MY BNR PLANT-WHY CAN'T I MAKE IT WORK?

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ABSTRACT

Within Queensland, effluent discharge requirements from wastewater treatment plants are some of the most stringent in Australia. Typically, effluent quality requirements are 5 mg/L Total Nitrogen and less than 1 mg/L Total Phosphorus. To meet these limits, the Biological Nutrient Reduction (BNR) process incorporating biological nitrogen and phosphorus reduction is becoming the mandatory process for new and upgraded larger sewage treatment plants. A number of plants have demonstrated outstanding performance in their ability to reliably meet these limits. However, an equally large number of plants are unable to meet these limits and either fail to meet their discharge criteria or require extensive supplementary chemical dosing. Often, it is left to the plant operator to identify and rectify plant operation. Many factors can contribute to failure of the biological nitrogen and phosphorus reduction processes and a number of these are presented.

1.0 INTRODUCTION

The biological nutrient reduction (BNR) activated sludge process incorporating biological nitrogen and phosphorus reduction was first introduced into Australia in the late 1980's. The technology was challenged within Australia due to the high influent nitrogen loads experienced here as compared to other developed countries where the technology has been applied. Further understanding of the design and operation of these plants has resulted in the development of plants that demonstrate world leading performance of less than 5 mg/L Total Nitrogen (as low as 3 mg/L Total Nitrogen) and less than 0.5 mg/L Total Phosphorus. In parallel with these successes, there have been a number of plants that have failed to meet their performance targets. The reasons for these failures have been attributed to a number of factors which may or may not be proven. Possible factors contributing to plant failure are critically reviewed to provide assistance in identifying those actions that may potentially improve performance and reliability.

2.0 FACTORS ATTRIBUTED TO PLANT PERFORMANCE

To achieve effective biological phosphorus reduction in municipal activated sludge plants, it is essential to provide an anaerobic zone to receive the raw sewage. By definition, the anaerobic zone does not contain any nitrate nor dissolved oxygen. A small anoxic zone is often provided to remove nitrate from the return stream discharged to the anaerobic zone.

Thus it sould be relatively simple to achieve biological phosphorus and nitrogen reduction. Simply provide an anaerobic zone, a main anoxic zone, an aerobic zone and possibly a small anoxic zone to protect the anaerobic zone from nitrate. Various process configurations have been developed to satisfy these requirements including the 3 and 5 Stage Bardenpho configurations, the Johannesburg configuration, the Modified Johannesburg configuration, the Johannesburg II configuration, the UCT, Modified UCT, Variation on the Modified UCT and VIP processes to name a few.

However, despite the apparent simplicity of the process requirements and the range of process configurations available, many BNR plants including some recently constructed, fail to meet the required performance.

The possible factors contributing to the poor performance of BNR plants may be broadly categorised into three groups. The three groups comprise;

- Bad influent
- Bad design
- Bad operations

The validity or otherwise of these reasons for poor plant performance must be critically evaluated.

3.0 EVALUATION OF FACTORS ATTRIBUTED TO PLANT PERFORMANCE

3.1 Bad Influent

Many or most plants that fail to meet their performance criteria from the outset are claimed to suffer from bad, or more correctly "unsuitable influent characteristics". Attributing poor plant performance to unsuitable influent characteristics is usually exclusively the domain of design engineers with their vast knowledge and experience and operators should not infringe on the copyright of this excuse. Once the designer has pronounced the influent characteristics as unsuitable (based on visual inspection of the influent or possibly one or two analytical results), it is then acceptable for operations staff to present this scientific judgement to all and sundry. There is no need to persist with attempting to achieve good plant performance as it is just plain bad luck that millions of dollars were spent with the wrong residents in the wrong sewage catchment.

Now, back to reality. Unsuitable influent characteristics can occur however, this is usually due to intervention rather than resident selection. Intervention that can inhibit plant performance includes;

- Oxygen injection into mains for odour control (bacteria consume substrate)
- Nitrate dosing into mains for odour control (bacteria consume substrate)
- Chlorine (or hypo) dosing into mains for odour control (oxidises substrate)
- Some trade wastes (toxic, strong oxidising, strong reducing or high nitrate)

All of these actions consume or destroy the Readily Biodegradable Chemical Oxygen Demand (RBCOD) essential for biological phosphorus reduction. Thus if poor plant performance is attributed to "unsuitable influent characteristics" and one of the above activities is being carried out, the influent may, in fact, be unsuitable.

Thus, if additives are not being used for odour there is no reason why the influent should be unsuitable. With domestic sewage, there is no reason why the people in that catchment should be vastly different from those in every other catchment in Australia. The nitrogen loads may vary slightly between catchments however, the organic and phosphorus loads are relatively constant.

Claims of "unsuitable influent characteristics" being the reason for poor plant performance are therefore unacceptable to operations staff and this should be re-iterated to designers. If a designer can readily identify unsuitable influent characteristics after construction, they should also be able to do so before commencing design.

3.2 Bad Design

This is highly unlikely in any project. There has been an extensive evaluation process in selecting the designer with price usually the prime consideration. After such an in depth selection process, it is most improbable that the designer would make a mistake.
Reality check number two. There have been many fundamental mistakes made in the design of BNR plant within Australia and, unfortunately, some of these repeated. Many designs are carried out according to the "rules" and, as the rules <u>must</u> be right, the plant <u>should</u> work and therefore the design is correct.

A quick review of the "rules" is warranted to identify some pitfalls in design.
Rule 1: Rules aren't rules, they are guidelines.
Rule 2: The computer model is always right
-The model is based on theories about the microbiology
-The microbes are not given the computer outputs.
Rule 3. All naming of tanks is correct.
-If the designer labels a tank anaerobic, it is anaerobic.
-If the designer labels a tank anoxic, it is anoxic.
-If the designer labels a tank aerobic, it is aerobic.
-Bacteria cannot read.
Rule 4. If it works overseas, it works here.
-We have higher nitrogen loads per person than anywhere else in the world.

With the disestablishment of there rules, a number of other shortcomings (not mistakes mind you, simply shortcomings) in design can be identified. These are briefly reviewed.

The multipurpose, can do anything ultimate flexible design. This is where you need to do several things and decide to do them all in the one vessel. The idea is that you can create anaerobic conditions, anoxic conditions and aerobic conditions in any proportion plus carry out solids separation all in the one box and get rid of all the unnecessary other structures. This is like wanting to have a sports car for fun, a station wagon for the family and a one tonne tray truck for work and trying to achieve by this by designing a one tonne sports tray wagon; it does all things but none of them well. The lesson is "One job, one vessel and keep it simple".

Once it has been resolved that we do in fact need a secondary clarifier and a couple of tanks, the next issue is ensuring that tanks are dedicated to the one task. Many plants incorporate "swing" cells that can either be operated as anoxic tanks of aerobic tanks. Unfortunately, bacteria grow slowest at the minimum temperatures and this is when you need the largest aerobic zone <u>and</u> the largest anoxic zone. Having a swing cell will rob Peter to pay Paul. The designer should be able to determine the correct anoxic volume, the correct aerobic volume and the correct sludge age thus there should not be any need for swing cells.

Even more complex than having to determine how to you use a swing cell is how to use the "Alphabet" configuration. This is the process where a high degree of flexibility is provided to permit various recycles to be directed to various locations. Operation in a variety of configurations is then possible including UCT, MUCT, VIP, A2O, Johannesburg I, Johannesburg II and 5 Stage Bardenpho to mention a few. This level of flexibility is somewhat similar to the one tonne sports tray wagon; it does all process configurations but none of them well. One job, one process and keep it simple.

A further area where multiple tasks are undertaken, is in the selection of mechanical equipment. Oxidation ditch plants utilising mechanical surface aerators attempt to achieve aeration and recirculation with the one device. Again, in my opinion, a device should be an aeration or recirculation; not both. There is nothing wrong with using diffused air aeration and separate pumps for recirculation. The opportunity then exists to accurately control aeration and to separately accurately control recirculation.

The need for independent means to control aeration and recirculation then leads to the operational issue of dissolved oxygen carryover. Due to the high nitrogen loads experienced in Australian domestic sewage (se Rule 4), it is necessary to provide high internal recirculation rates of approximately 20 times ADWF between the aeration zone and the anoxic zone when targeting low effluent nitrogen concentrations of 5 mg/L Total Nitrogen with higher rates utilised when targeting 3 mg/L Total Nitrogen. An international design "Rule" used to be that there was no benefit in providing internal recirculation rates of greater than 8 times ADWF. Further research and development within Australia demonstrated that this "rule" was incorrect (see Rule 2) and that higher internal recirculation rates could be utilised with clear improvements in the effluent Total Nitrogen concentrations achieved. Such high internal recirculation rates will result in a large carryover of dissolved oxygen to the anoxic zone. This then makes part of the anoxic zone aerobic (see Rule 3) reducing its size for the growth of denitrifying bacteria and, in addition aerobically consumes some of the substrate required for denitrification. This design issue can be addressed by providing a "de-aeration" zone at the end of the aerobic zone. This has been successfully done at several plants. The aerobic volume is reduced somewhat, however, it has been demonstrated that, with appropriate aeration and sludge age control, relatively small aerobic volumes can be used with complete nitrification (effluent ammonia less than 0.1 mg/L) still being achieved.

Apart from the design of the main treatment process train, a number of other fundamental design errors occur that could have been simply avoided by applying common sense with a basic understanding of biological phosphorus reduction rather than detailed process knowledge. A key aspect in the overall plant design is the return of various side-streams to the main process. Such side streams include those from thickening and dewatering of waste activated sludge, tertiary filtration backwash and reject streams from membrane based advanced water reclamation plants can also be included in this group. All of these streams will contain some nitrate in varying concentrations and overall loads. Many designers will simply return all of these streams to the head of the plant as was typically done prior to the advent of biological phosphorus reduction. The return of these streams containing nitrate may result in the anaerobic zone becoming anoxic (see Rule 3).

As demonstrated here, the design engineer has a broad range of opportunities to achieve a bad, or at leat, sub-optimal design. Unfortunately, these opportunities to make errors in design are all too often taken up. Fortunately, one can always fall back on the time proven excuses of bad influent or bad operations.

3.3 Bad Operations

In a similar manner to the designer having bad influent as the tried and trusted reason for plant failure, operations staff also have some well established reasons for plant failure.

These include;

- No one told me
- No one showed me
- No one made it work in first place
- It is too hard.

Unfortunately, the reasons are all too often real. The provision of any plant should require demonstration that performance is achievable and adequate training of operations staff. A detailed and comprehensive operations and maintenance manual that is readily usable should also form part of any project delivery.

However, the key aspect here is the issue of "no one made it work in the first place". It is all too often left to the operator to make a plant work. If the designer can't make it work, why should the operator need to work it all out. Doesn't appear that logical or fair.

4.0 IDENTIFYING THE CAUSES OF POOR PLANT PERFORMANCE

Confronted with a poorly performing plant, what can be done to identify the potential causes for this poor performance? As outlined in this review, it is best to start at the front and identify if the influent characteristics are suitable. Measurements may have been made in an attempt to quantify the amount of short chain fatty acids or readily biodegradable COD in the influent. However, the collection and storage of samples plays a critical role here. An extensive review of the impacts of collection and storage of samples for RBCOD and SCFA testing was presented in 1989 at a BNR seminar in Ballarat in Victoria with the findings reported in the AWA Journal *Water*. The crux of the findings was that, unless the sample is analysed within two hours of collection, don't bother. Thus influent testing is, at best, indicative only of the characteristics of the wastewater and by no means definitive.

Once a full scale plant has been implemented, the microbiology of the mixed liquor can indicate a number of factors relating to the influent characteristics and operation of the plant. Microbiological slides are prepared and evaluated for the presence, numbers and appearance of phosphorus accumulating bacteria and glycogen accumulating bacteria. Based on the relative numbers, key aspects of the influent and plant operation can be reached. The following table demonstrates the basic principles of the interpretation.

"G" Bacteria	PAO's	Effluent Phosphorus	Interpretation
Not Present	Not present	High	Probable nitrate leakage to anaerobic tank. Anaerobic zone is not anaerobic.
Present	Not present	High	Influent contains sufficient RBCOD for improved Phosphorus removal. Anaerobic zone is anaerobic. Probable poor dissolved oxygen profile or control
Present	Present	High	Influent contains sufficient RBCOD for improved Phosphorus removal. Anaerobic zone is anaerobic. Possible secondary phosphorus release is occurring or poor dissolved oxygen profile or control
Present	Present	Low	Influent contains sufficient RBCOD for improved Phosphorus removal. Anaerobic zone is anaerobic. Possible secondary phosphorus release is occurring or poor dissolved oxygen profile or control
Present	Present	Very low	Operation fine

The last aspect is important. The "G" bacteria have been reported in the literature as being a "nuisance" organism that out competes the PAO's. However, it has been shown that very well operating plants (effluent phosphorus less than 0.3 mg/L) can have "G" bacteria present without any detriment to performance.

Poor dissolved oxygen control can also be identified by microbiological examination. Again, the slides or "smears" are prepared as described previously. This technique has successfully been used during commissioning of BNR plants.

In addition to using the microbiological techniques described, "redox" (oxidation reduction potential) probes can be used to assist in the detection of nitrate leakage. The bioreactor is "surveyed" using the probe as is the incoming sewage. The redox probe has been used to detect "pulsed" leakage of nitrate to the anaerobic zone and to detect undesirable characteristics in a return stream from solids handling.

Secondary phosphorus is a common plant problem and may occur due to process selection (the 5 Stage Bardenpho process is prone to secondary phosphorus release) or incorrect dissolved oxygen profile. Secondary phosphorus release can also occur in secondary clarifiers for a variety of reasons. These problems can usually be relatively easily rectified. Microbial studies in conjunction with phosphorus profiling of the bioreactor will assist in assessing if secondary release is occurring.

5.0 SUMMARY AND CONCLUSIONS

Identification of many design faults can be identified utilising simple techniques such as microbiological examination of the biomass and oxidation reduction potential profiling. Having identified the cause of the failure, possible options to rectify the shortcomings can be identified and developed. At one plant, application of these techniques resulted in effluent nitrogen being improved from 6 mg/L Total Nitrogen to 3 mg/L Total Nitrogen and effluent phosphorus being improved from 5 mg/L Total Phosphorus to 0.5 mg/L Total Phosphorus. And this was done without any capital expenditure or civil modifications.

BNR plants therefore can, and do, work in Australia. Those that don't work are unlikely to simply be "unfortunate" or "unlucky" with influent characteristics. More likely, fundamental errors have been made in design. Many of these errors can be readily identified and rectified using the techniques outlined. Then the designer can rightly return to claim the glory for the outstanding plant performance achieved!