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TECHNICAL

Issues On Biosensor Based BOD Instruments

For On-Line Application

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INTRODUCTION

Developments are needed to use a biosensor based respirometer for BOD monitoring in wastewater treatment plants. This discussion is a supplement to Iranpour et al. (1996, CLA Report), which reported tests on the Nissin Electric BOD-2000.

Issues addressed herein have so far not received much attention in the published literature. Many reports such as Karube, et al. (1977), Hale, et al. (1989), and Matsumoto, et al. (1993) address basic issues of biosensor technology, and others, such as Harita, et al. (1985) and Strand and Carson (1984) are pioneering studies that demonstrate the basic concept of measuring wastewater BOD by a relatively brief series of measurements.

The principal motivation for using fast BOD instruments to monitor wastewater quality is to provide a degree of process control not available now. As discussed in more detail in Iranpour et al. (1996, CLA Report), a process upset at a wastewater treatment plant, resulting from toxins or a BOD shock loading in the plant influent, imposes many costs on a plant, including both measures to overcome the upset, and sometimes regulatory agency fines. The present standard five-day BOD test is so slow that plant operators can not use it for warning of conditions that could cause a process upset. However, if the plant influent were monitored by a machine that gave results in a few minutes, then this would provide plenty of time for secondary treatment to be adjusted to respond to potentially upsetting influent. Thus, there are strong economic and ecological reasons forintegrating such instruments into plant operation.

The principal difficulties encountered during the study in Iranpour et al. (1996, CLA Report) were clogging of small tubes by slime accumulation and sewage solids, and malfunctions caused by summer heat in an uncooled enclosure. However, toxicity, salinity, and machine durability are also potential problems. The following sections address each of these concerns in turn.

CLOGGING

Several methods of dealing with the clogging problem have been identified: cleaning with NaOCl solution or other disinfectants, filtering, ultrasonic cleaning, and the use of fouling resistant tubes.

Disinfection alone is not a satisfactory strategy for an instrument like the present BOD-2000. The rinse solution includes a low concentration of NaOCl, but this was insufficient to prevent frequent clogging, so the tubes had to be replaced frequently during the field test in Iranpour et al. (1996, CLA Report).

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Filtering the samples during the laboratory test phase of the study produced much more satisfactory results. Much less maintenance was needed. It therefore appears that additional work to determine an optimal combination of filtering and disinfection could lead to a self-disinfection instrument that would be resistant to clogging by wastewater. Such a unit might be different from current biosensor respirometers, since most disinfectants tend to kill the microorganisms in the biomembrane. The pipes and valves would have to be arranged to prevent the disinfectant from contacting the biomembrane.

An approach different from chemical disinfection would be to apply ultrasonic energy to the input stream. This has not been tried, but the ultrasonic waves might be used either for cleaning the input tubes or for killing the incoming bacteria to prevent slime buildup. Evidently, ultrasonic disinfection would not harm the biosensor if done at a sufficient distance, and would leave intact the dissolved nutrients that constitute soluble BOD. If possible, it would be desirable to substitute ultrasonic energy for both filtering and chemical disinfection, but additional lab work would be needed to determine if this can be done.

Copper piping is sufficiently toxic to bacteria that come in contact with it that is much more resistant to fouling than the plastic tubing used in the BOD-2000 and similar instruments. Building some or all of the intake system out of copper tubing might be the simplest anticlogging

measure if it were effective. If it were not sufficient by itself, it evidently could be combined with one or more of the previously mentioned methods. In short, so many ways of dealing with clogging are available that the principal question is to determine which is the most effective or least costly.

TEMPERATURE CONTROL

By contrast, since current biosensors operate with microorganisms that have relatively narrow temperature ranges at which optimum metabolic activity occurs, there is no prospect in the foreseeable future of increasing the temperature at which these instruments can be used. Thus, for field use in an area subject to strong sunlight in summer, such as Southern California, there is no substitute for maintaining controlled temperature.

Obviously, this can be done by using an air-conditioned shelter. For a device that has a large cabinet, such as the BOD-2200, which is the field model of the BOD-2000, it may be possible to incorporate cooling equipment into the cabinet. This could be either a conventional heat pump or any other device, such as the thermoelectric cooler that is the main component of the air drier offered by Columbus Instruments (Bio-Respiration News, 1994). Thermoelectric cooling would be mechanically simpler than a heat pump, and perhaps also more compact and durable, but would be less efficient electrically, so choosing a cooling method would depend on the relative importance of these constraints.

TOXINS

Toxins in wastewater are also a concern. Toxicity sufficient to cause sudden change in biosensor response would be detected during the calibration phase of each measurement cycle. A modest change in the programming of the microprocessor that controls a BOD respirometer would allow the instrument to detect and report such event.

SALINITY

Testing for the sensitivity of response to salinity changes is another prerequisite for operational use in a wastewater system such as that in Los Angeles. Relatively large fluctuations in salinity have been detected in Los Angeles wastewater over the past several years with the variation of rainfall from drought to flood conditions. Although considerable attention has been paid to biosensor sensitivity to the other basic conditions of temperature and pH, sensitivity to salinity has not been adequately addressed. If tests show that sensor response is significantly affected by salinities found in the field, then this could be addressed by further instrument modifications. A conductivity detector could be added, and microprocessor programming could be further modified to take the conductivity detector's output into consideration in converting sensor output currents into BOD readings. Calibration may require additional standard solutions of varying known salinity, or it may be possible to use varying dilutions of the buffer to obtain the desired variations in salinity.

DURABILITY

The durability of the hydraulics of a respirometer is another point of concern for its field use. The BOD-2000 technology might need to be implemented in a unit with more durable pipes and valves and a more durable pump than the present models. Evidently, if copper pipe were used for its antifouling property, this would contribute greatly to durability.

RESPIROMETER TECHNOLOGY ALTERNATIVES

A number of repirometers are currently available. These instruments are being offered to meet the anticipated demand for fast BOD measurements for process control. As previously noted, this group's experience so far has been with the Nissin Electric BOD-2000. This biosensor instrument measures BOD by using a dissolved oxygen electrode to detect reduction of oxygen when a nutrient-laden aerated solution passes through a membrane impregnated withtrichosporon cutaneum yeast. The LANGE ARAS instrument is very similar, but uses issatchenkia orientalis and rhodococcus erythropolis in its biosensor. These microbes are claimed to be less of a health hazard to humans than the yeast in the Nissin instrument, so disposing of used membrane needs fewer safeguards. The Cosa instrument BIOX1010, by contrast measures the respiration of biologically active substances by detecting the pressure reduction in a tightly sealed chamber and relies on the respiration of organisms from the wastewater that grow on the inner surfaces of small plastic carriers of known surface area. The sewage is highly diluted for this instrument, so that nearly all the biomass is in the plastic carriers. All of these technologies are relatively new. By contrast, an older method of relatively fast BOD measurement for sewage treatment plants relies on activated sludge from the plant, and measures the difference between the respiration of the sludge alone and the respiration of a mixture of sludge in the sample. This approach is used in the Anatel BioMonitor system. Columbus Instruments offers still another detection method, based on simultaneous measurements of oxygen uptake, using a special fuel cell as a detector, and carbon dioxide production, using an infrared spectrometer. An extensive effort would be needed to compare these instruments for the reliability of their results and their performance according to the criteria listed in this paper.

CONCLUSION

A number of issues arise when a BOD respirometer is used to monitor the influent to a wastewater treatment plant, but none of them appears difficult to resolve. The present discussion is based on experience with the Nissin Electric BOD-2000. These points should apply to other biosensor respirometers, such as the LANGE ARAS instrument. Some of these considerations apply to the other technologies, specially the problems of temperature control, durability and toxicity. Present economic and regulatory pressures imply a need for increased use of respirometry

in wastewater plant operation, so these issues of implementation are highly timely.

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