Foams in Wastewater Treatment Plants

Subjects: Environmental Sciences

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The formation of persistent foams can be a critical problem in wastewater treatment plants (WWTPs) as it could lead to a series of operational problems, especially the reduction of the overall system performance. To date, the effects of foaming in the WWTPs are a problem that is currently very common and shared, but which to date is treated mainly only at the management level and still too little studied through a globally shared scientific method: the complexity of the phenomenon and the systems have led to numerous partially contradictory descriptions and hypotheses over the years. The goal must be to suggest future research directions and indicate promising strategies to prevent or control the formation of foams in WWTPs. This study examines and investigates the problem of foams by a methodological approach of research through a review on the state of the art: the factors influencing the formation of foams are described first (such as surfactants and/or extracellular polymeric substances (EPSs)), then the known methods for the evaluation of foaming, both direct and indirect, are presented, with the aim of identifying the correct and best (from the management point of view) control and/or prevention strategies to be applied in the future in WWTPs.

Keywords: foaming ; chemical and biological foams ; evaluation method ; foam test ; control method ; WWTP.

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1. Introduction

Chemical and biological foaming in conventional activated sludge (CAS) plants [1] has been under study since the 1960s [2], and, in general, in wastewater treatment plants (WWTPs) is an issue that adversely affects worldwide the aeration tank and/or the final clarifier [3][4][5][6][7][8][9][10][11]. Foams are a set of stable bubbles, produced when air or other gases are introduced below the surface of the liquid that expands to enclose the gas with a liquid film called “lamellae” of the foams [12][13]. A condition necessary for foaming is the presence of surface-active components or surfactants in the liquid [14] because these substances settle on the interfaces between the gas and liquid and reduce the surface tension [15]. Gas bubbles in the system are originated from aeration and mixing in oxidation tanks and from gas production in denitrification reactors, anaerobic digesters [16] and in nitrification/anammox reactors [17][18][19]. The formation of persistent foams may be a critical issue as it could lead to a series of operative problems including: (i) reduction in oxygen transfer, (ii) decrease in the concentration of biomass in the biological reactor, (iii) odor problems and (iv) increase of the management and maintenance costs [12][20][21]. The production of uncontrolled foams in large volumes causes a physical hazard for operators due to exposure to pathogens, obstruction of passageways and formation of slippery surfaces causing dangers of falling [20][21].

2. Foaming

In recent years, foaming has also been studied in membrane bioreactors (MBRs) [2][21][22][23]. Membrane processes, by replacing the gravitational sedimentation tank of a CAS process, allow retaining all solids, with a size greater than the porosity of ultrafiltration or microfiltration, inside the reactor. The main management problems that derive from this are (i) the fouling of the membranes and (ii) the formation of biological foams [24][25]. The recirculation of the mixed liquor at the head of the membrane bioreactor worsens these conditions and the tank in which the MBR unit is submerged may become a real trap for foams [5][21].

Foaming represents also one of the most common operating problems in anaerobic digesters (ADs) of WWTPs and the main critical aspect deriving (in addition to those previously described) is the reduction of digester performance, which results in a lower production of biogas and volatile solids degradation [26]. Other serious operational problems that can be encountered are (i) gas mixing blocks, (ii) fouling of the gas collection pipes, (iii) covering of the digester wall with solid foams, (iv) proliferation of pathogenic bacteria due to the reduction of the active volume in the digester, (v) maintenance interventions for cleaning biogas pipes and (vi) foam spills with the formation of slippery areas [26][27]. From the AD management point of view, the economic losses deriving from the phenomenon of foams are another important and not negligible aspect. The estimation of the costs is not easy to quantify because different parameters must be included in the count: the cleaning costs of the digester, the repair costs and the personnel costs for increased monitoring and maintenance are equally essential [28][29][30]. The aspect of worker safety must not be underestimated. For instance, very dangerous explosion phenomena have also been observed in some barns in the USA following the formation of stable and thick foams in ADs [28].

The formation of foams can also reduce the overall WWTP performance, therefore in order to optimize its management, causes, quantification and removal of foams must be investigated [12][20]. As already expressed in literature [31][32] for drinking water treatment plants, also for WWTPs the same approach of monitoring and optimization could be applied. This would guarantee to cope with the increasing presence of industrial contaminants in wastewaters [33][34][35] and would allow producing a sludge that respects strict limits for the reuse in agriculture [36][37].

This entry aims at examination and investigation of the problem of foams through the methodological approach of research to identify the correct control and/or prevention strategies in WWTPs; therefore suggested future outlooks on the basis of previous studies in this topic area are presented and discussed at the end of this work.

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