

THE RELATIONSHIP BETWEEN WASTEWATER TREATMENT PLANTS AND NUTRIENT IMPAIRED SURFACE WATER BODIES IN SEVEN NORTHERN STATES

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ABSTRACT

Discharges from wastewater treatment plants (WWTPs) contribute significantly to nutrient loading of surface water bodies and to water body impairments in specific systems. As a result attention has been focused on the control of discharges from these point sources. However, the relationship between nutrient impairment and WWTP discharge on a broader scale is unclear. To investigate this relationship we examined the following factors in seven northern states: 1) the percentage of nutrient impaired water bodies that receive discharges from WWTPs directly or via tributaries 2) the percentage of WWTPs with advanced treatment to remove phosphorus (P) 3) the proportion of Total Maximum Daily Loads (TMDLs) for nutrients identifying WWTPs as significant sources of phosphorus and the fraction of the phosphorus load attributable to WWTPs. The results of this study suggest that on a state and regional scale WWTPs represent a small fraction of the P loading to impaired water bodies. However, in specific systems they may be the most important P source.

KEYWORDS

Waste Water Treatment Plants, Nutrient Impairment, Total Maximum Daily Loads, Phosphorus Loading

INTRODUCTION

Nutrients are the most common cause of water quality impairment in lakes and reservoirs and the fifth most common cause of impairment of rivers and streams in the United States (US EPA 2002). Excessive nutrient loads stimulate eutrophication resulting in a number of negative impacts to water quality including, odors, low dissolved oxygen, increased turbidity, and reduced the aesthetic appeal. In freshwater systems (the focus of this paper), the primary cause of eutrophication is excessive levels of phosphorus (P).

Wastewater was considered to be the greatest threat to water quality when the Clean Water Act was promulgated, but over the last 25 years enough progress has been made that non-point sources of pollution (mostly runoff from urban and agricultural areas) have become the primary concern in many areas. However, in other cases evidence indicates that point sources of P are the most significant sources of nutrients to certain water bodies. The most common point sources of nutrients are wastewater treatment plants (WWTPs). Discharges from WWTPs can contain high concentrations of P and nitrogen (N). In cases where they have been identified as a significant contributor to nutrient impairments, regulatory controls in the form of National Pollution Discharge Elimination System (NPDES) permit limits are frequently used to limit the

discharge of nutrients from WWTPs. This has been successful in many cases at significantly reducing the contribution of these sources of P to surface waters.

While the contribution of WWTPs to individual water bodies or watersheds is known in some cases, it is unclear what their relative contribution is on a broader scale. To investigate this relationship we examined the following factors in Illinois, Maine, Massachusetts, Michigan, Minnesota, Vermont, and Washington:

- Percentage of nutrient impaired water bodies that receive discharges from WWTPs directly or via tributaries – This provided a measure of the maximum fraction of nutrient impaired waters that could be impacted by WWTPs
- Percentage of WWTPs with advanced treatment to remove P (advanced treatment) – Those treatment plants with advanced treatment are unlikely to be significant sources of P
- Proportion of Total Maximum Daily Loads (TMDLs) identifying WWTPs as significant sources of P – In systems with nutrient TMDLs that do not identify WWTPs as significant sources of P other nutrient sources are the likely cause of the impairment

The results of this assessment varied among the states considered. In many cases less than half of the impaired water bodies had the potential to be impacted by WWTPs, suggesting that non-point source discharges are more important in many systems. In all of the states reviewed, less than half of the WWTPs were identified as having advanced treatment for P removal. Nevertheless, advanced treatment for reduction of P in effluent was not the standard condition in any studied state, despite renewed interest in nutrient controls in recent years and the re-issuance of NPDES permits every 5 years. The review of TMDLs found that few of them require reductions of P in WWTP effluent. In most cases, this is because point sources only contribute a minor portion of the estimated nutrient load to the impaired water body. This may indicate that, in general, non-point sources are more important contributors of P than WWTPs. However, in specific systems WWTPs do represent the most significant fraction of P load.

METHODOLOGY

This study relied on state water quality assessment data, EPA's database of NPDES permitted dischargers, and available TMDL reports. Using the information in these sources we assessed relationships between nutrient impairment, WWTP discharges, and the prevalence of WWTPs with advanced treatment.

Estimating the Percentage of Nutrient Impaired Water Bodies Receiving WWTP Discharge

Information on nutrient impaired water bodies was primarily collected from the individual state's 303(d) list of impaired waters and 305(b) water quality assessment reports. From these sources we identified the water bodies listed as impaired by nutrients. In addition, we included water bodies identified as impaired by nitrogen, P, and/or algal growth in the category of nutrient

impaired.

Much of the information on the permitted discharges was obtained from the U.S. Environmental Protection Agency's Permit Compliance System (PCS) (U.S. EPA no date). This database includes a variety of information on NPDES permitted facilities. We queried the PCS system for all permitted facilities with the standard industrial classification (SIC) code for sewerage systems (SIC code 4952) in each state. When feasible the information retrieved from PCS was crosschecked with any available NPDES permit documents.

To determine which discharges had the potential to impact nutrient impaired waters, we identified and compared the locations of the nutrient impaired water bodies and the dischargers. In many cases, location information for the nutrient impaired water bodies and dischargers was available in ArcMap Shapefiles from the State resource agencies. In these cases, ArcMap GIS software was used to plot the location of dischargers and nutrient impaired segments on a topographic map. The resulting map was visually inspected to determine if the receiving water body or any downstream water bodies were impaired. We categorized any facility discharging directly into an impaired water body or into a tributary of an impaired water body as potentially impacting that water body. In cases where water bodies extend long distances, professional judgment was used to determine how far downstream to consider dischargers as potentially impacting impaired water bodies. For example, in Minnesota the Mississippi River is a tributary to Lake Pepin which is impaired by nutrients. Rather than include all discharges to the Mississippi River watershed as potentially impacting Lake Pepin, we only included those within approximately 50 miles upstream.

Determining the Treatment Level of WWTPS

Information on the treatment level of the wastewater treatment plants was taken from the NPDES permit when feasible. When the permit was not available or the permit did not contain information on the treatment process we assessed the likely level of treatment based on the P limits and monitoring results. This approach was used for the majority of WWTPs since permits rarely contained information on the treatment technology a WWTP used. All facilities with limits or reported measured P concentrations of less than 2.0 mg/L were assumed to have advanced treatment of some kind. When both P limits and reported concentrations were available, the lower value was used to infer treatment level. All other facilities, including those without P limits or monitoring results, were assumed to have no treatment more advanced than basic secondary treatment.

We assessed the accuracy of the assumption that plants achieving P concentrations of less than 2.0 mg/L have advanced treatment to remove P. To conduct this assessment we determined if 64 treatment plants in Minnesota and Maine had advanced treatment for P removal by reviewing their permits and fact sheets. These results were then compared to the treatment level we would infer from their P limit and effluent monitoring results.

Comparisons of treatment levels inferred based on P limits and those contained in fact sheets or permits indicate that in most cases our assessment based on P limits and concentrations agree

with the information in the permits (Table 1). However, assessing treatment level based on the assumption that those achieving less than 2.0 mg/L of P have some form of advanced P removal overestimates the number of advanced treatment plants somewhat.

A review of the plants where the treatment level in the permit does not agree with that determined based on P limits and monitoring results indicated that in all cases the plants were achieving low P concentrations (less than 2.0 mg/L) without advanced P removal steps in the treatment process. However, none of the plants had P limits of less than 2.0 mg/L. When P limits below 2.0 mg/L are imposed on WWTPs, advanced treatment for P removal is employed in all cases reviewed. Treatment facilities without limits that achieve concentrations less than 2.0 mg/L could attain lower P levels due to high organic carbon loading. In these cases, the biomass (sludge) production results in stoichiometric uptake of P from the water. In other cases, very dilute wastewater inputs or operation below capacity could also result in lower P concentrations on the effluent. .

Table 1 Comparison of Treatment Levels Determined by Reviewing NPDES Permits and Determined Using P Limits and Effluent Concentrations

Approach	# Secondary	# Advanced	Total #
Use of P monitoring results and Limits	50	14	64
Use of treatment information from permit or fact Sheet	56	8	64

These findings support the notion that using a 2.0 mg/L threshold and permit limits results in a reasonable estimate of the number of WWTPs with advanced treatment for P removal. If adequate monitoring data were available for all WWTPs, a 1.0 mg/L limit could probably be applied to get the most accurate split between secondary and more advanced treatment with regard to P based on effluent P concentration. However, as monitoring data are not available for many WWTPs, most of the plants were classified as secondary or advanced treatment based on permit limits. Although our approach may result in a slight overestimate of the number of WWTPs with advanced treatment, we believe that the results based on data obtained from the PCS system provide a reasonably accurate assessment of the number of WWTPs with advanced P removal steps, and that such advanced removal typically results in P concentrations less than 1 mg/L. Furthermore, any overestimate would not influence our conclusion that the majority of WWTPs in the states studied do not have advanced treatment steps for P removal.

Reviewing Nutrient TMDLs for the Contribution of WWTPs

Nutrient and dissolved oxygen (DO) TMDLs for each state were either downloaded from state websites or obtained from state personnel. All nutrient TMDLs were included in the assessment. We only included DO TMDLs when P was clearly determined to be a significant cause of the DO impairment. When available, we recorded the existing, pre-TMDL implementation load from WWTPs and non-point sources, the waste load allocation for WWTPs, and the load allocation for non-point sources. When there was no specific statement in the TMDL regarding expectations for reduced loading from WWTPs, a comparison between the existing WWTP P

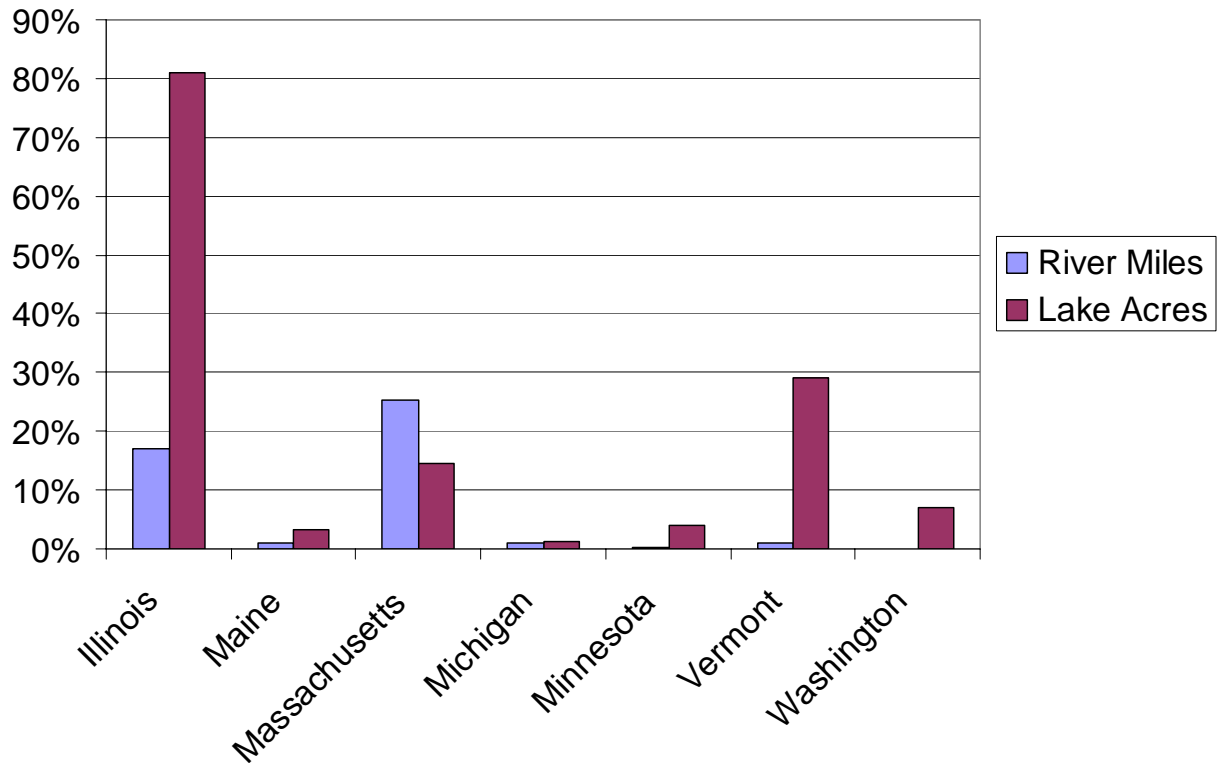
load and the waste load allocation for WWTPs was used to determine if a reduction in P load from these sources was required.

RESULTS

Percentage of Nutrient Impaired Water Bodies that Receive Discharges from WWTPS

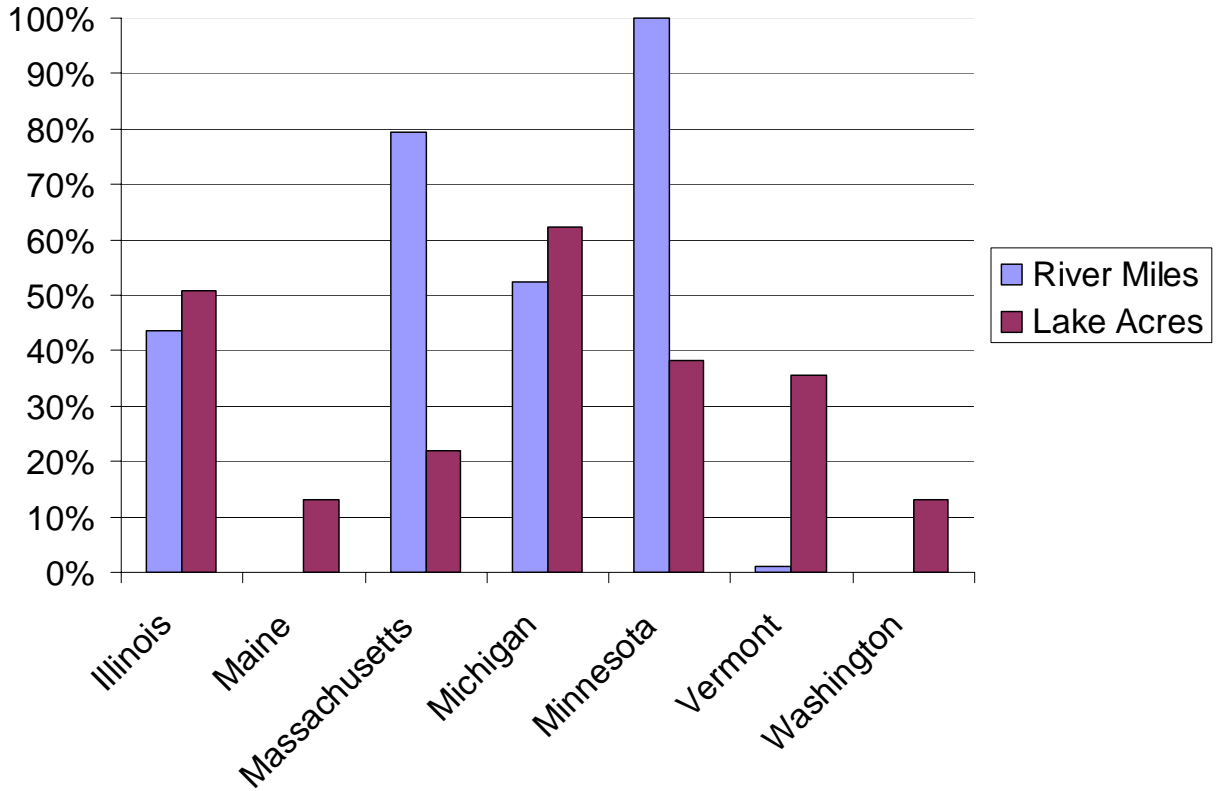
The review of state 303(d) lists indicated that the proportion of assessed water body area or length impaired by nutrients ranged from less than 1% of the river miles in Maine and Vermont to more than 81% of the lake acres in Illinois. However in most cases (Massachusetts is the exception) a higher percentage of the lakes were nutrient impaired than river miles (Figure 1).

Figure 1. Percentage of Lake and Rivers that are Nutrient Impaired



The proportion of nutrient impaired water bodies that had the potential to be impacted by WWTPs varied substantially among the states considered. However in many states, more than half of the nutrient impaired water bodies did not have any potential to be impacted by WWTPs (Figure 2).

Figure 2. Proportion of Nutrient Impaired Water Bodies Potentially Impacted By WWTPs



Treatment Levels of WWTPs

In all of the states reviewed, less than half of the WWTPs were identified as having advanced treatment for P removal (Figure 3). Massachusetts had the highest percentage of advanced WWTPs at 41%. In contrast, Washington had only one plant identified as having advanced treatment. In all states, the percentage of WWTPs with advanced treatment is higher in plants that discharge to nutrient impaired water bodies (Figure 4).

Figure 3. Percentage of WWTPs Identified as Having Advanced Treatment

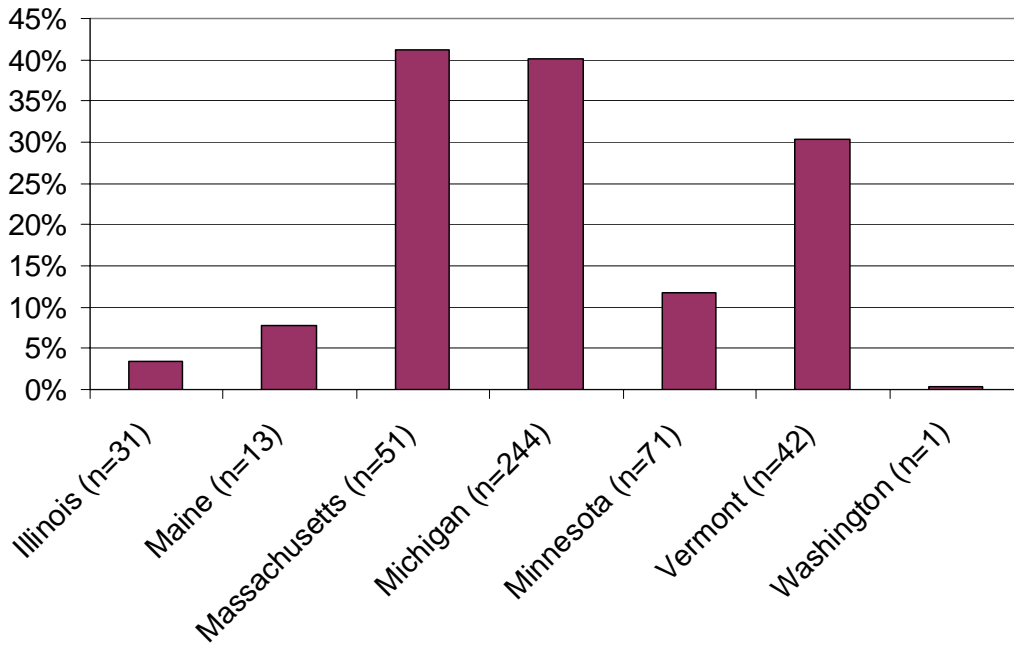
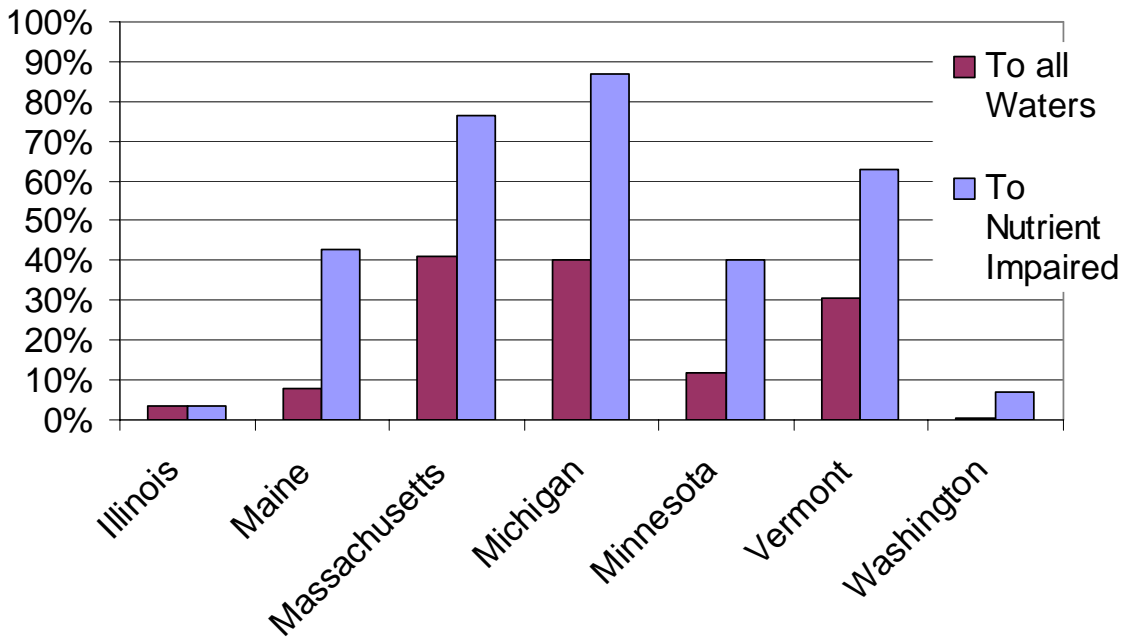


Figure 4. Percentage of WWTPs with Advanced Treatment Discharging to All Waters and Non Nutrient Impaired Waters.



WWTP Contributions to Nutrient Impaired Waters with TMDLs

Less than half of the TMDLs reviewed identified WWTPs as sources of P. Of those that identified WWTPs as sources of P, less than half required reductions in WWTP effluent (Table 3 and Figure 5). The numbers of completed TMDLs and the proportion identifying WWTPs as sources of P varied widely between the states (Figure 5). A review of the existing loads attributable to WWTPs and non-point sources in the TMDLs indicated that on average WWTPs only comprised 17% of the P loads. However, in some individual systems they were the most important source of P to the water body (Figure 6).

Figure 5. TMDLs Identifying WWTPs as Sources of P

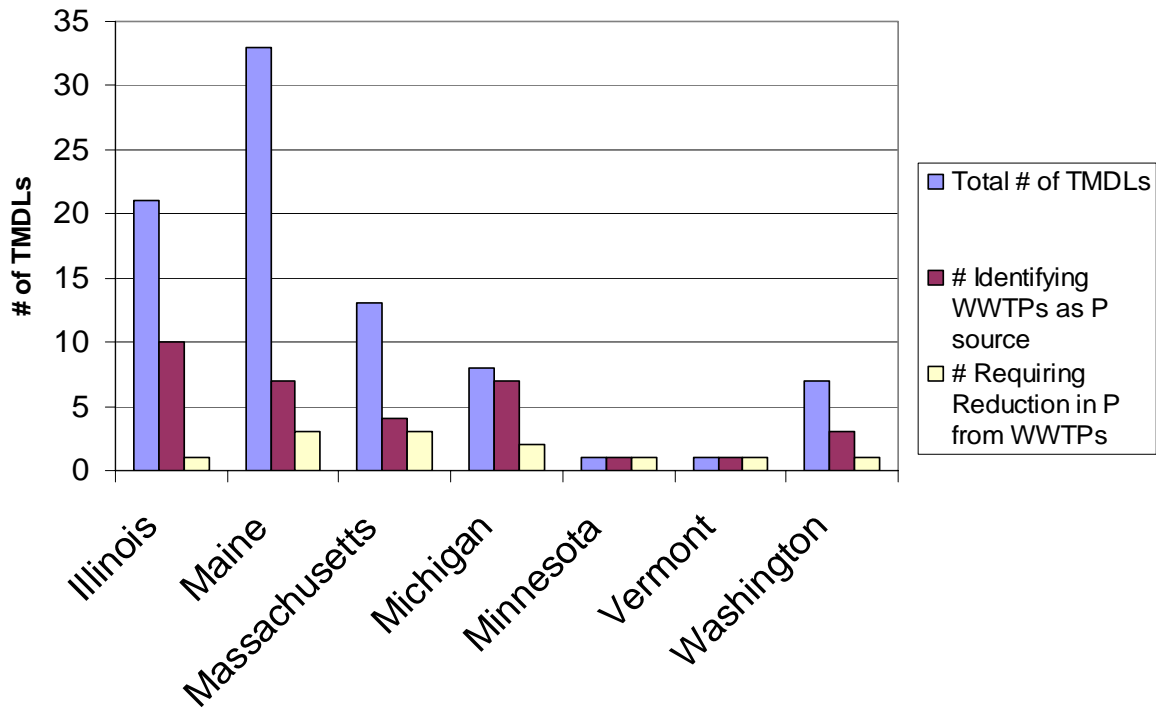
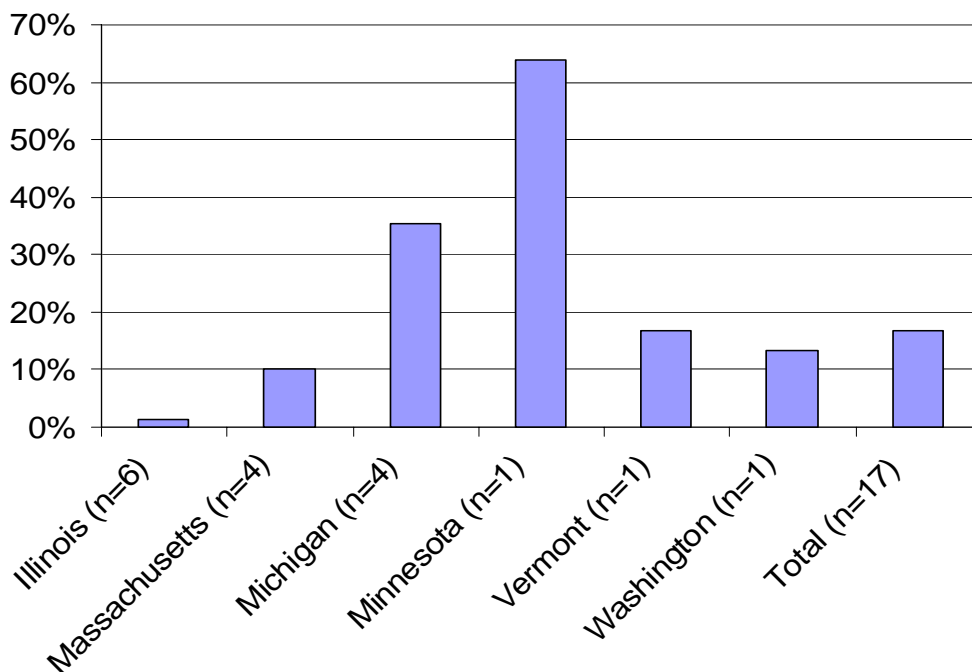


Figure 6. Percentage of P Load Attributable to Discharges from WWTPs to Waters with Nutrient TMDLS



DISCUSSION

Percentage of Nutrient Impaired Water Bodies that Receive Discharges from WWTPS

The percentage of nutrient impaired water bodies varied widely between states (Figure 1). This variability is likely due to several causes that fall into two broad categories: actual differences in conditions and differences in how conditions are assessed, perceived, and/or reported. The studied states have different land use patterns, geology, and topography. These factors all affect the water quality of water bodies and the likelihood they will be impaired by nutrients.

Additionally, differences in the way water bodies are listed in each state's list of impaired waters may also contribute to the variation in the proportion of water bodies that are listed as impacted by nutrients. Each state uses a different method for determining which water bodies are impaired and cause for impairment. In addition, the states each report the results of their assessment of water quality slightly differently. For example, in some states a water body might not meet the water quality criteria for dissolved oxygen (DO) (i.e. it is 'impaired' for DO). This impairment might have multiple causes including P inputs, the oxygen demand associated with point source discharges, and run off containing organic materials. These causes may all be included in the list of impaired water bodies. In contrast, other states only list which parameters exceed the water quality criteria. Therefore, a water body might be listed as impaired only by DO even when the cause of the DO impairment is the loading of P, and as a result not included in our assessment unless further information was readily available.

Differences in regulations and perceptions of water quality also impact the listing of waters as impaired. By definition, waters that do not meet state water quality standards are impaired, but the standards differ among states and the standards are often subjective. The majority of the states do not have numeric water quality standards for nutrients. Instead, most states have narrative standards that rely on a subjective assessment of the condition of the surface water. The differences between these standards and the application of the subjective nature of some of their elements likely cause many of the differences.

In the studied states a significant percentage of the nutrient impaired water bodies were not identified as potentially impacted by WWTPs (Figure 2). This indicates a substantial fraction of nutrient impairments are unrelated to discharges from WWTPs. Instead, these impairments are likely caused by runoff from agriculture, urban areas, or other non-point sources of nutrients.

Treatment levels of WWTPs

Advanced treatment for reduction of P in effluent was not the standard condition in any studied state, despite renewed interest in nutrient controls in recent years and the re-issuance of NPDES permits every 5 years (Figure 3). Since NPDES permits are designed to be protective of water quality, this finding suggests that in many systems discharges from WWTPs without advanced treatment are not perceived by the regulatory agency to be causing water quality problems at existing treatment levels.

In all states, the percentage of WWTPs with advanced treatment is higher in plants that discharge to nutrient impaired water bodies (Figure 4). This suggests that in cases where water bodies are identified as being impaired by nutrients regulatory agencies are more likely to require advanced treatment to remove P. Despite this, there are a significant number of WWTPs that discharge to nutrient impaired waters suggesting either that they aren't significant contributors to the impairment or that political or economic pressure has stopped regulatory agencies from imposing stricter discharge limits on these facilities.

WWTP Contributions to Nutrient Impaired Waters with TMDLs

For the vast majority of completed TMDLs reviewed, point sources contribute a minor portion of the nutrient load to the impaired water body. The review of TMDLs found that few of them require reductions of P in WWTP effluent. In most cases, this is because point sources only contribute a minor portion of the estimated nutrient load to the impaired water body (Figure 5). This suggests that in general, non-point sources are more important contributors of P than WWTPs. The suggestion that non-point sources are more important sources of P to surface waters than WWTPs agrees with previous work that found that non point sources, including agriculture and urban runoff, are responsible for a greater portion of the impaired river miles and lake acres than point source (US EPA 2002). Despite this, the high levels of P in WWTP discharges from facilities without advanced treatment suggest a potential impact on receiving waters unless dilution is high. This notion is supported by the finding that in some systems WWTP discharges are the most significant source of P. Alternatively, more TMDLs may be completed for water bodies where non-point sources are the primary source because these TMDLs may be less controversial and therefore more quickly completed. The wide variation in

the importance of WWTPs to impaired water bodies suggests that knowledge of conditions and expectations in each state are critical to understanding the role of WWTPs in nutrient impairment.

CONCLUSIONS

The evidence suggests that the impact of WWTPs on nutrient impairment of waters at a state or regional scale is small compared to non-point sources. Many nutrient impaired water bodies have limited potential to be impacted by WWTPs at current levels of treatment and a review of nutrient TMDLs suggests that in the majority of cases discharges from WWTPs represent a small fraction of the total P loads to impaired water bodies. However, few WWTPs have advanced treatment for P removal and in specific systems WWTPs do represent the most significant sources of P. Although WWTPs appear to be relatively minor contributors to nutrient pollution on a state and regional level, their impact needs to be carefully assessed on a case-by-case basis. In addition, although WWTPs may not represent a large fraction of the P load in many cases, controlling the discharge from them may be relatively easy compared to controlling loading from non point sources.

ACKNOWLEDGEMENTS

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