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Environmental and Public Health Engineering

TESTIMONY OF

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Public Health Implications Associated with the Practice of Wastewater Treatment Plant Blending – Concerns and Misconceptions

Testimony of Adam W. Olivieri, Dr. P.H., P.E.
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Opening

Good morning Chairman Duncan, Congresswoman Johnson, and members of the Committee, my name is Adam Olivieri. I am currently a Principal Engineer for EOA, Inc. and have acted in this capacity since 1985. I have over 19 years of experience as a consulting engineer on projects related to water recycling, water quality, public health assessment, and storm water management. I also have 10 years experience working for a California state regulatory agency and the University of California at Berkeley. I have a B.S. degree in Civil Engineering and a M.S. degree in Civil Engineering with a Sanitary/Environmental Specialty from the University of Connecticut. I also have an M.P.H. degree and a Doctor of Public Health (Dr.P.H.) in environmental health sciences from the University of California at Berkeley. I am a professional Civil Engineer registered in the State of California (Certificate Number CE 26605) and a registered Environmental Assessor I (Certificate Number REA 00391).

I would like to thank you, Chairman Duncan, and the members of this Committee for your continued commitment to clean water issues – in California and nationwide. Your dedication to solving the challenges our communities face across the nation is essential to achieving the goals of the Clean Water Act.

The purpose of my testimony is to help improve the understanding the public health implications associated with the practice of wastewater treatment plant blending relative to exposure to microbial pathogens. There is significant concern regarding the current practice of blending treated effluents during high treatment plant flow events prior to discharge to local receiving waters, and the potential pubic health risks associated with probable exposure to pathogens in the receiving water. My testimony on this subject is based on my education, experience and the evidence in the scientific literature.

Background

Waterborne diseases such as cholera were rampant during the middle of the nineteenth century. Epidemics killed thousands of people. Awareness of the role of microorganisms in causing diseases led to improvements in the treatment of both wastewater and potable water. Today the public awareness and concern about the safety of the nations' water resources is high, and thus the public expectations are high as well.

In the United States, there are over 15,000 wastewater treatment facilities, most providing primary and secondary treatment with some form of disinfection. These plants are typically designed to treat both domestic and industrial wastewater. Domestic wastewater includes human and animal waste (urine and feces) as well as grey water from bathing washing and cooking. Infectious diseases caused by pathogenic bacteria, viruses, and protozoa or by parasites are the most common health risks associated with exposure to water through recreational activities. A summary of the most important microbial organisms that may be pathogenic to humans and that can be directly or indirectly transmitted by the waterborne route are shown in Table 1. While many pathogens are known it is likely that many waterborne pathogens are still not recognized.

Further, contaminated food, hands, utensils and clothing play a significant role in the transmission of microbial pathogens and infectious diseases.

Table 1 Major Waterborne Bacterial Diseases

Bacterial agent	Major Disease	Major reservoir
Salmonella typhi	Typhoid fever	Human feces
Salmonella paratyphi	Paratyphoid dysentery	Human feces
Shigella	Bacillary dysentery	Human feces
Vibrio cholerae	Cholera	Human feces
Enteropathogenic E. coli	Gastroenteritis	Human feces
Yersinia enterocolitica	Gastroenteritis	Human/animal feces
Campylobacter jejuni	Gastroenteritis	Human/animal feces
Legionella pneumophila	Acute respiratory illness (legionnaire's disease)	Thermally enriched waters
Mycobacterium tuberculosis	Tuberculosis	Human respiratory exudates
Leptospira	Leptospirosis (Weil's disease)	Animal feces and urine
	Variable	Natural waters
Opportunistic bacteria		

Adapted from Bitton (1994).

In general, wastewater flows are directly related to the domestic household use of water. Roughly, 80% of the wastewater is derived from household use. Other flows come from industry and groundwater infiltration. The latter source, together with rainfall entering the sanitary sewer system, can dramatically increase the flow in sewers during wet weather to a point where the management of all flows (i.e., transport, treatment and discharge) becomes a significant issue, in terms of both the potential water quality impacts and the very high costs associated with mitigating such flows through flow reduction and/or increased treatment capacity.

Pathogens of Public Health Concern

When considering the infectious disease implications of human exposure to wastewater, the following factors need to be considered: (1) for waterborne illness or disease to occur an agent of disease (pathogen) must be present, (2) the agent must be present in sufficient concentration to produce disease (dose), and (3) a susceptible host must come into contact with the dose in a manner that results in infection or disease (Cooper 1991b). To evaluate the potential public health significance of blending or varying degrees of treatment, it is necessary to evaluate all of the above for a given site.

Although a wide range of pathogens have been identified in raw wastewater, relatively few types of pathogens appear to be responsible for the majority of the waterborne illnesses caused by pathogens of wastewater origin (Mead et al. 1999). The pathogens of public health concern, based on food borne disease in the U.S, were identified by the Centers for Disease Control (CDC) (Mead et al. 1999). In characterizing food-related illness and death in the United States, Mead and co-workers estimated the annual total number of illnesses caused by known pathogens, adjusted for the fact that many illnesses are not reported, at 38.6 million cases with 5.2 million cases (13.5%) from bacterial pathogens, 2.5 million cases (6.5%) from parasitic pathogens, and 30.9 million cases (80%) from viral pathogens. With this background it follows that many of these pathogens find their way into domestic wastewater.

Review of the CDC research data approximates that 85% to 90% of all non-foodborne cases (i.e., cases related to other routes of transmission such as waterborne) in the United States are thought to be caused by viral pathogens (i.e., enteric viruses). The relative importance of viral pathogens in waterborne transmission of disease, is supported by data from the World Health Organization (World Health Organization 1999) and by research conducted over the last 20 years on exposure to waterborne pathogens through recreational activities (Cabelli 1983; Fankhauser et al. 1998; Levine and Stephenson 1990; Palmateer et al. 1991; Sobsey et al. 1995; Wade et al. 2003).

Human contact with water in fecally contaminated receiving waters may also cause other non-gastrointestinal disease outcomes such as acute febrile respiratory illness (Fleisher et al. 1996), general respiratory illness, ear infections (Fleisher et al. 1996), eye ailments, skin rashes (Ferley et al. 1989), and other less common health outcomes. While the cumulative risk faced by recreators is a function of all of the pathogens present in the receiving water, investigations associated with recreational exposure have focused on the risk of gastroenteritis which is consistent with federal regulatory guidelines and recently published state-of-the-art risk assessment studies (Soller et al. 2003).

Sources of Microbial Pathogens

The pathogens that have been reported to be responsible for the vast majority of illnesses in the United States ("pathogens of public health concern") come from a variety of sources including:

- Tributary inflows (composed of urban and agricultural runoff, including stormwater);
- Food wastes;
- Discharge of sanitary vessel waste; and
- Fecal waste of wildlife, including waterfowl that inhabit and/or utilize the receiving waters and environs;
- Leakage of sewer lines;
- Wastewater Treatment discharges;
- Animal wastes (from domestic animals) (Young and Thackston 1999);
- Illegal and/or illicit waste discharges (from industrial, commercial, and/or residential sources); and
- Recreators (EOA Inc. and U.C. Berkeley 1995; Yates et al. 1997).

Concentration of Pathogens in water

Unfortunately, only limited data have been published in the scientific literature to date on microbial pathogen concentrations in receiving waters and stormwater (Table 2). The limited amount of pathogen data available may be because most receiving water standards are still based on bacterial indicator. Furthermore, data characterizing the potential concentration of pathogens associated with blended wastewater treatment plant effluents is even more limited but is currently under investigation by the Water Environment Research Foundation (WERF).

Regardless of the availability of data, it is clear that microbial organisms (i.e., pathogens and indicator organisms) can be associated with numerous sources and do exist in receiving waters. Several studies in southern California have clearly demonstrated that indicator organisms are present in stormwater from both urban and undeveloped areas, where the potential from human sources is limited (Schoeder et. al. 2002, Schiff et. al. 2001)[1].

Table 2 Overview of Pathogens in Environmental Waters

STORMWATER CONCENTRATION TABLE

Pathogen Type	Pathogen	Range	Source	Notes
Virus	Rotavirus	2.4 X 10^{-1}/L	Rose et al. (1987)	surface water
		0.05 - 2.9 X 10^{1}/L	Gerba et al. (1996)	marine and freshwaters
	enteroviruses	0.1-6/10L	Griffin et al. (2003	marine water
		<0.01-0.24	MWRCD (2000, 1996, 1995, 1994)	urban fresh water
	reovirus	0.2-0.5/L	Griffin et al. (2003	Marine water
	adenovirus	8.8 X 10^{2} - 7.5 X 10^{3}L	Jiang et al. (2001)	PCR results: genomes/Liter
Protozoa	Cryptoporidium parvum	20 oocysts/L	States et al. (1997)	g. mean CSO discharge
		0.4 - 4/L (ICR) 0.1 - 0.8/L (EPA1623)	WWETCO (2003)	urban and rural creeks
		20 samples ND	Schroeder et al., (2002)	MDL ranged from 0.3-580oocysts/100mL
		130 cysts/L	Gibson et al. (1998)	mean, CSO discharge
	Giardia lamblia	20 samples ND	Schroeder et al., (2002)	MDL ranged from 0.3-580oocysts/100mL
		12-13/L (ICR) 0.35 - 3.75/L (EPA1623)	WWETCO (2003)	urban and rural creeks
		30-1000 cysts/L	Knauer et al. (1999)	CSO discharge
		150-300 cysts/L	Bowman (2002)	CSO discharge
		300 cysts/L	States et al. (1997)	g. mean CSO discharge
		600 cysts/L	Gibson et al. (1998)	mean, CSO discharge
Bacteria	Shigella	20 samples ND	Schroeder et al., (2002)	MDL ranged from 2.5-5000cfu/100mL
	Salmonella	<0.15 - 0.88/100mL	1997, 1996, 1995, 1994, 1993, 1991, 1989)	urban fresh water

Routes of Exposure

An exposure pathway may be defined as the course taken by a microorganism from its source to reach its receptor (human). Exposure is the most important link in the chain of infection and disease. There are a number of routes of exposure (Bitton, 1994):

- Person to Person – the most common route with AIDS and the common cold being good examples; however according to Bitton (1994), this route of transmission is important in the transmission of fecally transmitted diseases
- Waterborne –Individuals may be exposed to microbial pathogens released from a municipal wastewater treatment plant during blending events while swimming or recreating in surface water that received the discharge. In addition, during periods of high stormflows, it is extremely dangerous to swim or wade in the receiving waters, so the potential for human contact with bacteria and/or human pathogens that may be present is minimal.
- Foodborne - foods serve as a significant vehicle in the transmission disease microorganisms as noted previously.
- Airborne – this route may be associated with the transmission of aerosols generated by wastewater treatment plants and the beneficial reuse of effluents. However, in the United States, numerous studies have shown no increase in the incidence of human disease has occurred as a result of exposure to microbial aerosols either generated by a treatment plant or by the reuse of effluents (Bitton, 1994, NRC 1996 and 1998, Cooper 1991a).

1 Epidemiological studies to investigate the relationship between indicators and pathogens and illness have generally been conducted during the summer recreational season and not during periods of stormwater runoff and thus the results are not directly applicable to stormwater runoff.

- Vector-borne – transmission can occur from arthropods (fleas, insects) or vertebrates (dogs, cats, rodents) with the possibility of the pathogen multiplying in the vector, however, this route is not as important as person-to-person for the transmission of fecally transmitted diseases.
- Fomites – some pathogens can be transmitted by nonliving objects such as clothes toys, utensils, etc.

Public Health Risk - Assessment

Risk assessment has generally been the tool used to estimate risk associated with environmental exposures to pathogens[2]. Microbial risk assessment involves evaluating the likelihood that an adverse health effect may result from human exposure to one or more pathogens. A review of the recent work conducted in the field of microbial risk assessment indicates that two approaches for microbial risk assessment are commonly reported in the literature (Soller et al. 2003). In general, those approaches may be categorized as static, individual–based risk assessment, or dynamic, population-based risk assessments.

The static model (NRC 1983) is commonly used as a framework for carrying out microbial risk assessments related to water- and food-borne pathogens (Crabtree et al. 1997; Farber et al. 1996; Hass et al 1999, Sanaa et al. 2000; Voysey and Brown 2000). Assessments using a static model typically focus on estimating the probability of infection or disease as the result of a single exposure event. These assessments generally assume that multiple or recurring exposures constitute independent events with identical distributions of contamination (Regli et al. 1991), and that secondary transmission (e.g., person-to-person transmission) and immunity are either negligible or effectively cancel each other out. In actuality, secondary transmission would increase the level of infection/disease in a community relative to a specific exposure to pathogens, and immunity would decrease the level of infection/disease in a community relative to a specific exposure to pathogens.

In the static model, it is assumed that the population may be categorized into two epidemiological states: a susceptible state and an infected or diseased state. Susceptible individuals are exposed to the pathogen of interest and move into the infected/diseased state with a probability that is governed by the dose of pathogen to which they are exposed and the infectivity of the pathogen.

Another methodology that has been employed as a risk assessment model is a dynamic model (Eisenberg et al. 1996; Eisenberg et al. 1998; EOA Inc. 1995; EOA Inc. and U.C. Berkeley 1995; EOA Inc. and U.C. Berkeley 1999; Soller et al. 2003). In a dynamic risk assessment model, the population is assumed to be broken into a group of epidemiological states. Individuals move from state to state based on the natural history of the specific infectious disease (duration of infection, duration of immunity, etc.).

The infectious disease process in a population is, fundamentally, a dynamic process. Therefore, the most rigorous and scientifically defensible approach for mathematically modeling the infectious disease processes is to employ a dynamic model[3]. The two most important factors

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[2] Depending on the exposure scenario, health effects studies are sometimes used instead of risk assessments to develop regulatory policy. Health effects studies have played a significant role in developing regulatory policy for recreational water risks. While, in contrast, risk assessment models have historically been the primary toll used to develop regulations for drinking water exposures.

[3] Please note that under some conditions the results of the two risk assessment models yield similar results.

that affect the results of the modeling approaches are the dose of pathogens (which is directly related to the concentration in the receiving water) and the exposure intensity (which is a function of the frequency of exposure) (Soller et al 2003).

The reported results of a very simple static assessment (Katonak et.al, 2003) used to evaluate the potential public health concern associated with blending represents an estimate of the theoretical probability of illness/infection for a single exposure event for one individual. The static estimate is based on a number of conservative assumptions (e.g., no inactivation from disinfection) and only provides a gauge from which potential risk to an individual may be evaluated for a single exposure event. Clearly, as the authors' noted, the estimated risks will be lower if all flow is treated. However, the authors' estimated risks, even those based on the conservative assumptions, are within the range of risks considered acceptable by U.S. EPA national bacterial water quality criteria (i.e., the estimated maximum risk of infection 1/100 to 1/1000 vs. the median national water criteria risk of disease of 8/1000 to 1.9/100[4]).

Management of Risk

From a risk management perspective, the number of people exposed during events when blended effluent is discharged must be taken into consideration. Risk of infection/disease from a single exposure event above some predetermined tolerable level does not necessarily imply that public health concern is warranted. Specifically, the expected number of "cases" from an exposure event can be thought of as the product of the probability of illness (or infection) and the number of people exposed. It is within this paradigm that occupational exposure standards (where a lower number of people are exposed) for hazardous substances may be many times higher than levels acceptable for the general population (higher number of people exposed).

The protection of public health clearly dictates that when more individuals are potentially exposed to pathogens, a greater level of concern and thus protection is warranted when making risk management decisions. For example, one reason that a risk manager may decide to implement a control strategy at a specific location over another could be based on the actual or expected number of individuals potentially exposed.

Water quality regulation strategies endorsed by U.S. EPA follow the above public health concept. In the Ambient Water Quality Criteria for Bacteria (U.S. EPA 1986), EPA defines an acceptable swimming associated gastroenteritis (illness) rate and derives water quality criteria for designated beach areas, moderately used full body contact recreation areas, lightly used full body contact recreation areas, and infrequently used full body contact recreation areas. EPA's derivation of indicator bacteria limits based on the acceptable illness rate results in a maximum allowable density of indicator bacteria that increases as the potential number of exposed individuals decreases.

The current U.S. EPA approach is also consistent with a health based monitoring approach for recreational waters recently outlined by the World Health Organization (WHO) (WHO 1999) in which experts called for "an improved approach to the regulation of recreational water that better reflects health risk and provides enhanced scope for effective management

[4] The U.S. EPA Water Quality Criteria for Bacteria are the basis from which recreational water quality objectives are derived nationwide. EPA's water criteria document identifies an acceptable swimming associated gastroenteritis rate (median value) for freshwater of 8 cases per 1000 swimmers (U.S. EPA 1986). It should be clear, that this EPA acceptable illness rate is for a single recreational event and is regulated as a median (geometric mean) value.

intervention"[5]. The WHO approach also classifies health risk as a function of both degree of overall fecal contamination and susceptibility to human contamination.

Summary and Conclusions

Since the 1950s, numerous studies have examined the association between recreational water quality and health outcomes and many of these studies have reported an increased risk of illness associated with exposure to recreational waters (Wade et.al. 2003). However, epidemiological studies to investigate the relationship between indicators and pathogens and illness have generally been conducted during the summer recreational season and not during periods of stormwater runoff, and thus the results are not directly applicable to stormwater runoff and/or situations where blending may have occurred.

U.S. EPA recently reviewed the epidemiological and statistical methods used to derive the 1986 national water quality criteria (EPA, 2003). U.S. EPA has stated that it continues to believe that when appropriately applied and implemented the water quality criteria are protective of human health for acute gastrointestinal diseases. Although a number of new studies are underway (i.e., the BEACH Act 2000), EPA stated that no new epidemiological studies conducted since 1984 offer new or unique principles that significantly affect current water quality criteria (EPA, 2003).

An additional review of the most relevant epidemiological studies (Wade et.al. 2003) found that exposure below the EPA suggested water quality criteria presented no significant risk (i.e., swimmers vs. non-swimmers), while exposures above the criteria were associated with elevated and statistically significant risk of gastrointestinal illness to recreators. Further, taken as a whole, the body of literature supports use of the U.S. EPA water quality as useful predictors of gastrointestinal illness in recreational waters (Wade et.al 2003)[6].

The reported results of a very simple static assessment (Katonak et.al, 2003) used to evaluate the potential public health concern associated with blending represents an estimate of the theoretical probability of illness/infection for a single exposure event for one individual. The static estimate is based on a number of conservative assumptions (e.g., no inactivation from disinfection) and only provides a gauge from which potential risk to an individual may be evaluated for a single exposure event. Clearly, as the authors' noted, the estimated risks will be lower if all flow is treated. However, the authors' estimated risks, even those based on the conservative assumptions, are within the range of risks considered acceptable by U.S. EPA national bacterial water quality criteria (i.e., the estimated maximum risk of infection 1/100 to 1/1000 vs. the median national water criteria risk of disease of 8/1000 to 1.9/100).

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[5] According to this new approach for health based monitoring of recreational waters, the most robust, accurate, and feasible index of health risk is provided by a combination of a measure of microbiological indicator of fecal contamination with an inspection based assessment of the susceptibility of an area to direct influence from human fecal contamination (because "sources other than human fecal contamination present a significantly lesser risk to human health and by adopting a combined classification it is possible to reflect this modified risk").

[6] The author's note that no studies to date have specifically examined the impact of water exposure on persons whose immune system is compromised (Wade et.al. 2003). One recent comprehensive review of the literature on sensitive subpopulations' exposure to enteroviruses in recreational waters found that both qualitative and quantitative data currently available on populations of increased susceptibility to enteroviral disease offers limited insights for microbial risk assessment (Parkin et.al. 2003). Further, the results of the literature review indicated that there is more evidence ruling out waterborne transmission, or is not definitive than there is evidence that is suggestive or definitive for transmission of enteroviruses through recreational water (Parkin et.al. 2003).

A “one-size-fits-all” approach to address the potential public health concerns associated with blending would probably divert limited resources towards efforts where a commensurate public health benefit would not be realized. A risk-based management approach would better allow resources to be focused on the most important public health concerns and at the same time protect the beneficial use of the receiving waters.

It should be recognized that many aspects of the estimation and evaluation of potential health risks associated with exposure to microbial pathogens during recreational activities and the potential relationship to the use of blending as a management tool to treat wastewater during peak flow conditions are poorly understood. Many decisions must be made in an atmosphere of uncertainty with the “precautionary principle” encouraging decisions be made to err on the side of caution. However, it is imperative that sensible decisions are made that further a balanced approach to managing health risks.

There is concern regarding potential health risks associated with exposure to waters receiving discharges from treatment plants that are blending with storm waters. However, based on the above discussion, a number of factors support the use of a risk-based management approach that allows for the continued use of bending under conditions where current water quality criteria are met and the public health is protected.

I hope that above discussions helps to improve the understanding of the nature of the public health implications associated with the practice of wastewater treatment plant blending relative to exposure to microbial pathogens.

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