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Understanding The Biological Process Control Problem - An Overview:

Primary and tertiary treatment processes are expensive, as they require significant investment in specialized capital equipment, infrastructure and real-estate. However they are rather simple compared to the biological processes on which successful secondary treatment depends.

To solve any problem it is best to understand it. But the Bioprocesses upon which the successful removal of ammonia, nitrates and other nutrients depend, is easily the most mysterious, as it goes on invisibly, performed by microbes, and is subject to many independent variables.

The key to controlling the biological process for optimal results at the lowest cost is to understand the metabolism of the essential microbes. The microbes must be able to convert all of the BOD, ammonia and other nutrients (load), in the time allowed by the rate of flow through the processing tanks. The speed at which they can do this is determined largely by the ratio of dissolved oxygen (DO) to load. As the microbes are carried along in the processing tank by the water stream consuming the load, they gain body mass. As they gain mass, they settle towards the bottom, where they can be recovered through a pipe system and pumped back to the beginning of the tank (recycled). Ideally, the microbes won't fully consume the load until the very end of the process stream. This is important for a few reasons to be more fully explained later.

Therefore the key variable that can be controlled to influence process performance, is the concentration of DO. This DO is supplied, typically through a forced air system. Although other means of aeration are sometimes used (surface agitation, etc), they all require the use of substantial electricity to power the motors. The cost of energy used for aeration is typically the most significant piece of the municipal energy bill (avg. 65%), and maybe the single largest line-item in the budget of some plants.

If the DO concentration is insufficient for the load, then the load will not be fully removed in the time it takes to pass through the tank. In this event, excess BOD, ammonia and other toxins will be discharged into the water resource. However, if the DO concentration is too high, the microbes will work faster, and complete removal will occur too early in the process stream. In this case the microbes will begin to "starve". Some of them will die, and the rest will become lethargic. Also, the starving microbes lose body mass, and don't settle (but will remain near the surface). If they don't settle, they can't be recycled, and will wash out of the system altogether.

So to summarize, too little DO for process conditions and the process will not finish, the and treatment goal (permit limit) will not be met. Too much pollution will be discharged. However, if the DO is too high, attrition will occur within the microbial ranks, fewer and less robust microbes will be returned to the front of the stream to digest the next batch or the continuing stream of load coming into the plant. Significant energy (to provide the unneeded DO) is wasted, and unless the situation is remedied, the process may never work as intended, in worst cases, failing to meet permit standards, but in all cases inefficiently. Ironically, lacking an understanding of microbial metabolism, the typical response to this problem is often to further exacerbate it by providing either more air or bigger tanks.

Because the incoming load to a typical wastewater plant varies in volume, type and concentration throughout the day (quite significantly), then the optimal concentration of DO to load also varies. With this understanding of the process, two distinct elements of the control problem, or questions, arise:

I. ***What is the optimal DO concentration for conditions - right now?***

II. ***How much air will it take to go from the current concentration, to the desired concentration?***

Neither one of these answers is easily obtained, and the difficulty lies in the essential characteristics of the process variables that determine the answers:

Characteristics of Biological Process Variables:

1) The microbes which are able to convert ammonia (nitrifiers), have a very slow reproduction rate when compared to typical microbes (several hours versus minutes). This speaks more to the importance of preserving a healthy microbial population, than the general problem of control, but it is an important characteristic to be aware of, as it exacerbates the problem of poor control.

2) Microbial metabolism (hence the load conversion rate), varies with DO / load ratio, nonlinearly, such that below a critical point it acts independently, above that point it has no additional effect.

3) Both microbial respiration, and the rate at which water can absorb oxygen, vary nonlinearly with temperature.

4) The rate at which water can absorb oxygen varies nonlinearly with the relationship to a saturation point.

5) The oxygen uptake rate (the total rate of oxygen consumption by all biological and chemical activity), varies with load volume, concentration and characteristics (relative mix), and temperature.

Conventional Control Approach:

The common, heretofore approach to trying to gain some control over this process by answering the two questions we asked earlier has been:

I. What is the optimal DO concentration? - The conventional approach does NOT answer the question. Rather the most common approach to this question has been to operate, or attempt to operate at a fixed DO concentration. This fixed concentration or "set-point", is generally set high enough to accommodate either an expected peak or a maximum load condition. As a practical matter, the targeted setpoint is rarely realized, for as we will see problem number II is not adequately dealt with either. But nevertheless, because the highest expected DO requirement is targeted, actual DO concentrations for most of the day (regardless of relationship to setpoint) tend to be higher than actually necessary. Because of this, significant energy is routinely wasted, and the process itself never works as well (in terms of pollutant removal) as it should, because the plant's biology is not as robust as it could be.

II. How Much Air Should Be Provided to Hit / Maintain the Desired Concentration? - Technically, even the most sophisticated of conventional approaches (PID) to this aspect of the control problem, doesn't answer this question either. But lacking the answer, such control systems simply react to measured deviations (DO too high or low relative to setpoint), by using a mathematical model, to send more or less air to the deviant process zones. It is a purely reactive, essentially "trial and error" approach, that in practice **continually chases, rarely hits, and never maintains** the desired setpoint. For a more detailed discussion of this issue, see our paper entitled: "Why PID is Poorly Suited to Wastewater Aeration Control".

The BioChem Approach to Biological Process Control

BioChem's approach to biological process control is to actually answer both critical questions: I. What should the DO concentration be (real time)? II. How much air is required to achieve it?

Through BioChem's biochemical expertise, algorithms have been developed, modeled and reduced to practical software, that can:

Optimize Process Operating Parameters:

For a measured ammonia concentration, calculate the optimal DO concentration in real-time. By employing this technology a treatment plant can adjust its DO target (use dynamic, as opposed to static set-point control) to the best appropriate for actual conditions. Not only can the DO setpoint be optimized, but several other controllable parameters in the process including recycle rates, chemical dozing and swing zone condition can also be optimized and automatically controlled.

Hit and Maintain DO Setpoint:

Whether using fixed or dynamic setpoint control, BioChem's aeration control system hits and maintains the DO setpoint regardless of incoming load conditions, while using the least possible energy. Our system (and only our system) can do this, because our patented technology uses the real-time oxygen uptake rate to calculate precisely how much air is required to maintain the desired DO concentration. It doesn't "hunt and peck" through a trial and error algorithm. It simply calculates the "answer" and delivers it.