VIP *Innovation* in Biological Nutrient Removal

WHAT IS THE VIP PROCESS?

The VIP process is a high-rate biological wastewater treatment process using activated sludge recycle. It is suitable for treatment of municipal and certain industrial wastewaters and consists of a suspended growth biological reactor, secondary clarifiers, return activated sludge (RAS) pumping, and mixed liquor recycle pumping facilities. The VIP process is a single-sludge biological nutrient removal (BNR) process that removes the nutrients phosphorus and nitrogen. It also meets conventional secondary treatment standards for chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), and total suspended solids (TSS).

WHY WAS THE VIP PROCESS DEVELOPED?

The VIP process was developed jointly by the Hampton Roads Sanitation District (the District) and CH2M HILL to upgrade the District's Lamberts Point Wastewater Treatment Plant from primary to secondary treatment. The plant is located in Norfolk, Virginia. Studies conducted during early stages of project planning indicated that the benefits of biological phosphorus and nitrogen removal could be achieved at essentially no added cost through the use of this newly developed process.

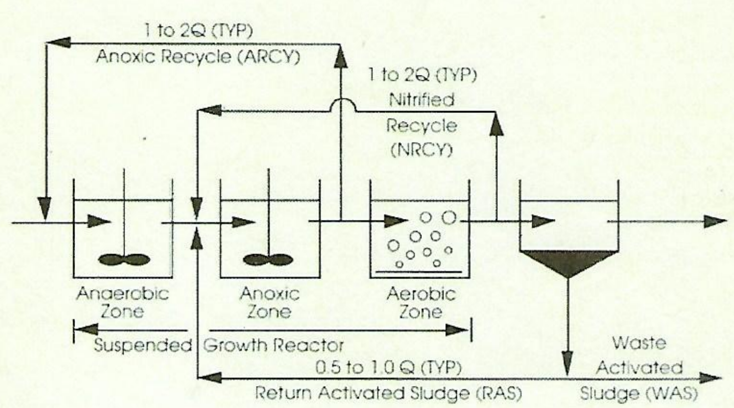
The term "VIP" stands for Virginia Initiative Plant. The upgraded Lamberts Point facility was renamed the Virginia Initiative Plant because it represents the initiative undertaken by the District to provide cost-effective nutrient removal as a contribution to the Chesapeake Bay Cleanup Initiative. The District's initiative was the first of its kind in the Commonwealth of Virginia.

HOW DOES THE VIP PROCESS WORK?

Phosphorus removal occurs because the process selects for, and enriches the population of, specialized bacteria capable of accumulating large quantities of phosphorus. This phosphorus is removed from the process in the waste activated sludge (WAS). All biological treatment systems remove some phosphorus because phosphorus is a necessary component of microbial cell biomass. However, enhanced removal through the VIP process results in three to seven times more phosphorus being accumulated in the WAS than would be accumulated through conventional biological treatment.

Nitrogen removal occurs through two biological reactions, nitrification and denitrification. Nitrification is an aerobic reaction (i.e., oxygen requiring) in which influent nitrogen is converted into nitrate. Denitrification is the conversion of nitrate-nitrogen into nitrogen gas. The inert nitrogen gas is released into the atmosphere.

A schematic of the VIP process is presented in Figure 1. The process consists of a suspended



Note: A staged reactor configuration is provided by using at least two complete mix cells in series for each zone of the biological reactor.

Figure 1
VIP Process Schematic

growth reactor divided into three zones: (1) the anaerobic zone, (2) the anoxic zone, and (3) the aerobic zone. The anaerobic and anoxic zones contain mixing equipment to keep the mixed liquor in suspension without transferring oxygen. The aerobic zone contains aeration equipment to suspend the mixed liquor and to transfer oxygen. Mixed liquor is recirculated between the various zones. The anoxic recycle (ARCY) transfers mixed liquor from the anoxic zone effluent to the anaerobic zone influent. The nitrified recycle (NRCY) transfers mixed liquor from the aerobic zone effluent to the anoxic zone influent. Conventional secondary clarification and RAS pumping are required, as with the activated sludge process. Typical flow rates for the various recycles are shown in Figure 1 as a fraction of the influent wastewater flow rate (Q).

WHAT OCCURS IN EACH OF THE ZONES?

Phosphorus removal occurs in the anaerobic zone. The term "anaerobic" refers to the absence of all oxygen sources, such as dissolved oxygen and nitrate. Anaerobic conditions are required to develop a population of the specialized bacteria necessary for phosphorus removal. Although the anaerobic zone is used to achieve biological phosphorus removal, the bacteria actually release phosphorus into solution when they are in this zone. Released phosphorus concentrations can range from 15 to 30 mg/l, compared to influent phosphorus concentrations of 6 to 10 mg/l.

Phosphorus release allows the phosphorus-removing bacteria to take up large quantities of organic matter. This organic matter is subsequently oxidized in the downstream aerobic zone (see Figure 1), allowing uptake of both the released phosphorus and a high percentage of the influent phosphorus. Selective uptake of organic matter in the anaerobic zone is the mechanism that allows the high population of phosphorus-removing bacteria to develop in the system.

Nitrogen removal occurs in the anoxic zone. The term "anoxic" refers to the absence of oxygen and the presence of nitrate-nitrogen. Nitrate-nitrogen is added to the anoxic zone by recirculating nitrate-containing mixed liquor from the aerobic zone (i.e., the NRCY flowstream shown in Figure 1). The recycled nitrate-nitrogen is reduced to nitrogen gas in the oxygen-free environment of the anoxic zone through denitrification.

Nitrification occurs in the aerobic zone in the presence of dissolved oxygen. Nitrification is a necessary component for nitrogen removal because it results in the conversion of the influent nitrogen into the nitrate form required for denitrification.

WHAT MAKES THE VIP PROCESS DIFFERENT?

The VIP process differs from other BNR processes in two important aspects: (1) the RAS recycle location and (2) the configuration of each reactor zone. RAS from the secondary clarifier is recycled to the anoxic zone. This is in contrast to other processes where it is recycled to the anaerobic zone (see Figure 2). Because RAS is added to the anoxic zone in the VIP process, a separate recycle stream is required to recirculate mixed liquor to the anaerobic zone. This added recycle stream is the ARCY shown in Figure 1. The

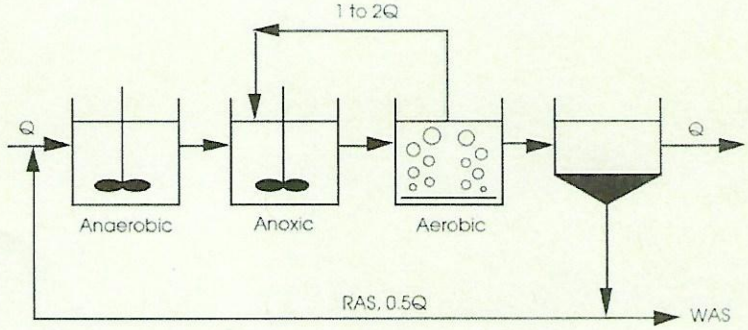


Figure 2
Alternate BNR Process Schematic

recycling of RAS to the anoxic zone is beneficial because it allows for complete removal of nitrate-nitrogen before mixed liquor is recycled to the anaerobic zone. The RAS will typically contain some nitrate-nitrogen. This nitrate interferes with biological phosphorus removal if added to the anaerobic zone, as is done in other processes (see Figure 2).

The second major difference is the configuration of each reactor zone. In the VIP process, each zone is divided into at least two completely mixed cells in series. This improves the process kinetics by increasing the plug-flow characteristics of the reactor. It also allows more complete development of the appropriate environmental conditions in each zone, thereby optimizing reaction rates.

An additional feature of the VIP process is that the aerobic zone must be sized to achieve reliable nitrification. Sizing is a function of influent waste strength and temperature, so basin size will vary with each application. However, optimum performance is obtained by sizing the basin to achieve just adequate nitrification—that is, by the use of the smallest basin possible. This will also result in the most economical system.

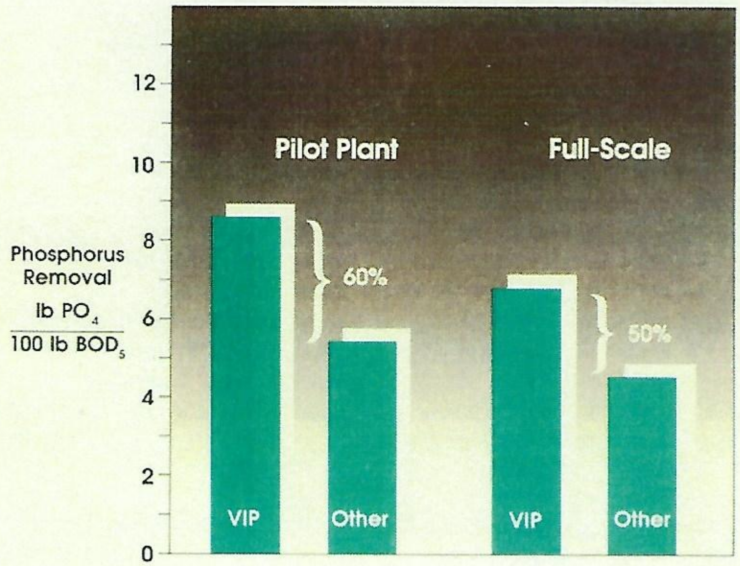


Figure 3
Phosphorus Removal Comparison

WHAT ARE THE ADVANTAGES OF THE VIP PROCESS?

The VIP process offers two major advantages over other comparable BNR processes: (1) higher reaction rates leading to smaller reactor volumes and (2) greater biological phosphorus-removal capability. For example, results from pilot- and full-scale studies demonstrate that biological phosphorus and nitrogen removal can be achieved with the VIP process operating at total hydraulic residence times of less than 4 hours during warm weather operation and at approximately 7 hours during cold weather operation. Phosphorus and nitrogen removal averaged 85 and 70 percent, respectively, during these periods. Cost analyses demonstrate that significant phosphorus and nitrogen removal can be achieved for essentially the same cost as for secondary treatment.

Phosphorus removal capability is greater in the VIP process because of the RAS recycle location, which limits the recycle of nitrate-nitrogen to the anaerobic zone. This results in maximum use of the influent organic matter for biological phosphorus removal. Figure 3 presents both pilot- and full-scale data demonstrating the increased phosphorus removal capability of the VIP process. As illustrated, the VIP process removes 50 to 60 percent more phosphorus than other comparable processes under both pilot-scale and full-scale operating conditions.

WHEN CAN THE VIP PROCESS BE USED?

The VIP process can typically be used when phosphorus removal is required along with either nitrification or total nitrogen removal. If nitrification is required, the nitrogen removal component of the system is necessary to "protect" the anaerobic zone from nitrate contained in the RAS recycle. The process is capable of producing an effluent with total nitrogen concentrations in the 5- to 12-mg/l range. A greater degree of nitrogen removal can be achieved by the addition of another anoxic zone.

HOW MUCH DOES THE VIP PROCESS COST?

The cost depends on nitrogen removal requirements. If nitrogen removal is required only when the wastewater is relatively warm (20 °C or higher), the cost will be about the same as that for conventional secondary treatment. Costs will increase somewhat if nitrogen removal must be accomplished during cold wastewater temperatures. Costs will be site-specific.

IS THE VIP PROCESS PROPRIETARY?

By obtaining a U.S. patent, the District and CH2M HILL have succeeded in differentiating the VIP process from other proprietary BNR technologies. They developed the process for the public domain and have waived licensing fees to encourage process innovation and use. The actions of the VIP process co-inventors have ensured the development and application of this cost-effective and much-needed technology in the widest possible municipal and industrial arenas.

CH2M HILL