Turbidity of Drinking Water Supplies and Risk of Gastrointestinal Illness
[Project #4589]

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OBJECTIVES

This project was initiated to review the epidemiological studies of turbidity of drinking water supplies in relation to the incidence of acute gastrointestinal illness (AGI). The project sought to accomplish the following tasks:

1) Evaluate the scientific literature on turbidity of drinking water in relation to AGI in human populations and produce a summary paper of the findings
2) Organize and conduct a facilitated expert workshop to provide a forum for in-depth discussion of the initial summary paper from Task 1
3) Produce a final report that combines and communicates the results from Tasks 1 and 2, and places the body of work in context, to help guide future research on this topic

BACKGROUND

Several epidemiological studies have investigated the association between turbidity of unfiltered and filtered drinking water supplies and AGI incidence. These studies were designed as time series, in which turbidity measurements are correlated with counts of AGI over time, usually as daily measures. The studies use turbidity as an exposure proxy for the presence of microbiological contamination that can directly cause illness. Mann et al. reviewed this literature in 2007, and concluded that an association between turbidity and AGI is likely in some settings or over a certain range of turbidity (Mann et al. 2007). Several new studies have been conducted on this topic since the Mann review was published, including studies in Le Havre, France (Beaudeau et al. 2012); Massachusetts, USA (Beaudeau, Schwartz, and Levin 2014); Atlanta, USA (Tinker et al. 2010); and New York City, USA (Hsieh et al. 2015). The drinking water community believed that an updated review of the topic would be valuable, and thus WRF initiated a Request for Proposals for conducting such a review, including a comprehensive examination and evaluation of the methods used in these studies, in addition to a synthesis of the overall evidence that can be derived from the collective results. The body of work may also provide insight into the potential utility of turbidity measurements and the time-series study design to characterize public health risks related to the municipal drinking water supply.
APPROACH

The project included the three tasks outlined above. Task 1 consisted of a review of the scientific literature by the research team. The team identified 14 distinct studies (distinct by study region, time period, and/or study population) from searches of peer-reviewed literature, conference proceedings, dissertations, and government reports. All of the 14 studies evaluated turbidity of finished (filtered) water at the point of distribution or source water, and one of the studies additionally evaluated measurements of turbidity taken within the distribution system. Each member of the team systematically reviewed the studies and commented on methodological points of pre-defined interest, including study design, exposure (turbidity) and outcome (AGI) measurement, statistical methods, confounding, assessment of multiple lags, and presentation and conclusions. The research team met to discuss each study with regards to its contribution to the overall weight of evidence. The team drafted an initial summary paper with the findings, which was distributed to the Project Advisory Committee (PAC) in July, 2015.

The workshop for Task 2 was held in Philadelphia, PA on October 15, 2015. Invited experts included statisticians, epidemiologists, engineers, risk assessors, and general environmental health scientists (for names and affiliations, see Table 3.1 in the full report). Other participants included the research team and the PAC. The participants discussed strengths and weaknesses of the studies conducted on this topic, the overall weight-of-evidence, and identified research gaps and recommended future studies to address the gaps. A set of charge questions was developed by the research team to guide each discussion, with particular focus on measurement of turbidity, assessment of multiple lags, confounding and effect modification, mechanistic plausibility, population impact, and data gaps. In the final session, participants were invited to discuss the overall weight of evidence and research needs.

For Task 3, this report was generated to combine the work conducted for Tasks 1 and 2, and to generate overall conclusions and recommendations for utilities and researchers.

RESULTS/CONCLUSIONS

Positive associations between turbidity of water supplies and incident AGI were reported by most of the published studies that investigated the topic, although the finding was sometimes limited to certain subgroups of the population or to certain subanalyses. The association was observed in different cities and time periods, in regions with varying characteristics of source water, with both unfiltered and filtered supplies, and with varying turbidity levels. There is some consistency between the studies in the lag times with associations (e.g., the time between the measured turbidity and the appearance of the AGI case in the healthcare system), which fall between 6 to 12 days in many studies. The studies appear to adequately adjust for possible biases, including confounding, although it is acknowledged that unknown biases may still occur. Some differences between study findings included the age groups and seasons in which an AGI increase was observed, differences in association by the source of AGI counts (e.g., emergency department visits vs. hospital admissions), the lag times with associations, and the strength of association. Statistically significant associations were reported by all but one of the studies; however, some studies adopted an exploratory approach in which multiple comparison issues make the relative importance of findings difficult to determine. The more convincing studies presented all the associations examined, across multiple lags and for various subgroups, allowing the reader to evaluate patterns and the consistency of results within the study. The observed associations
between turbidity and AGI suggest a low-level incidence of waterborne AGI from source water contamination in the systems and time periods studied. However, the discrepant results suggest that the association is not universal. Turbidity is typically used as a measure of treatment system performance, and it does not correlate with pathogen occurrence in a consistent fashion across different contexts. Therefore, the use of turbidity as a proxy for the presence of microbiological contamination in these studies should be interpreted on a study-by-study basis. Some of the water systems previously studied have since implemented enhanced treatment processes or operational procedures, so follow-up research in those systems would be needed to evaluate current conditions.

A point of consensus from the workshop is that the existing studies, on their own, do not provide a weight of evidence to infer causality. Establishing a causal link would require complementary, supporting research. There was considerable disagreement among workshop participants with regard to the utility of conducting additional, similar studies of turbidity in relation to AGI, with some participants finding limited value in a study that does not link a direct measure of a specific pathogen to incident disease. Other participants (including the research team) concurred that similar time-series studies using turbidity and other operational water quality measures as proxies for microbiological contamination may be useful, particularly as a relatively inexpensive research tool to obtain preliminary data on the possible existence and scope of a public health issue.

APPLICATIONS/RECOMMENDATIONS

Moving forward, it may be useful to conduct additional studies of turbidity in relation to AGI to “screen” drinking water supplies for source water quality and treatment effectiveness. Combining turbidity with additional water quality measures, treatment data, system operations information and source water conditions may enable exploration of stronger correlates of microbiological contamination. Time-series studies are recommended as a reasonable first-step for epidemiological evaluation of a water supply; although the time-series design has weaknesses that limit causal inference, such studies are relatively inexpensive to conduct, given ongoing generation of turbidity (and other water quality) measurements by water systems and increasing availability of electronic health records. These studies may help identify regions, seasons, and source water conditions of potential concern, which could then guide more targeted research to identify specific pathogens that may explain those “high-risk” conditions, and to trace the pathogens back to contributors of microbiological contamination within a watershed. Given time-series results supplemented by focused, contextual research to help determine whether there is indeed a causal link, ongoing time-series surveillance might be useful as an additional means to assess the effectiveness of utilities in managing various conditions posing increased risk for exposure to microbiological agents of AGI. Additional epidemiological research with collection of individual-level data on exposure and AGI (as in a case-control, cohort, or randomized trial study design) may be useful for quantification of the risk of AGI attributable to drinking water supplies. Engaging major stakeholders may facilitate research by providing access to timely and accurate data and increasing stakeholders’ acceptance of whatever results are found. In epidemiological studies involving drinking water, such stakeholders include the water utility managers, local health agencies, and local regulatory agencies.