and iron, measured at the inlet, primary effluent, mixed liquor, and effluent. For the WWTP solids treatment, the parameters tested were total and volatile solids. The performance of the WWTP process was analyzed with and without sludge addition: 'without sludge' in years 2005 and 2006 and 'with sludge' from January 2007 to March 2008. During the second period, the WTP sludge addition increased the WWTP removal efficiencies for solids (93%–96%), organic matter (92%–94% for BOD) and phosphorus (52%–88%), when compared to the period 'without sludge'. These improvements can be explained by higher feed concentrations combined to same or lower effluent concentrations in the 'with sludge' period. No critical negative impacts occurred in the sludge treatment facilities, since the treatment units absorbed the extra solids load from the WTP sludge.

1. Introduction

Water treatment for public supply generates certain waste because it is a process aimed at the separation and removal of impurities, such as suspended solids and algae. In the so-called conventional treatment process, the most common residues are those generated from the cleaning or discharges of the filters and decanters. Filters' washing produces the largest volume fraction of residues, the backwash water, which is commonly recirculated to the entrance of the plant and recovered in the treatment process. The decanters, on the other hand, are responsible for the largest mass fraction of waste produced, called sludge.

The volumetric flow rates of sludge and its concentration of suspended solids depend on various factors, such as the raw water quality, the purity of the chemicals injected, the type of salt used as coagulant, and the way the solids generated are removed from the decanter. Several equations can be used to predict the amount of sludge generated when using iron and aluminum salt coagulants (Cornwell, 1987; ASCE, 1996).

Sludge generated in water treatment plants (WTPs) and wastewater treatment plants (WWTPs) are considered solid waste, even though it contains more than 95% water by volume. Therefore, for technical and environmental reasons, such waste must be properly treated before being disposed of in the environment.

There are several ways of treating the sludge produced in a WTP. The most common process is conditioning, followed by thickening and dewatering. This process occurs by means of centrifuges, filter presses, and drying ponds, among others. Such treatment can happen inside or outside of the WTP facilities. The 'dry cake' produced is finally disposed, most commonly in landfills, which is becoming a non-sustainable practice. In addition, some WTPs do

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not have sludge treatment units yet and have no space or resources available for their installation, and even more sustainable destinations for the sludge, such as agriculture and construction materials (Babatunde and Zhao, 2007; Kyncl, 2008; Hidalgo et al., 2017), demands previous treatment.

An alternative practice, already in place, is the co-treatment of WTP sludge in wastewater treatment facilities (WWTP), added to the liquid stream of the WWTP and then mixed with the plant primary and secondary sludges. Therefore, all solids are finally treated in the structures commonly existing in WWTP. Thus, the concentrated treatment in only one plant ensures cost savings (Walsh et al., 2008; Ferreira Filho et al., 2013).

In order to provide technical evidence for this practice, many researches have been evaluating the effects of adding the WTP sludge on WWTPs, in the most diverse process configurations for both plants, applying the most diverse types of flow combinations. In summary, what is observed in a WWTP after the addition of WTP sludge is (Asada et al., 2010; ASCE, 1996; AWWA, 1999; Babatunde and Zhao, 2007; Babatunde et al., 2009; Cornwell, 1987, Ferreira Filho et al., 2013, Georgantas and Grigoropoulou, 2005; Guan et al., 2005; Zhao et al., 2008):

- Greater removal of organic matter and phosphorus in the primary clarifiers. The removal of both organics and phosphorous is through sedimentation by sweeping and adsorption to the flocs formed during flocculation.
- Decrease in the value of volatile suspended solids/total suspended solids (VSS/TSS) ratio in the WWTP influent, since WTP sludge is primarily inorganic (fixed solids);
- Non-significant changes in nitrification processes;
- Occurrence of microbial toxicity by the presence of metals in the WTP sludge. This toxicity could make biological processes unfeasible, especially anaerobic digestion and the use of WWTP sludge in agriculture;
- Larger volumetric sludge generation in primary clarifiers. The sludge has therefore a lower concentration of solids, affecting the solid phase treatment facilities and the sludge recirculation/return lines. Because of this, there is a greater need to increase the density and the amount of sludge for dewatering. Sludge settling problems can also occur (increase in sludge volumetric index - SVI).

The most important observations from these studies is that adding WTP sludge in WWTPs does not cause significant negative impacts on the wastewater treatment process, regardless of the process design or the operational changes that may occur in the WWTPs. Moreover, existing studies are mainly bench-scale or pilot-scale and focused on certain units of the treatment process, mostly only on the liquid phase treatment. Few studies focus on the solid phase treatment. It is necessary, then, to understand the overall effect of adding WTP sludge to WWTPs in both phases of treatment (liquid and solid). In addition, it is key to understand the impacts in real full-scale processes, mainly in large facilities and in those with the most common process configurations: WTPs with complete conventional treatment and WWTPs with complete activated sludge treatment.

In this sense, the objective of this study was to evaluate the effects of adding the Rio Grande WTP sludge in the ABC WWTP, both being large plants, located in the Metropolitan Region of São Paulo (MRSP). This evaluation focused on analyzing the WWTP primary and final effluents quality variables and the operational parameters of the various treatment process components. This study also aimed to confirm the real-scale impacts of WTP sludge addition on the removal of solids, organic matter (BOD and COD), and nutrients (nitrogen and phosphorus) throughout the treatment process and sludge production in the WWTP.

2. Materials and methods

2.1. Rio Grande WTP

The WTP had an average feed volumetric flow of 4.50 m^3/s, which accounts for about 6.5% of the production of treated water in the MRSP. The raw water comes from a reservoir, which often faces algal blooming. The turbidity of the raw water was low throughout the year (2–5 NTU). The apparent color values were in the range of 15–90 C.U. The process configuration at the time of the study included flocculators, decanters with tubular modules, and conventional double-layer sand-anthracite filters. The WTP used ferric sulfate as coagulant and auxiliary polyelectrolyte, with average dosages of 17 mg/L and 0.06 mg/L, respectively.

2.2. ABC WWTP

The WWTP had a conventional activated sludge treatment process that contained both the liquid and solid phases. The process was designed to achieve a 90% removal efficiency for both the organic load and the suspended solids. The treatment of the liquid phase comprised the preliminary treatment (not analyzed in this study), and the primary and secondary conventional treatments. The solid phase was treated with gravity thickeners for the primary sludge, flotation thickeners for secondary/biological sludge, anaerobic digesters, chemical conditioning of the digested sludge (application of lime and ferric chloride), and the final mechanical dewatering using press filters.

The WWTP had an installed capacity of 3.0 m^3/s, but the actual volumetric flow at the time of the study was about 1.6 m^3/s. Therefore, in order to adequate operation to the actual flow, not all the units for each processes were in use (stand-by units), which means the WWTP did not operate with loose capacity.

The primary sedimentation occurred the most of time in 3 of the 4 existing prismatic tanks, with dimensions 75.0 m × 18.0 m x 3.5 m each (length x width x depth). The removal of the primary sludge occurred by a mechanized scraper and pumping to the gravity thickeners. The designed performance expects a 60% solids removal and a 30% BOD removal in the clarifiers.

The aimed performance of the gravity thickeners is to raise the primary sludge TS to about 4%–5% w/w, and then send the sludge to the anaerobic digesters. During the period of analysis, only one of the four existing 29 m diameter thickeners operated.

The conventional activated sludge process occurred in only one of the four existing aeration tanks, each with a useful volume of 17,595 m^3. Thus, sludge from a large WTP was added in a high-rate activated sludge system. The reactor operated under a complete mixing regime and aeration occurs through fine bubble diffusers with dissolved oxygen concentration in the range of 2.0–3.0 mg/L. The expected removal efficiencies in design for TSS and BOD are 75% and 85%, respectively. These values, along with the primary treatment efficiencies, result in an overall efficiency of 90% removal for both TSS and BOD.

The effluent from the aeration tank flows into four of the six existing circular 46 m diameter secondary clarifiers, with sludge removal by a rotating scrapper. A portion of the removed sludge returns to the aeration tanks, and the other portion discharges to the flotation thickener. The final liquid effluent was collected in peripheral channels.

The biological wasted sludge thickening occurs in one of the two 14 m diameter circular tanks installed. The thickening aimed TS is close to 3% after flotation assisted by air injection. The floated sludge is then scraped and sent to the digesters.