Chemical Engineering Journal 230 (2013) 195–201

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Bio-P release in the final clarifiers of a large WWTP with co-precipitation: Key factors and troubleshooting

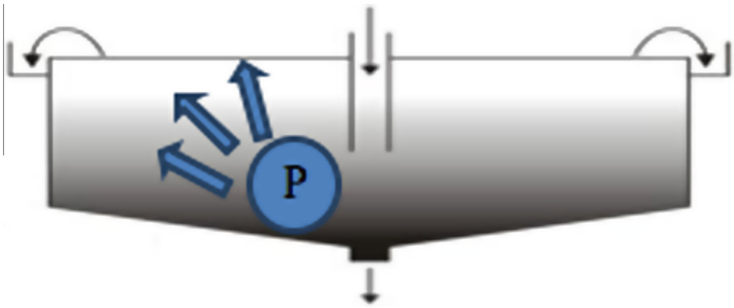
Giorgio Bertanza [a,*], Roberta Pedrazzani [b], Livia Manili [b], Laura Menoni [a]

[a] *Department of Civil Engineering, Architecture, Land, Environment and Mathematics, University of Brescia, via Branze 43, I-25123 Brescia, Italy*
[b] *Department of Mechanical and Industrial Engineering, University of Brescia, via Branze 38, I-25123 Brescia, Italy*

HIGHLIGHTS

- Failures in chemical phosphorus removal arise, occasionally, in some plants.
- P release occurs based on settlers SRT, aerobic tanks DO, final effluent N-NO_3^-.
- Unsuccessful control of these parameters can be corrected by post-precipitation.
- Experimental outcomes could provide valuable information for practical applications.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 February 2013
Received in revised form 12 June 2013
Accepted 16 June 2013
Available online 27 June 2013

Keywords:
Activated sludge
Aluminum polychloride
Aluminum sulfate
Phosphorus
Process
Sedimentation

ABSTRACT

Phosphorus removal by chemical precipitation is a well-established and widely used technique in municipal waste water treatment plants (WWTPs). Very low effluent concentrations can be achieved in order to comply with standards for discharge in sensitive areas, in force in the EU; nevertheless, failures of this system are occasionally recorded. In this work, a 330,000 people equivalent (p.e.) WWTP was studied, where co-precipitation was not effective to guarantee an effluent concentration stably below 1 mg P/L, despite the great expenditure for chemicals (around 260,000 €/y) and additional sludge disposal (around 160,000 €/y). Based on results of laboratory tests and mathematical simulations, it was shown that bio-P release occurs in final clarifiers under special conditions, related to Sludge Retention Time (SRT) in the settling tanks, Dissolved Oxygen (DO) in nitrification basins and nitrates concentration in the effluent. Therefore, complying with effluent standards should require keeping process conditions as follows: DO > 1 mg/L, $N{-}NO_3^- > 5$ mg/L and SRT < 3 h. As additional measure, a post-precipitation (required dosage: 4–5 mg Al/mg P) could be applied.

1. Introduction

The presence of phosphorus in wastewater treatment plants (WWTPs) effluents contributes to the eutrophication of receiving water bodies. For this reason, since the 1970s, it is recognized the widespread need to reduce the level of nutrients, namely phosphorus, entering surface waters [1–4]. Total P concentration of raw wastewater ranges, in general, from 4 to 14 mg/L, inorganic phosphates (ortho- and poly-) being the predominant components [5,6]. The EU Directive 91/271/ECC sets stringent requirements for total phosphorus discharge into sensitive areas: agglomerations of more than 100,000 p.e. must comply with a maximum allowable concentration of 1 mg/L [7].

Moreover, attention has been recently paid to the issue of recovery, since phosphorus is a depleting resource [3,8,9].

The most common phosphorus removal techniques for municipal and industrial wastewater are biological treatment and chemical precipitation [10]. The former (BPR: Biological Phosphorus Removal) is a cost-effective method based on the activity of

---

[*] Corresponding author. Tel.: +39 030 3711301.
E-mail address: giorgio.bertanza@ing.unibs.it (G. Bertanza).

1385-8947/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cej.2013.06.067

phosphorus accumulating bacteria (PAB), which uptake this nutrient in excess over their basic metabolic requirements and store it as polyphosphate. Chemical phosphorus removal is achieved by adding chemicals (the most suitable metal salts being aluminum [Al(III)], iron [Fe(II), Fe(III)] and calcium [Ca(II)]) to the wastewater (upstream the primary sedimentation • pre-precipitation •, directly into the activated sludge aeration tank • co-precipitation • or downstream the final clarifier • post-precipitation) in order to form insoluble salts consequently removed by sedimentation and/or filtration.

Alternative systems such as, for instance, struvite crystallization, polymeric ion exchangers and strongly adsorption filter [3,8,11–16] have been proposed so as to focus on P-recovery.

The achievement of very low effluent standards (0.5–1.0 mg P/L) via BPR process may be difficult, in case the removal efficiency has to be kept stably high, accordingly with the best-practice conditions [5]. Therefore, a complementary chemical precipitation might be required [1,2,17–19]: in fact, it remains the leading technology today, even though it implies additional costs for reagents purchase and sludge disposal [1,8,20]. Moreover, this technique fulfills P-recovery requirements, whenever the chemical/biological sludge meets the standards for re-use in agriculture.

Actually, failures have been encountered also in case of chemical precipitation: the excess of coagulants may alter the biological process [21–23]; the application of high [Fe(III)] doses for an extended period causes a gradual accumulation of fixed solids in the activated sludge, which finally favors the formation of dispersed flocs, thus deteriorating WWTP effluent quality [23,24]; moreover, competing reactions make it difficult to calculate the amount of additives necessary for chemical precipitation [24]; in turn, chemical precipitation requires pH correction of the sewage, in many cases, leading to cost increase [22,25].

Nevertheless, as far as scientific literature is concerned, experimental studies at full scale are rare, as well as technical hints for the operators.

The present study examines the performance of an activated sludge WWTP (330,000 p.e.) where co-precipitation was not effective to guarantee an effluent concentration stably below 1 mg/L, despite a great expenditure for chemicals (around 260,000 €/y) and additional sludge disposal (around 160,000 €/y). The research was conducted in order to understand the reasons of these troubles and to identify possible remedy strategies.

2. Materials and methods

Experimental work consisted of two phases: (1) in field activity, by means of a monitoring campaign; (2) laboratory tests and modeling, aimed at (a) estimating P release under anaerobic conditions, so as to repeat phenomena possibly occurring within final clarifiers, (b) simulating final clarifiers behavior for the estimation of Sludge Retention Time (SRT) as a function of WWTP operating conditions and (c) assessing the optimal conditions for achieving phosphorus post-precipitation.

2.1. The wastewater treatment plant

The studied WWTP is an activated-sludge plant (design size 330,000 p.e.), located in Northern Italy and treating domestic wastewater. The process scheme (Fig. 1) includes fine screen, grit chamber, pre-denitrification (volume = 8943 m^3, 6 parallel basins), oxidation–nitrification (volume = 21,473 m^3, 6 parallel basins), secondary settling (8 parallel basins with volume = 2200 m^3/each + 2 parallel basins with volume = 3907 m^3/each), final disinfection (volume = 1000 m^3, 5 parallel basins). Biological reactors are circular basins with internal baffles, so that a channel-type flow is obtained for the denitrification sections, while the nitrification zone consists of three in series tanks. Aluminum Polychloride (PAC) is dosed (6 mg Al/L) in the last tank of oxidation reactors to achieve phosphorus co-precipitation (the plant discharges in a sensitive area).

The sludge treatment line consists of: dynamic and gravity thickening/storage and mechanical dewatering. The process water resulting from different stages is recycled back to the plant inlet.

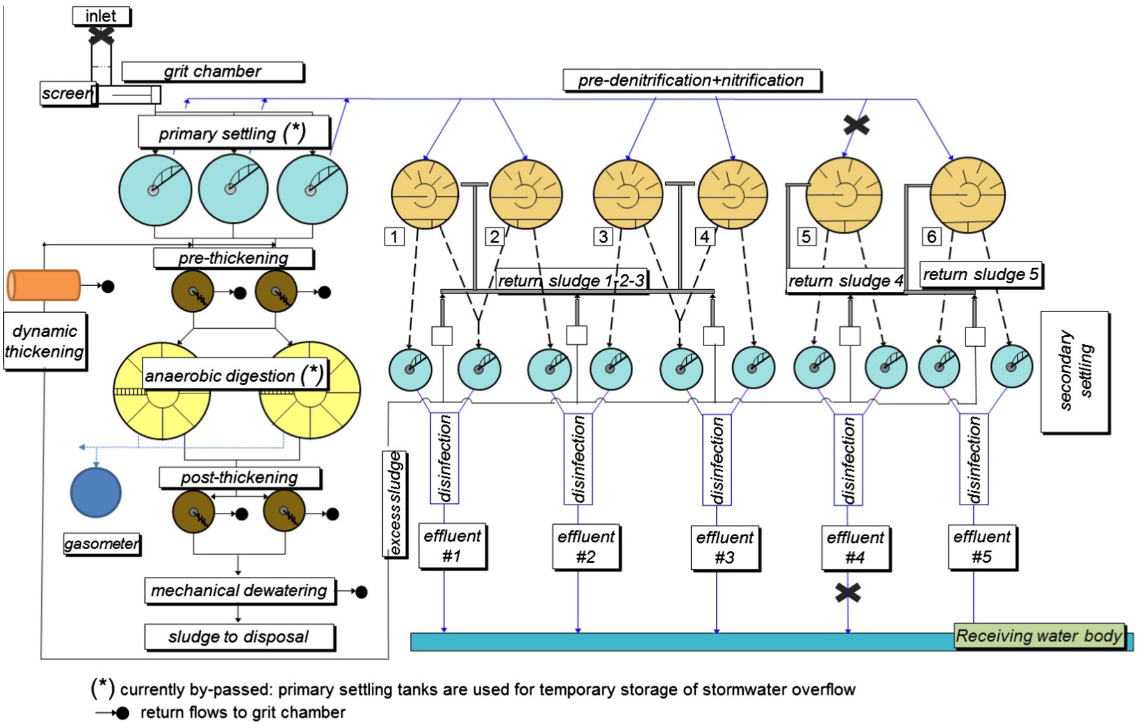


Fig. 1. Schematic flow diagram of the WWTP ("X" show the sampling points within the monitoring campaign).