The Biological Approach To The Rotating Disc Process

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Presented at the First National Symposium on Rotating Biological Contactor Technology, February 4-6, 1980, at The Seven Springs Mountain Resort, Champion Pennsylvania

Introduction

Much of our (United States of America) current water and wastewater treatment technology has been imported from Europe. The Rotating Biological Surface (RBS) process was also conceived and thereafter commercialized in Europe. Professors Hartmann and Popel deserve the majority of the research credit for the process as we know it today. A short twenty-five years ago, in Stuttgart, West Germany, they were rotating discs and were most careful in observing and recording the several phenomena that had occurred throughout their test programs. In 1965, after ten years of intensive RBS process development work, Dr. Hartmann [1] cautioned against loading the first stage of an RBS process multistage system beyond about 20 pounds of BOD per 1000 square feet per day. This biological caveat, although followed throughout the common market, was cast aside by the RBS process practitioners in this country. This paper attempts to explain where we went wrong, and what we must now do in order to optimize RBS process applications.

Overcoming and thereafter modifying the existing gross misunderstandings of the RBS process will not be quick or easy. Wastewater treatment technology changes most slowly. Lag time between process design and actual plant operation is several years. It is hoped that the disclosures herein will assist in the diagnosis of RBS process problems and their cure. By applying the organic loading design principles enunciated by Hartmann, future RBS process problems ought to be minimized, if not eradicated.

Background

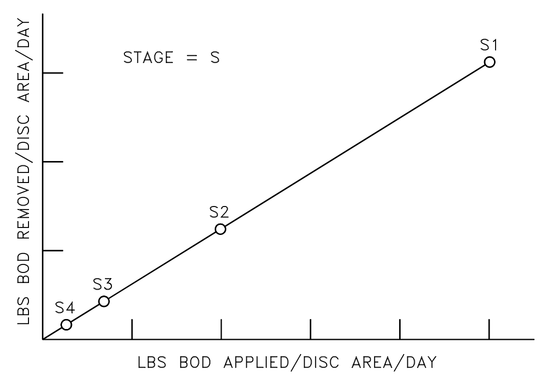
The first West German installations of the RBS process were on rather small sanitary waste applications. Disc plants were designed on the basis of number of inhabitants. Since treatment plant designers were well aware of the correlation between number of people and volume of liquid wastes, and while not unmindful of the 20 pounds per 1000 square feet maximum organic loading per day limitation, a "short hand" hydraulic design basis was developed which utilized GPM per square foot disc area per day. As combinations of sanitary/industrial wastes were gradually encountered, the hydraulic approach was modified to "population equivalents" so as to take into consideration the organic loading of the industrial waste contribution. As a result of this consistent observation of and respect for biology, RBS process failures in the common market over the last 20 years are virtually non-existent.

In this country, the RBS process was boldly and confidently applied frequently when biological treatment was possible. By relying upon the supplier sponsored pilot testing and thereafter adjusting the hydraulic design approach, RBS process designs were formulated on high strength industrial wastes and nitrification applications. However laudable the effort to expand the frontiers of this technology, to do so beyond the stopping range of a car's headlights. As a result, several RBS process crashes have occurred and more are imminent. We must now return to the realities of biology while discarding the convention of hydraulics in order to properly understand the RBS process.

Design Considerations

Some [2, 3] investigators have discussed the importance of organic loading vis-à-vis hydraulic turbulence, disc rpm, dissolved oxygen, oxygen mass transfer, and associated considerations. That organic loading is the single and exclusive basis for RBS process design was first disclosed by Steiner.[4] The hydraulic design approach has lost its credibility. Indeed, the express purpose of this Symposium is to discover the true bases upon which the RBS process is dependent, and, if thought advisable, to recommend additional RBS process testing.

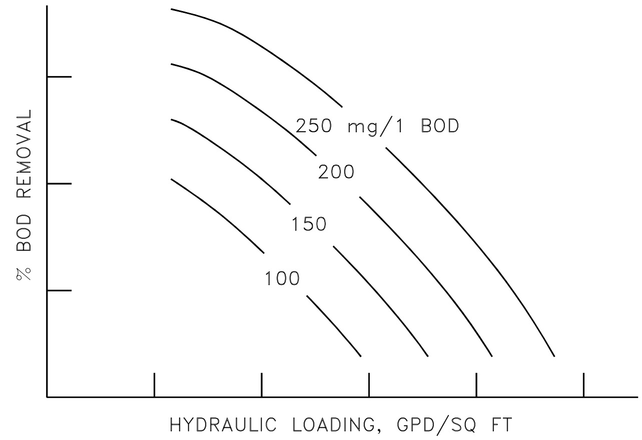
By plotting organic loading versus organic removal, a typical 4-stage (with equal surface area per stage) RBS process system would appear as shown in Figure 1.



Typical four-stage RBS process treatment curve.

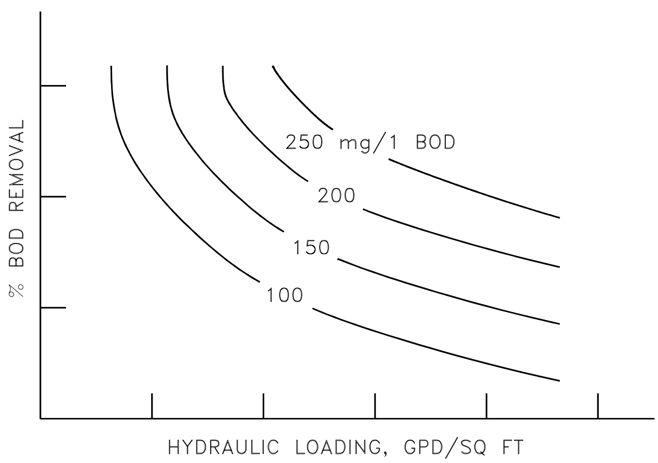
Figure 1

RBS process equipment suppliers, [5, 6, 7, 8, 9, 10, 11, 12] however, publish design curves of two types, namely those characterized by Figures 2 and 3.



Hydraulic loading versus percent BOD removal

Figure 2



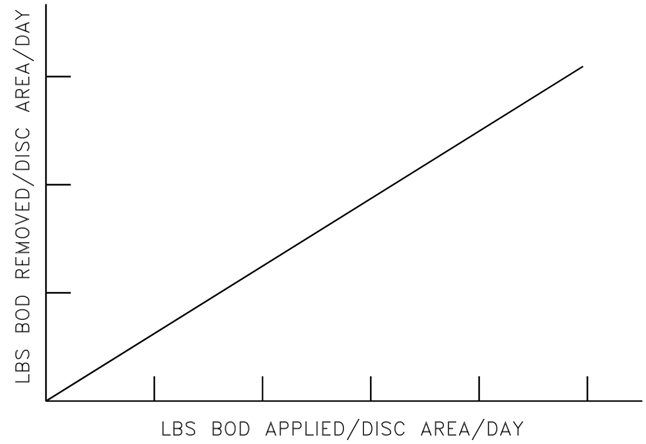
Hydraulic loading versus percent BOD remaining.

Figure 3

In calculating the mass organic loading versus BOD removal represented by either family of curves in Figures 2 and 3, we again obtain a curve identical to Figure 1! See Figure 4. In fact, the characteristic curve shown in Figure 4 is consistent with all RBS process data published worldwide to date. The conclusion, therefore, that it truly represents the RBS process becomes virtually inescapable. The extreme simplicity of the RBS process is based upon this curve and the fact that the slope and extension of the curve are its only variables.

The slope of the curve is exclusively influenced by the treatability of the waste. Both cooler temperatures and the presence of inhibitory toxins retard microbiological activity and the treatment curve lessens. However, a full 50% decline in treatability in a typical 4-stage system would result in only a theoretical 27.1% decline in effluent quality. [4]

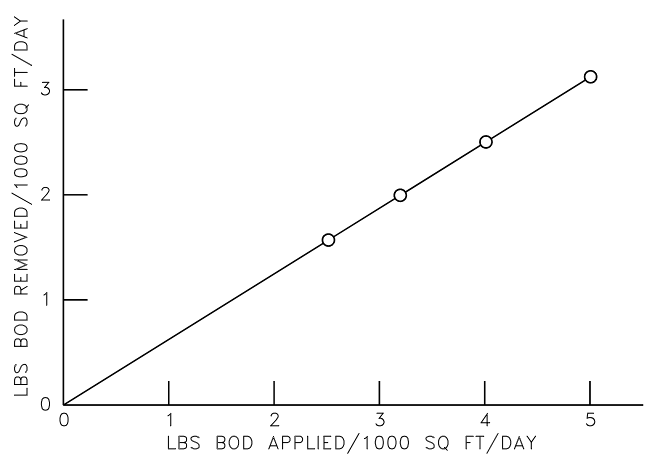
The extension of the curve is limited by either oxygen mass transfer into the liquid waste, or limiting microbiological activity, whichever first occurs. In BOD removal systems, disc rpm control the removals obtainable, while in nitrification applications, metabolic rates control.



Characteristic RBS process treatment curve obtained from RBS process equipment design manuals and trade literature.

Figure 4

The significance of this RBS process curve disclosure becomes evident as we again examine the treatment characterized in Figure 1. Lets attach some typical removal kinetics to the graph while progressively **reducing** the square feet of surface area by 1/2 per stage. That is, stage 2 now has 1/2 the disc surface area of stage 1, stage 3 has 1/2 of stage 2 or 1/4 of stage 1, and stage 4 has 1/2 of stage 3, or 1/8 of stage 1. The revised points in Figure 5 show the new loadings and removals (compared with Figure 1).



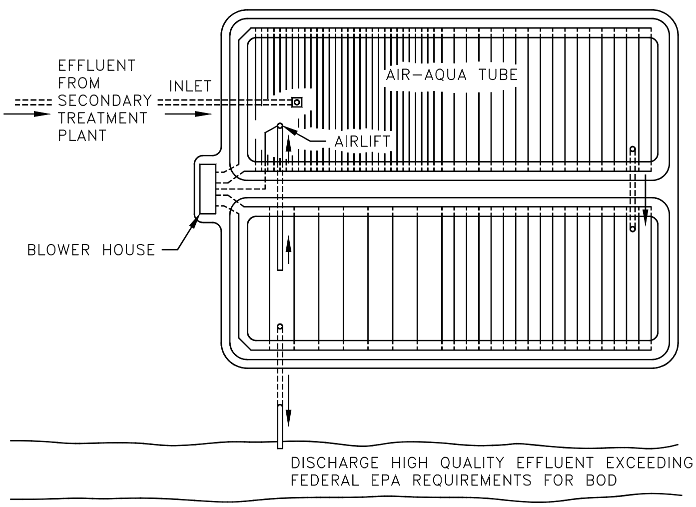
Typical RBS process treatment curve of 60% removal per stage.

Figure 5

In now adding up the mass removals per stage, we arrive at the **same** number of lbs. BOD removed as with the equal surface area per stage system represented in Figure 1. The Figure 5 system, however, uses less than 1/2 the disc surface area used in Figure 1 (and therefore installed and energy costs are also halved).

Discussion

From a microbiological purview, there is absolutely nothing profound with the RBS process. The literature, for example, is filled with similar references to the simultaneous increase in dissolved oxygen and the concurrent decrease in biological growth in each successive treatment stage. This phenomenon is nothing more than a restatement that aeration requirements decrease with each increase in treatment stage. With Hinde's [13] diffused air aeration system, their recommendation as shown in Figure 6 calls for successive **less** aeration as more treatment is achieved. Note the progressive decrease in aeration tubing concurrent with increase in treatment.



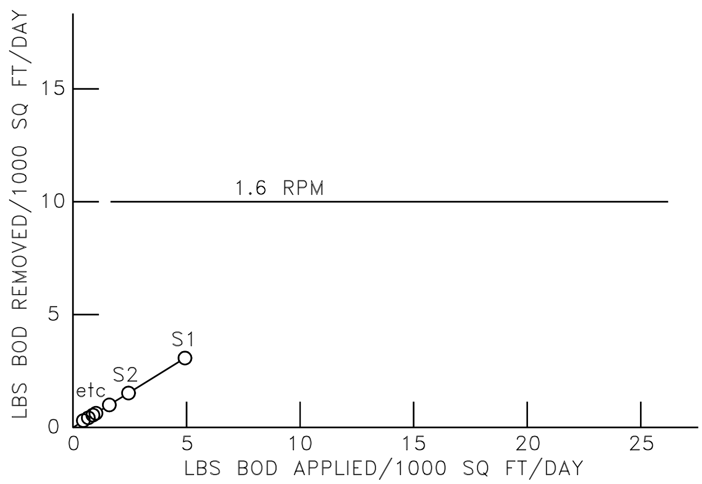
Typical layout of Air-Aqua tertiary treatment system.

Figure 6

The "10-States Standards" [14] recommend a minimum of 2 mg/L dissolved oxygen in the mixed liquor of activated sludge systems. It also recommends maximum aeration tank **organic** loadings for conventional, step, and complete mix aeration; contact stabilization; and extended aeration and oxidation ditch methods of treatment. Hydraulics seem to be completely lacking in the recognized design manuals for biological systems other than the RBS process. Absent therefore is the requirement for equal aeration in successive stages of RBS process treatment, which is represented by equal surface area per stage. And since the later stages of disc surfaces can physically support a biological population equal in density to stage 1, there remains no reason to have equal surface areas per successive treatment stage, since zoogloea slimes neither know nor care what particular stage of treatment they inhabit.

Field Problems

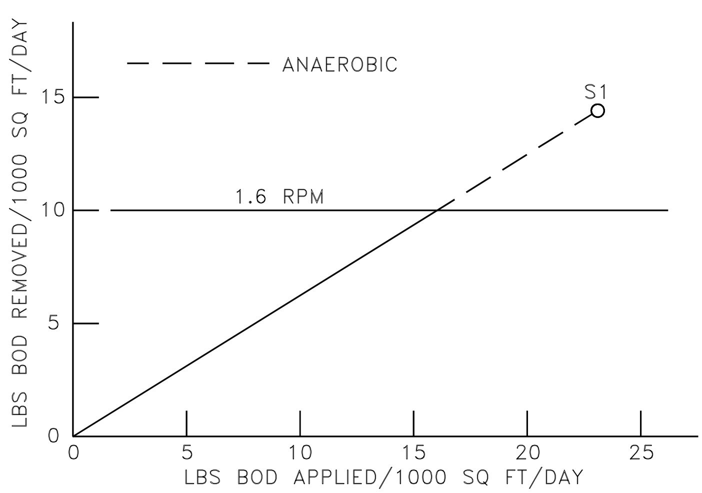
The Spencer, Iowa RBS process facility was designed for carbonaceous BOD removal followed by RBS process nitrification. It is a ten-stage system with 100,000 sq. ft of surface area in the first six stages and 150,000 sq. ft of surface area in the last four stages. Plant flow is equally divided into four flow streams through the RBS process facility. A local meat packing plant was to contribute about 75% of the organic loading with domestic wastes accounting for the balance. During the first year of RBS process plant operation, the meat packing plant was idle due to a strike. The then treatment curve is approximately represented as shown in Figure 7.



RBS process treatment curve for Spencer, Iowa without meat packing wastes.

Figure 7

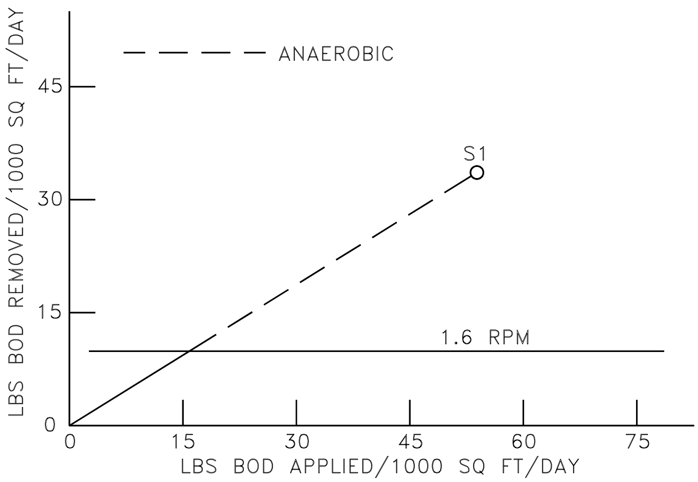
The packing plant was eventually purchased by Land O' Lakes and as their production capacity gradually increased to pre-strike levels, the RBS process treatment plant began going anaerobic. Treatment is now represented by the curve in Figure 8. Since the entire organic load is passed through stage 1, and because the mechanical aeration capability of stage 1 is fixed by its rpm (and therefore limited), the metabolic oxygen demand goes unsatisfied. As a result, the first stages have already gone anaerobic and its now merely a matter of time before the effluent quality deteriorates beyond design expectations, with concurrent violations of Iowa DEQ discharge regulations.



RBS process treatment curve for Spencer, Iowa with meat packing wastes.

Figure 8

Figure 9 represents the design curve for a waste which is extremely high (4,000 to 5,000 mg/L BOD) in organic strength. At the time of preparing this article, the Twin Cities Metropolitan plant had yet to start. Its failure is sure to occur when evaluated on the organic loading design principles.



RBS process treatment curve for filter cake pressate return liquor at Minneapolis/St. Paul Metropolitan Waste Control Facilities.

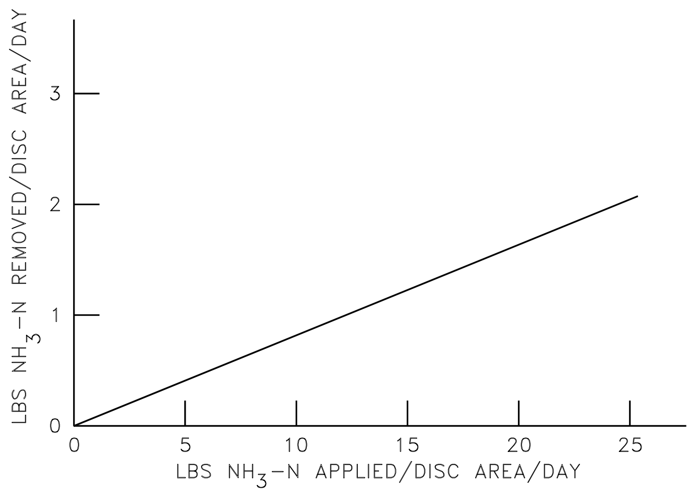
Figure 9

Generally, when carbonaceous BOD and Nitrification are designed for in the same flow stream using multiple stages, or when high strength organic wastes are subject to multistage treatment based on hydraulics, RBS process problems are likely to occur. Figures 8 and 9 represent dozens of existing like designs. Resulting RBS process failures should be attributable to the hydraulic design approach rather than the viability of the process itself.

Nitrification

The organic loading versus removal curve that represents the carbonaceous kinetics also represents the RBS Nitrification process. When one plots data on loadings versus removals, [15, 16, 17] a similar curve is produced, except that the slope is far less. See Figure 10.

It follows from the Figure 10 curve that high NH_3-N loadings/surface area coupled with multiple stages will each enhance removals while reducing RBS process equipment requirements.



Typical RBS process nitrification curve.

Figure 10

Conclusions

Since the RBS process is immune from the hydraulic considerations of residence time and hydraulic loading, it may be considered for the treatment of:

- Combined sewer overflows
- Inflows and infiltration

For full scale proof of this, the Spencer, Iowa plant is connected to a combined sewer system and has withstood scores of hydraulic surges during the last year and one half without impairing treatment.

Recommendations

The organic design approach will make the RBS process at least twice as attractive from installed costs and energy consumption considerations when viewed form current state-of-the-art. Comprehensive RBS process testing should be initiated to prove the organic loading approach respecting both carbonaceous and nitrification removals. ■

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