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Rheology – Key to Process Control in Conventional and Advanced Wastewater Treatment Plants

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Wastewater treatment processes have become an integral part of the world today subject to population increase, urbanization and consecutive pollution. Readers who are familiar with a typical wastewater treatment process, it contains a primary treatment step which is important to eliminate the inorganic and organic matter; secondary treatment step principally used for reduction of organic matter and tertiary treatment step as a polishing stage to finally render the treated effluent within the environmentally regulated limits along with sludge treatment and control processes. During the entire wastewater treatment process, sludge is produced at two different stages as primary and secondary sludge which further needs to be processed for ease of handling. These wastewater sludges have a defined hydrodynamic regime which sets the ground for their rheological or physical-chemical properties. Most of the literature until date has reported the sludge rheological behavior to be non-Newtonian subject to the fact that it does not change with the time. In fact, rheology can offer a valuable tool to characterize the hydrodynamic behavior of the sludge suspensions which can be ultimately used to optimize the treatment processes. Most important rheological property which is to be considered is viscosity which defines the resistance of the fluid to flow. Sludges are particularly difficult materials to characterize in a quantitative manner that is both based on fundamental data and useful for process management. Thus, it is possible to define for a given sludge, on one hand physico-chemical properties that can be theoretically measured (e.g. concentration or size distribution, particle shape and density, surface chemistry, particle electrokinetic properties or conductivity, colloidal stability, etc.), and on the other hand, the technical properties and attributes (e.g. foaming or sticking properties, settling or flotation ones, pumping properties, drying characteristics or dewater ability) which play an important role in the actual process control. This is due to the importance of the apparent viscosity of sludges on their behavior in different processes of both wastewater treatment (in particular on the hydrodynamic and transfers phenomena in aeration and settling tanks) and sewage sludge treatment (disposal, dewatering, physico-chemical conditioning, anaerobic digestion, etc.). The different rheological behaviors depicting shear thinning profile can be accountable for the inter-particle interactions in the bacterial flocs constituting microbial sludges.

The sludge behavior will not only dictate the design of the conventional steps in the wastewater treatment process, but also the advanced pre-treatment processes, such as oxidation processes used to enhance biodegradability and removal of toxic organic compounds, comprising endocrine disrupter compounds, pharmaceuticals and many more. In fact, sludge rheology will help monitor the dose of different chemicals or optimize process parameters and aid in complete degradation of these compounds. Furthermore, the sludge rheology will adjudge the partitioning behavior of the toxic organic compounds defining the space and volume occupied by them in the different wastewater treatment steps, helping choose the best treatment process. Likewise, wastewater sludge is not being subjected to more and more value-addition into different products comprising, aggregates, oils, composites, fertilizers, biological products, such as bioenergy, biopesticides, enzymes, bioflocculants, among others which again requires the utilization of rheology as a determinant tool. Each of the value-added products includes various steps to result in the final product so that rheology can serve an important purpose of determining the process parameter and design of the process, for example, in going from upstream to downstream processing steps in a typical sludge fermentation derived value-added product. It would be wise to say that wastewater sludge rheology has come a long way from being a conventional tool to control wastewater treatment process to also allowing choosing the best technology for removal of emerging contaminants and also the value-addition routes of wastewater sludge completing the sustainable loop.

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