Why PID Systems Are Poorly Suited to Wastewater Aeration Control:

Proportional Integral Derivative (PID) Control is a method of controlling a process variable to a desired value, or "set point", by employing linear algorithms, without a specific knowledge of the underlying processes. It is purely a reactive system, first developed in the 1920s to assist in steering ships. Using some measured value, such as compass heading, temperature, or in the case of waste water aeration, dissolved oxygen (DO), the system measures the deviation, (+/-) from the target value (setpoint) and calculates corrective actions. In the case of steering a ship (or a torpedo - its most significant nautical role) the rudder angle is adjusted. In the case of aeration control, first the valves regulating the airflow are adjusted (air is distributed by control zone), and secondarily the blower speed, to regulate the volume of air provided to the entire process. There are three inherent problems in applying this common method of control to waste water aeration:

1) Underlying Process Complexity - Nonlinear, Transient State Variables
The fewer process variables, and the simpler the relationships between them (linearity, steady state), the easier it is to achieve tight control. However the oxygen dependent processes which treat wastewater (BOD and nitrification) are very complicated, and nonlinear. The rate at which oxygen will dissolve into water, and the rate at which bacteria consume oxygen, both vary with existing load, and concentration, as well as other factors. Therefore, the corrective actions programmed into a PID control loop, are only valid within a relatively narrow range of operating conditions. In order to be useful as real conditions fluctuate beyond this effective range, the system must be retuned - meaning that a knowledgeable operator must change the degree, and timing of the programmed responses. These conditions, do not vary occasionally, but continually and significantly throughout a single day. Often constant tuning is required to obtain any beneficial result versus no control.

2) The System is Purely Reactive
The PID control logic only reacts to what has already happened, using residual DO concentrations. It does not "know" or account for the direction, up or down (relative to the target) in which the biological process is already moving the DO, or where it will be 10 minutes from now. Because of this, the response is typically slow, and often "obsolete" before its implementation.

3) An Element of Divergence Relative to Process Goals is Built In
Typically PID aeration control schemes are designed to run the air blowers at a constant pressure, within a (+/-) dead band. If the DO concentration in a given control zone drops below the setpoint, the system will adjust that zone's valve to increase its airflow. The blower will not immediately react, as system pressure does not change sufficiently to trigger a response; rather more air is diverted to the control zone that was adjusted. However, this will cause other zones to receive less air, as the total system volume of air has not changed. Eventually, as the other zones are starved for air, their valves will react. The blower will finally react when total system pressure drops out of the dead band. In the meantime the initial control action to correct the DO deficiency in one zone, has caused a DO deficiency in other zones. Thus the system lacks harmony as a "whole" in relation to the control target. It will not allow the conditions of one zone to be corrected, without forcing other zones to diverge from the target.

Summary
PID fails as an adequate solution to wastewater aeration control, because the wastewater environment does not meet the conditions of steady state linearity. There's too much going on, and it changes all the time.

The essential problem, in the simplest terms, is that a PID controlled system never actually "knows" how much air is needed where, and when. Rather it is always "guessing" and "chasing".

Consequences
The inability of PID control to overcome these inherent difficulties in trying to maintain a desired DO concentration, is usually manifest by wide oscillation of actual DO concentrations on either side of the targeted setpoint. The plant may operate at an "average" concentration near the setpoint, but is rarely, if ever actually at the setpoint. Significant energy is wasted as evidenced by frequent cyclical periods of overshooting the setpoint. Process effectiveness suffers as evidenced by frequent periods of undershooting the setpoint.

An additional consequence, is that very tightly tuned systems, trigger such frequent control responses (exacerbated by the conflict between control zones inherent in pressure based schemes), that valve and actuator life is severely retarded. In the worst cases the valves are virtually constantly adjusting. Process stability is never achieved while actuator life is intolerably short.

On the other hand, detuned systems (very wide deadbands), respond so slowly, that control goals are never met. However systems are sometimes deliberately detuned to extend equipment life.