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Characterizing the Quality of Effluent and Other Contributory Sources during Peak Wet Weather Events

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CHARACTERIZING THE QUALITY OF EFFLUENT AND OTHER CONTRIBUTORY SOURCES DURING PEAK WET WEATHER EVENTS

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ABSTRACT AND BENEFITS

Abstract:

Wastewater treatment plant effluent blending has been used since the 1970s to prevent overflows in a wastewater collection system or washout of a wastewater treatment plant's biological secondary process during peak wet weather flows. Unfortunately, very limited data exist regarding effluent pathogen concentrations during blending, and the additional risk of disease resulting from blending practices has not been quantified. Additional data are necessary to ensure that decisions regarding wastewater infrastructure improvements to properly manage peak wet weather wastewater flows are optimized based on quantifiable water quality and public health benefits.

The project team, therefore, evaluated the impacts of blending practices at a municipal wastewater treatment plant on effluent and receiving water quality, and estimated public health risks associated with recreation in surface waters receiving blended flows. Field samples were collected at four municipal wastewater treatment plants for in-plant processes and receiving waters during wet weather blending, wet weather non-blending, and dry weather events. Laboratory analyses for *Giardia, Cryptosporidium*, viruses (adenovirus, enteric viruses, rotavirus, norovirus), pathogen indicator organisms (fecal coliform, *Escherichia coli,* enterococcus, and male-specific coliphage), and other water quality parameters were performed on many of these samples. Field sample results for the East Bay Municipal Utility District's (EBMUD) Main Wastewater Treatment Plant (MWWTP) served as the basis for developing hydrodynamic and water quality computer models to predict receiving water conditions as well as a quantitative microbial risk assessment (MRA) to estimate risks of gastrointestinal and respiratory infections for people recreating in waters receiving blended flows.

EBMUD field sampling results indicated that only *Giardia* and adenovirus concentrations in plant final effluent increased during wet weather blending events in comparison to wet weather non-blending events and dry weather events out of all the organisms tested in this study; therefore, receiving water modeling was conducted for these organisms. T-test results indicated that the differences between blending and non-blending were not statistically significant for any of the pathogen and indicator organisms except *Giardia* cysts. Additionally, total suspended solids, 5-day biochemical oxygen demand, and particle concentrations from final effluent grab samples also appeared higher during blending events, but no increase was observed in volatile organic compound levels during these periods, and no permit limits were exceeded. An estimate of the incremental annual number of infections associated with blending practices at EBMUD's wastewater treatment plant was developed based on two pathogens (adenovirus and *Giardia* sp.) and three exposure sites. Estimated individual risk per exposure event for people recreating in waters receiving blended flows were greater by about an order of magnitude (10-fold) at the EBMUD MWWTP outfall location and less than an order of magnitude at three other exposure sites, than if these blended flows received full secondary biological treatment during wet weather conditions. The relative increase of annualized risk was less than one infection annually assuming 180 exposure events per day for 30 blending days per year. The number of exposure events was based on best estimates of water contact recreation at each exposure site and the number of blending days was a conservative estimate based on historical frequency data. The MRA results described in this

report are site-specific to EBMUD and may not be representative of impacts from blending practices at other wastewater treatment facilities because of differences in receiving water conditions, ability to collect samples during wet weather, and pathogen presence.

This study also identifies and discusses some alternatives to reduce or eliminate blending, including rainfall-derived infiltration and inflow reduction, peak storm-flow storage, and treatment capacity expansion. A guidance document based on the approaches and methods undertaken in this study was prepared and is included in this report to assist other agencies in conducting similar evaluations to estimate their blending impacts.

Benefits:

- Constructs a methodology to estimate water contact recreation exposure risk from wastewater treatment blending practices using field sampling, water quality modeling, and microbial risk assessment tools.
- Summarizes literature review of the impacts of blending practices on human health risk and basis for the selection of pathogen and indicator organisms included in this study.
- Describes a framework (e.g., blending event types, sampling locations, frequency, parameters, methods) for in-plant and receiving water quality monitoring to evaluate the impacts of blending practices.
- Provides water quality data at four treatment plants to compare blending and non-blending event concentrations of pathogens, indicator organisms, and other pollutants.
- Estimates the incremental water contact recreation exposure risk from wet weather blending practices at the EBMUD MWWTP at less than one additional infection annually assuming conservative wet weather frequency and recreational use.
- Describes receiving water quality modeling approaches, techniques, and limitations for assessing blending impacts.
- Identifies pathogen die-off rates for *Giardia* and adenovirus in marine waters based on data obtained from the literature.
- Demonstrates use of a microbial risk assessment methodology for estimating the risk of gastrointestinal infection associated with water-contact recreation in receiving waters impacted by municipal wastewater treatment plant blending practices.
- Identifies wet weather flow management alternatives to blending including inflow and infiltration reduction, wet weather flow storage, and treatment capacity expansion, and discusses their relative merits.
- Provides a how-to guide for other municipal wastewater facilities conducting site-specific evaluations on the human health impact of blending, based on the methods used in this study.

Keywords: Blending, wet weather flows, municipal wastewater treatment, pathogens, water quality model, microbial risk assessment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

2-D	Two-dimensional
3-D	Three-dimensional
ADWF	Average dry weather flow
AMS	Applied Marine Sciences, Inc.
ASCE	American Society of Civil Engineers
ASM	American Society for Microbiology
AWWA	American Water Works Association
BACWA	Bay Area Clean Water Agencies
BOD	Biochemical oxygen demand
BOD_5	5-Day biochemical oxygen demand
BPS	Booster Pump Station
CB	Crown Beach (Alameda, CA)
$cBOD_5$	5-Day carbonaceous biochemical oxygen demand
CCSF	City and County of San Francisco
CDC	Centers for Disease Control
CDEC	California Data Exchange Center
CEPT	Chemically enhanced primary treatment
CFU	Colony forming units
CIP	Capital Improvement Program
CPE	Cytopathic effect
CSS	Combined sewer system
CTD	Conductivity, temperature, depth
CWS	Clean Water Services (Portland, OR)
DAPI	4', 6'-diamidino-2-phenylindole
DAPI/PI	4', 6'-diamidino-2-phenylindole-propidium iodide
DFA	Direct fluorescent antibody
DGSD	Downer's Grove Sanitary District (Illinois)
DIC	Differential interference phase contrast
DNA	Deoxyribonucleic acid
DO	Dissolved oxygen
DW	Dry weather
DWR	Department of Water Resources (California)
EBMUD	East Bay Municipal Utility District

EBRPD	East Bay Regional Parks District
ELAP	Environmental Laboratory Accreditation Program
ELISA	Enzyme-linked immunosorbent assay
E/S WPCF	Eugene/Springfield Water Pollution Control Facility (Eugene, OR)
F+	Male specific
FC/FS	Fecal coliform to fecal streptococci
FDA	Flourescein diactetate
FEDWA	Flocculating energy dissipation well arrangement
FWPCA	Federal Water Pollution Control Administration
FT	Feet
GI	Genogroup I
GII	Genogroup II
GM	Geometric mean
GPD	Gallons per day
GPS	Global positioning system
GUI	Graphical user interface
HRC	High-rate clarification
ICS	Influent control structure
IEC	Interstate Environmental Commission (New York, NY)
IEP	Interagency Ecological Program
I/I	Inflow and infiltration
IMS	Immunomagnetic separation
INELA	Institute of National Environmental Laboratory Accreditation
IPS	Influent pump station
ISO	International Organization for Standardization
ISS	Inline storage system
JI WWTP	Jones Island Wastewater Treatment Plant (Milwaukee, WI)
L	Liter
L/ha-d	Liters per hectare per day
MCRT	Mean cell residence time
MDL	Method detection limit
MGD	Million gallons per day
Mg/L	Milligrams per Liter
mL	Milliliter
MLLW	Mean low low water

MLSS	Mixed liquor suspended solids
MMSD	Milwaukee Metropolitan Sewerage District
MPN	Most probable number
MRA	Microbial risk assessment
MWWTP	Main Wastewater Treatment Plant (EBMUD)
NACWA	National Association of Clean Waters Agencies
NaOCl	Sodium Hypochlorite
NH_3	Ammonia
NO_2^-	Nitrite
NO_3^-	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
O&M	Operations and maintenance
OGM	Outfall Geometric Mean
OH	Outer Harbor (Lake Michigan)
OPR	Ongoing proficiency recovery
OWC	Outfall Worst Case
PCR	Polymerase chain reaction
PE	Primary Effluent
PFU	Plaque forming units
PI	Propidium iodide
POTWs	Publicly-owned treatment works
PPT	Parts per thousand
PSC	Project subcommittee
PSD	Particle size distribution
PTS	Peltier Technical Services
Q	Qualifier
QA/QC	Quality assurance/quality control
QC	Quality control
RDII	Rainfall derived infiltration and inflow
RDI/I	Rainfall dependent inflow and infiltration
RMA	Resource Management Associates
RNA	Ribonucleic acid
RT-PCR	Reverse-transcriptase polymerase chain reaction

SE	Secondary effluent
SEWPCP	Southeast Water Pollution Control Plant (San Francisco, CA)
SFBA	San Francisco Boardsailing Association
SFPUC	San Francisco Public Utilities Commission
SSOs	Sanitary sewer overflows
SSS	Sanitary sewer system
THM	Trihalomethane
TI	Treasure Island
TSS	Total suspended solids
UG/L	Micrograms per Liter
UNC	University of North Carolina at Chapel Hill
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultra violet
VOCs	Volatile organic compounds
WAS	Waste activated sludge
WERF	Water Environment Research Foundation
WHO	World Health Organization
WSSC	Washington (DC) Suburban Sanitary Commission
WW	Wet weather
WWF	Wet weather facility
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

ES.1 Project Objectives

Wastewater treatment plant effluent blending has been used since the 1970s to prevent overflows in a wastewater collection system or washout of a wastewater treatment plant's biological secondary process during peak wet weather flows. To avoid exceeding the secondary process's hydraulic capacity, the practice limits the flow of wastewater to the secondary process by blending a portion of primary-treated effluent with the final secondary-treated effluent prior to disinfection and discharge to receiving waters. Secondary system washout could potentially have longer-term consequences (on the order of days) with respect to effluent quality than the blending event and its associated effluent quality impacts (on the order of hours). Recently, questions regarding blending's potential impacts to receiving water quality and possible public health risks have emerged. Unfortunately, very limited data exist regarding effluent pathogen concentrations during blending, and the additional risk of disease resulting from blending practices has not been quantified. Additional data are necessary to ensure that decisions regarding wastewater infrastructure improvements to properly manage peak wet weather wastewater flows are optimized based on quantifiable water quality and public health benefits.

ES.2 Project Approach

A literature search and review was conducted to:

- Identify available studies evaluating the impacts of blending practices on water quality and human health risks.
- Provide a basis for the selection of pathogen and indicator organisms included in the field sampling program.
- Identify appropriate analytical methods for the detection of selected pathogen and indicator organisms in wastewater and receiving water matrices.
- Evaluate die-off rates for organisms used in hydrodynamic and water quality computer modeling.

A quality assurance field sampling plan was developed and field sampling was conducted per the plan at four field test sites to:

- Collect in-plant and receiving water samples at specified locations, and under three weather conditions: dry weather, wet weather non-blending and blending. The main goal was to allow a direct comparison of the blended effluent and receiving water quality during peak wet weather blending events to two different "baseline" conditions: dry weather and wet weather non-blending events.
- Ensure quality of samples collected and data obtained.

Field sampling was conducted at the following four field sampling sites:

- East Bay Municipal Utility District (EBMUD) Main Wastewater Treatment Plant (MWWTP) in Oakland, California.
- City and County of San Francisco Southeast Water Pollution Control Plant (CCSF SEWPCP) in San Francisco, California.

- Milwaukee Metropolitan Sewerage District Jones Island Wastewater Treatment Plant (MMSD JI WWTP) in Milwaukee, Wisconsin.
- Cities of Eugene and Springfield Water Pollution Control Facility (E/S WPCF) in Eugene, Oregon.

EBMUD blending results were carried forward for the detailed modeling and analysis described below. Data from the remaining agencies were not modeled but are included in this report as Appendix A. Insufficient data were available for Milwaukee and Eugene for modeling blending scenarios, in part because recent system improvements resulted in fewer blending events for these agencies, but mostly because weather conditions did not provide sufficient rain to require blending at these treatment plants. In the case of San Francisco, the project team decided to focus on blending practices at treatment plants taking flows from separate collection systems (such as EBMUD) rather than from those taking flows from combined systems (such as San Francisco).

Based on the findings from the EBMUD MWWTP field sampling results, computer hydrodynamic and water quality modeling of pathogens discharged from the EBMUD MWWTP into the San Francisco Bay and quantitative microbial risk assessments were performed to:

- Analyze relative impacts of blending practices at the EBMUD MWWTP on receiving water quality in the San Francisco Bay due to potentially elevated pathogen concentrations.
- Estimate the transport and distribution of viable pathogens from blended effluents discharged into the San Francisco Bay to selected exposure sites using hydrodynamic and water quality models.
- Estimate human health risk associated with pathogens present in EBMUD MWWTP's effluent based on field sample results and hydrodynamic and water quality modeling. The focus was on the incremental risk associated with increased concentrations of pathogens measured in the final effluent and modeled in the receiving water during blending events using typical (geometric mean) and worst-case scenarios (second highest pathogen concentration). The microbial risk assessment (MRA) methodology evaluated the risk of gastrointestinal illness (i.e., gastroenteritis) to people participating in water contact recreation (e.g., swimming and windsurfing) in central San Francisco Bay.

Other activities associated with the project included:

- Identify and discuss alternatives to blending for handling wet weather wastewater flows.
- Prepare a guidance document to outline the approach and procedures for evaluating blending impacts so that other agencies can conduct similar studies.

ES.3 Field Sampling Results

Based on seven blending events at the EBMUD's MWWTP, grab samples collected at the plant's final effluent location showed no increase in concentrations of *Cryptosporidium* (enumeration and infectivity), enteric viruses, rotavirus, and pathogen indicator organisms including fecal coliform, *E. coli,* enterococcus, and male-specific coliphage, compared to the seven wet weather non-blending events (i.e., peak secondary) and two dry weather events sampled. *Giardia* and adenovirus were the only organisms to be present in greater numbers in final effluent samples during blending events at the plant. Even so, the difference of adenovirus density between blending and non-blending samples was not found to be statistically significant based on