

Point Source Nutrient Reduction Technology Innovation in the Chesapeake Bay Watershed

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The Chesapeake Bay watershed covers about 64,000 square miles and portions of six different states including most of Maryland large portions of Virginia, Pennsylvania and Delaware, as well as smaller portions of New York and West Virginia. The use of the land within this watershed is the predominate factor that defines the ultimate health of the Bay. While 60% of the land is covered with forests, 30 percent of the watershed is used by agriculture, and urban and suburban lands cover about 10 percent of the watershed. Based on projections of a steadily increasing population, the largest change in land use will be from forest and agriculture to urban and suburban. As a watershed becomes more developed, the amount of pollutants carried in the stormwater runoff increases, as does the amount of wastewater and solid waste requiring disposal. How to manage resulting increases in nutrient pollution is a central purpose of a multi-stakeholder effort to restore this valuable estuary known as the Chesapeake Bay Program.

On June 28, 2000 a landmark gathering of state, city and federal leaders culminated in the signing of an agreement which leaves no doubt as to the commitment by the Chesapeake Bay jurisdictions to do everything in their power to protect and restore the Chesapeake Bay and its living resources. This agreement, entitled the *Chesapeake Bay 2000 Agreement*, signed by the U.S. Environmental Protection Agency (EPA), the governors of Maryland, Virginia, Pennsylvania, the Mayor of the District of Columbia, and the Chair of a tri-state legislative body known as the Chesapeake Bay Commission, not only continues a long standing partnership initiated in 1983 with the first Chesapeake Bay Agreement, but delineates specific tasks that must be implemented by government, citizens and other stakeholders as they continue their restoration efforts. In particular, as is the case with past agreements, nutrient over enrichment is acknowledged as the principle ubiquitous problem facing this estuary because it continues to cause dangerously low ambient dissolved oxygen levels. An overabundance of nutrients, or nitrogen and phosphorus, can adversely impact underwater living resources by causing algae blooms which decrease light penetration, and upon their decomposition, consume ambient quantities of essential dissolved oxygen.

This 2000 Agreement calls for continuing efforts, earlier specified in the 1987 *Chesapeake Bay Agreement*, to reduce by 40% the amount of nutrients entering the Bay. This goal targeted a 40% reduction by the year 2000 of controllable nutrient loads from point and nonpoint sources in the entire 64,000 square mile Bay watershed from levels being discharged in 1985, and that once achieved, this level would be maintained thereafter. In addition to confirming the need to carry on the maintenance of the 40% reduction goal, the 2000 Agreement boldly commits the signatories to correct the nutrient related problems in the Chesapeake Bay and its tidal tributaries sufficiently to remove the Bay and the tidal portions of its tributaries from the list of impaired waters under the Clean Water Act by 2010.

Certainly the process of reducing nutrients in the Bay has been a longstanding one, and specific measures are and have been applied to reducing nutrients for many years. The 1992 *Amendments* to the 1987 *Chesapeake Bay Agreement* included a provision that would require all of the Bay signatory jurisdictions, MD, VA, PA, and the District of Columbia to develop tributary strategies to address what actions would be necessary to achieve the 40% reduction goal for both nitrogen and phosphorus, and how these reduced levels would be maintained. As part of the tributary strategy development process, reduction levels representing the 40% reduction goal, were determined, in terms of pounds per year, for the Bay watershed as a whole, and then for each major river basin. The remaining amount of nutrients allowed after the 40% reduction was applied is termed the load cap and is apportioned to each major tributary in the Bay watershed. The tributary strategies therefore focused on how to reduce their load to

meet and maintain these caps. Such documents have been developed for the river basins from the Potomac River north. These include a Tributary Strategy for all of MD in the Bay watershed, for the Potomac River in VA, for the Susquehanna and a small part of the Potomac in PA, and for the District of Columbia. Tributary Strategies for the lower river basins in Virginia including the York, the Rappahannock, and the James are in the process of being developed at this time. While each jurisdiction assimilated reduction measures tailored to the conditions relative to their areas, they generally address reduction efforts that must be employed collectively by point and nonpoint sources. Most of the reduction efforts include end of pipe treatment for point sources - particularly municipal wastewater treatment plants, as well as Best Management Practices that should be implemented at agricultural operations and urban areas.

As the year 2000 approached, the Bay Program established a Task Force of jurisdictional representatives to determine actions that could be taken to supplement the existing tributary strategies to help in holding the line on nutrient pollution. The Task Force authored a report which emphasized that maintaining a capped nutrient load will require total offsets in any increase in nutrient load associated with expansion or development in any sector^[1]. Additionally, the report pointed out that growth in load may be expected from increases in sewage flows and polluted runoff from new development. Growth in load from agriculture will be primarily from expansion and further intensification of animal agriculture.

Key recommendations coming out of this Task Force report included that each jurisdiction develop and begin implementation of a cap and goal management strategy by January 1, 2001. It was at this point that it was recognized that, faced with growth in population, agriculture and development, new innovative and creative measures would have to be sought out in order to meet the challenges this goal presented. Advanced end of pipe wastewater treatment, effluent trading, and more efficient and measurable BMPs are among the innovations being explored to meet future demands.

Also at about this same time, the need to develop Total Maximum Daily Loads (TMDLs) for all impaired water bodies became a principle environmental issue across the country. Once a water body is determined impaired, i.e. if it is not meeting its water quality standards, then TMDLs must be developed which specify the pollutant load that water body can accept without being impaired. While water quality standards have been developed for many water bodies for phosphorus, a dilemma arose with respect to nitrogen as water quality standards for this parameter do not exist. Thus, regulatory programs country-wide were unclear as to how to develop TMDLs for impaired water bodies due to over enrichment from an excess of nutrients. Partially in response to this dilemma, and also in response to the emerging problem of nutrient over enrichment across the country as well as the need for environmental protection on a watershed basis, EPA developed its Clean Water Action Plan in 1998. Among a host of nutrient management components, this Plan delineated plans for the development of water quality criteria for nutrients and specified that such criteria be developed by 2000, and that the states adopt and begin implementing these standards by 2003. Thus, efforts to rectify this situation were underway. Nutrient reduction in the Chesapeake Bay now became a multifaceted effort with programs underway and more being developed through the tributary strategy process, yet overlaid with potential regulatory programs emerging in the near future.

As of the year 2000, for those areas with tributary strategies, it is estimated that the Bay jurisdictions are within 4 million pounds of the Bay Program's collective 40% reduction goal for nitrogen. For phosphorus, the goal has been met and then some.

For point sources, baywide reductions by the year 2000 in total nitrogen have amounted to 35% since 1985. Interestingly enough, a large portion of this reduction has been due to industrial reductions through in-process changes and some end of pipe treatment. However, significant reductions have also been accomplished by municipal wastewater treatment plants, and through improvements in nutrient reduction technologies, we expect that amount to increase beyond earlier projections. As illustrated in Table 1, nutrient reduction technology has been implemented in 65 facilities in the Bay watershed, with plans to employ such technology in an additional 38 facilities in the next few years. In general, the effluent Total Nitrogen concentration target for these facilities employing BNR is 8 mg/l. However, it is encouraging to discover that the actual performance of the 65 facilities is often substantially lower than 8 mg/l. In fact, roughly half of the 65 facilities are operating at ranges from 2 mg/l—7 mg/l on an annual average basis, and many of these are in northern parts of the watershed.^[2] Granted, these reductions may

be due, in part, to under capacity operations, but the fact that such level are achievable and maintainable year round are inspiring.

General knowledge about BNR performance has traditionally been that BNR works better in warmer climates and engineers have been skeptical of its ability to maintain an annual average of 8 or below in the Bay. However, recent experience has shown that BNR's performance in this area can maintain such levels and even less. One of the greatest success stories involves the largest facility in the Bay watershed - the 370 MGD Blue Plains Wastewater Treatment Plant in Washington DC. This facility is currently operating BNR full scale and has so far experienced an effluent of 5 mg/l—6 mg/l TN and the operations manager there expects that they will be able to do better than that as they develop more experience with the system. Even in Stamford, CT, their 20 MGD facility there has been designed to meet 4 mg/l TN and has limits to that effect in their NPDES permit. And finally, nitrogen limits on all 8 of the major wastewater treatment plants in the Patuxent River, discharging from MD into the Chesapeake Bay, are for 3 mg/l TN due to this river's sensitive waters designation. Thus, while 8 mg/l will help in achieving the Bay's 40% nutrient reduction goal, and has taught us a lot about BNR's capability in this region, we know that BNR can do better should it be necessary to offset growth or meet tighter goals. Additionally, there remain many large facilities in the Chesapeake Bay where there are no plans for BNR as yet, and these represent great opportunities for achieving additional reductions.

The advantages of nutrient removal technology are becoming increasingly numerous, in addition to its potential to make significant contributions, even in relation to nonpoint sources, to overall reductions. As almost any recent study on nutrient removal will tell you, a significant savings in operation and maintenance costs can result in the implementation of nutrient removal technology. For facilities that are required to remove ammonia there are several reasons why going the step further for denitrification would save in operation and maintenance costs including:

- (1) Reduction in energy costs due to reduction in aeration energy requirements
- (2) Reduction of the need for chemical usage
- (3) Reduction in the amount of waste sludge produced.

A large operational expense for secondary plants is the energy required to operate the large blowers used for aeration. Because denitrification occurs under anoxic conditions, no aeration is required, yet the microorganisms continue to metabolize pollutants. In fact, a 20% reduction in energy costs have been shown at a full scale plant by the incorporation of an anoxic zone in the secondary treatment process, and that savings by as much as 30% are not unrealistic.⁹

BNR can save on the cost of chemical addition: nitrification effluent is acidic, and standard practice is to add significant and costly amounts of lime or caustic for pH adjustment (increase). Denitrification will promote this pH adjustment naturally without the need for chemicals. Estimates are that at least a 50% reduction in chemical costs could result. Also, by incorporating biological phosphorus removal into the nitrogen removal system, additional chemicals needed for phosphorus precipitation would be reduced. Additionally, because BNR can result in the production of less waste sludge, additional costs are clearly realized for sludge disposal. Estimates are that 5%—15% reductions in sludge volume can be realized for BNR. Finally, another important advantage of BNR is that it typically improves sludge settleability and control of filamentous microorganisms. This is because the anoxic denitrification zones act as biological selectors and discourage the growth of filamentous microorganisms.

Technological innovations related to BNR technology are developing rapidly to not only improve the performance of nutrient removal, but allow it to operate in colder climates, as well as to retrofit existing facilities. The Chesapeake Bay Program sponsored a grant by Virginia Tech to determine the cost and feasibility of retrofitting existing facilities across the Bay watershed for BNR.^[4] This study, which examined 50 facilities, determined that in many cases BNR could be applied to existing infrastructure for a capital expenditure of \$5 million or less, and that the savings that would result in O&M could often offset the capital expenses over time. Of course there are many situations where retrofit is either not practical or not cost effective and for these situations other technologies are being explored. The use of automatic biological monitors which monitor real time activity in wastewater treatment tanks is showing substantial promise in its application to BNR, especially in several PA facilities. Other technologies such as bioaugmentation, algal turf scrubbers, and even wetland treatment are also showing promising results in other states in the Bay watershed. Supplementation using methanol, and even other

carbon sources such as molasses, are being used to promote additional reductions for more efficient operations.

Industries are also discovering the nutrient reduction potential BNR and Pollution Prevention provides for their effluents. Several meat processing facilities in the Bay watershed are currently operating BNR and getting extremely good results, some in the range of 5 mg/l—6 mg/l Total Nitrogen in their effluents. Other industries including a tannery in western Maryland are piloting BNR, and some facilities are in the process of evaluating the use of BNR to remove Organic Nitrogen which is often the principle nitrogen component in industrial wastes.

What is in the future? As previously mentioned, new tributary strategies will be developed by January of next year which will focus on maintaining the 40% nutrient reduction goal. Additionally, the Bay Program is working very closely with its state partners in determining what endpoints will best measure the nutrient related health of the bay, and how to translate that information into NEW tributary caps to be applied to each major Bay river in order to achieve the endpoints. It is expected, as written in the *Chesapeake 2000 Agreement*, that achievement of these new caps can be attained by 2010 in which case, the Chesapeake Bay's nutrient related impairment status would be removed and Bay tidal TMDLs would not be necessary. But whether voluntarily or regulatory, nutrient reduction is a very real and essential necessity. Technological innovations whether they be pollution prevention, in-process modifications, or end-of-pipe treatment, will be key in attaining and maintaining these goals.

Table Municipal wastewater treatment facilities using biological nutrient removal (BNR)

Jurisdiction	# of significant ¹ facilities (2000)	# of significant facilities using BNR (2000)	# of significant facilities to be using BNR by the year 2005	# of significant facilities with plans to be using BNR (By 2010)
Pennsylvania	123	11	11	14
Maryland	62	28	37	62
Virginia	68	7	10	19
District of Columbia	1	1 ²	1	1
Federal Facilities	7	2	6	7 ³
Total	262	49 (total municipal flow under BNR=664 MGD or 41%) ⁴	65 (total municipal flow under BNR=783 MGD or 48%) ⁴	103 (total municipal flow under BNR=1,057 MGD or 64%) ⁴

Source: CBPO BNR and Point Source Data Bases

(1) A significant facility is defined here for MD as having a flow greater than 0.5 MGD or total nitrogen discharge greater than 75 lbs/day; for VA, having a design flow of 0.5 MGD or greater, or the industrial TN equivalent discharge of 75 lbs/day, and also all minor BFL facilities; for PA, having a 1985 annual flow of 0.4 MGD or greater. However, this also tracks four minor facilities in MD.

(2) Only half of the flow from Blue Plains facility currently treated with BNR. All of the flow will be treated by 2000.

(3) Out of 7 Federal Facilities to be using BNR after 2000, 5 are in MD and 2 in VA.

(4) 1998 flow is used to calculate "current" flow under BNR. 2000 flow projections used to calculate flow under BNR in 2000 and after.

References

- [1] Chesapeake Bay Program, "Maintaining Progress in Restoring the Chesapeake Bay: Holding the Line on Nutrient Pollution after 2000", August, 1999.

- [2] Chesapeake Bay Program Nutrient Point Source Database. Chesapeake Bay Program. Spring 2000.
- [3] Randall, Clifford *et al.*, Design and Retrofit of Wastewater Treatment Plants for Biological Nutrient Removal, 1992.
- [4] Randall, Clifford *et al.*, Evaluation of Wastewater Treatment Plants for BNR Retrofits Using Advances in Technology, VaTech, May 1999.