Health Effects Associated with Wastewater Treatment, Disposal, and Reuse

Keisuke Ikehata1*, Mohamed Gamal El-Din1 and Lisa N. Gochenour2

1Department of Civil & Environmental Engineering, 3-133 Markin/CNRL Natural Resources Engineering Facility, University of Alberta, Edmonton, Alberta T6G 2W2

2City of Omaha Department of Public Works, Omaha, Nebraska 68183

*Corresponding Author: Tel. 780-492-6197; Fax. 780-492-8198; e-mail: keisuke.ikehata@ualberta.net

doi:10.2175/106143006X119512

This review summarizes the literature published during 2005 and related to the health effects associated with wastewater treatment, disposal, and reuse. The following topics are covered: wastewater treatment upgrade and public health, wastewater treatment in developing countries, health effects of biological and chemical contaminants in wastewater, bioaerosols at wastewater treatment plants, wastewater reuse for agricultural irrigation, and wastewater and sludge disposal. This review focuses on the issues related to municipal (domestic) wastewater and human health.

Wastewater Treatment Upgrade and Public Health

Sadowska (2005) reviewed the sanitary and epidemiological conditions in the Łódź region in Poland. Significant improvement of the sanitary situation in Łódź was recognized in the period of the Second Polish Republic (1918-1939) primarily due to the creation of Sanitary
Divisions at the Łódź Department of Public Health and construction of water supply and sewage systems. In the same period, the control of trachoma (infectious disease caused by gram-negative bacterium *Chlamydia trachomatis*) was implemented in Łódź, which coincided with the improved sanitary conditions in the city (Berner, 2005).

The successive effluent upgrades for the metropolitan Boston area in 1991-2000 had led to reduced organic contaminant exposure and chronic hepatic sub-lethal impacts (hepatic hydropic vacuolation and tumor) in winter flounder in Massachusetts Bay (Moore et al., 2005). The effluent upgrades included the provision of primary and secondary treatment and outfall extension and diversion, as well as aggressive toxicant source reduction program.

**Wastewater Treatment in Developing Countries**

Poor environmental sanitation, such as direct deposition of human excrement, garbage, and wastewater in surface drains, open spaces, and streams in poor neighborhoods, is primarily responsible for the serious health impacts in developing countries (Boadi and Kuitunen, 2005). Since the conventional approach to sanitation is not adapted to their current socio-economic situations, it is desired to develop novel approaches to design and operate wastewater treatment systems for developing countries in Africa, Asia, and Latin America. An integrated modeling approach, which accounted for technical, institutional, financial, socio-economic, environmental, and public health issues, was proposed to provide a practical methodology for sanitation and drainage planning in Brazilian cities (Soares et al., 2005). Schertenleib (2005) discussed an advanced (sustainable) environmental sanitation approach (The Bellagio Principles and the Household Centered Environmental Sanitation Approach) to protect public health and aquatic ecosystems, as well as to conserve freshwater and non-renewable resources.

**Biological Contaminants in Wastewater**

**Bacterial Infections.** Food-borne listeriosis has become a serious public health issue in France. The primary sources of contamination are likely treated wastewater and sewage sludge. *Listeria* spp. (e.g., *L. monocytogenes*) has been detected in most treated water (84.4%) and raw sludge (89.2%) of six French wastewater treatment plants and in one composting facility (Paillard et al., 2005).

Oliver et al. (2005) reported that chlorine disinfection on *Escherichia coli* (and *Salmonella typhimurium*) in secondary-treated wastewater induced the bacteria into the “viable but nonculturable (VBNC) state”. They suggested that the presence of such nonculturable cells in treated wastewater could cause a potential public health hazard.

**Protozoan Infections.** Eisenberg et al. (2005) reported a new analysis of the 1993 *Cryptosporidium* outbreak in Milwaukee, Wisconsin. The analysis indicated that the outbreak was caused by a transmission cycle due to infectious persons shedding pathogens into the sewage, environmental transport of these pathogens via Lake
Michigan to the drinking water treatment plant, and infection of susceptible persons via exposure to drinking water.

A protozoan parasite, *Leishmania chagasi* causes visceral leishmaniasis, which is a growing public health concern. Since 1980, there have been two large outbreaks of visceral leishmaniasis (1981-1985 and 1993-1996) in Teresina, Brazil (Costa et al., 2005). These outbreaks were attributed to the inadequate sewage treatment system and non-regular rubbish collection in some of the households; thus improving household structure and providing sanitation services were suggested as effective strategies for controlling the future occurrence of visceral leishmaniasis.

**Coronaviruses (Severe Acute Respiratory Syndrome and Avian Influenza A).** Severe acute respiratory syndrome (SARS) and avian influenza A (H5N1) pandemic occurred in 2003 and killed a large number of people and animals in many parts of the world. Matsui (2005) discussed the possible link between the origin of SARS pandemic in South East Asia and the living conditions of farmers (including the way to raise birds and pigs) in that region. It was suspected that viral transmission might have occurred among ducks/chickens, pigs, and humans by sharing ponds for domestic wastewater discharge, fish culture, and raising ducks. Provision of good human, pig, and chicken sanitation, such as wastewater treatment, was suggested for the successful control of these viral infections. The possibility of the transmission of severe acute respiratory syndrome coronavirus (SARS-CoV) by the sewage system was also investigated (Wang et al., 2005). In Beijing, China, SARS-CoV ribonucleic acid was detected in the sewage from two hospitals receiving SARS patients by semi-nested real-time polymerase chain reaction and sequencing of genes. Although no live SARS-CoV was detected, they suggested that closer attention should be paid to the treatment of stools of patients and the sewage of hospitals to control SARS transmission.

**Hepatitis Viruses.** In the Zenica-Doboj Canton, Bosnia and Herzegovina, 1106 hepatitis A virus infections were reported during 2000 (Uzunovic-Kamberovic et al., 2005). Poor sewage sanitation systems in rural households that deteriorated the water supplies were implicated as a promoter of the outbreak. Bofill-Mas et al. (2005) suggested that the prevalence of pathogenic viruses, such as hepatitis E virus and human polyomaviruses, in the environment represented significant health risks even in highly industrialized countries. The biosolids generated in wastewater treatment plants were considered a major source of viral contamination in the environment.

**Human Noroviruses.** Norovirus infections are the most frequent causes of non-bacterial gastroenteritis, which lead to high virus loads in sewage. A number of norovirus variants were detected in 49 out of 53 sewage samples collected in the Netherlands in 2000 and 2001 with average concentrations of approximately $10^5$ per detectable unit (pdu) per liter (van den Berg et al., 2005). Of these, two strains were prevalent among populations in Europe during the same period. Wastewater treatment achieved 2.0 to 2.7 log10 unit of virus removal, resulting in $10^2$ to $10^3$ norovirus pdu/L in treated wastewater that possibly
polluted drinking water, shellfish culture and recreational water. Ueki et al. (2005) demonstrated a potential geographical association of noroviruses between human and cultivated oysters via water environment in Miyagi prefecture, Japan. Treated wastewater (89% of the samples were positive for norovirus gene) was considered as one of the major sources of norovirus pollution.

Gelting et al. (2005) demonstrated the importance of an environmental health assessment as a component of infectious disease outbreak investigation using an incidence of waterborne norovirus outbreak in Sheridan County, Wyoming in 2001 as an example. A systems-based environmental health assessment revealed that an on-site wastewater disposal system, which was not well suited to local soil and geologic conditions, in the recreational area of the Sheridan County was overloaded by increased use and contaminated drinking water wells that received no treatment or disinfection. The environmental health assessment can be useful to develop prevention strategies for avoiding reoccurrences of similar incidents.

**Polioviruses.** A clinico-virological survey of poliomyelitis has been carried out in the Czech Republic (Matyasova, 2005). Within the surveillance, 15,460 sewage water samples (plus 1,280 samples from refugee camps) were analyzed. No wild virus has been detected since 1961, which is consistent with the absence of paralytic poliomyelitis in this country. The vaccine-derived polio virus (VDPV) represents a major challenge to the eradication of polio as VDPV may acquire the virulence and transmission characteristics of wild poliovirus (Černáková et al., 2005). In 2003, type 2 polioviruses (later found to be VDPV) were detected in three samples taken from wastewater treatment facilities in the Slovak Republic, while no case of polio has occurred there since 1961. The use of oral polio vaccine is considered to be responsible for the circulation of VDPV in the environment.

**Nematode Infections.** Moubarrad and Assobhei (2005) reported a possible association of wastewater discharge and ascariasis (disease caused by a parasitic round worm *Ascaris lumbricoides*) among the children in El Jadida, Morocco. The incidence of ascariasis was significantly higher ($p < 0.001$) in the group of children living near an area of wastewater effluent (18.1%) than in the control group (1%). They also noted that boys, particularly those aged 7 to 10, were the most vulnerable to contracting ascariasis. More cases regarding nematode infections are presented in the subsection entitled *Wastewater Reuse for Agricultural Irrigation.*

**Chemical Contaminants in Wastewater**

**Endocrine Disrupting Compounds (EDCs).** Significant estrogenic effects in bream (*Abramis brama*) in major inland surface waters in the Netherlands were investigated (Vethaak et al., 2005). Hormones (especially 17a-ethynylestradiol) and nonlyphenol ethoxylates from a wastewater treatment plant were considered primarily responsible for those effects. Klein et al. (2005) also demonstrated elevated vitellogenin levels in breams sampled at near to or downstream of sewage plants’ discharges in Southwestern Germany, although the linkage between the bioaccumulation and the effects of alkylphenols (such as 4-nonylphenol) and their ethoxylates...
McMaster et al. (2005) reported that some responses of altered reproductive function in resident fish populations were observed downstream of a municipal wastewater treatment plant discharge as well as in the proximity of a pulp and paper mill in the Northern River Basins, Alberta, Canada.

The uptake and effects of 4-nonylphenol in the insectivorous tree swallow (Tachycineta bicolor) in wastewater lagoons in Vancouver, Canada (Dods et al., 2005), where elevated levels of 4-nonylphenol were found in lagoon sediment and insects (82 to 383 µg/g dry weight and 156 to 310 ng/g wet weight, respectively). The clutch size and fledging success were significantly lower ($p < 0.05$ and $< 0.001$, respectively) in 2000, while the mean mass of nestling livers was significantly higher ($p < 0.001$) in tree swallows in the study site as compared with the reference site. They suggested the use of tree swallow as a possible indicator species for exposure of 4-nonylphenol at wastewater treatment plants.

Vine et al. (2005) investigated the possible endocrine disruption in a top predator fish, pike (Esox lucius), by a wastewater treatment plant effluent in the United Kingdom. They hypothesized that this top predator fish might have been affected by lipophilic EDCs through predator-prey relationship; however, no evidence of severe disruption, measured by yeast-based estrogen assay of bile and histological analysis of gonads, was found in the sampled fish from 16 sampling sites.

Weak biological effects were detected in wild carp (Cyprinus carpio) from three rivers in Spain, which were related to the exposure to estrogenic compounds (hormones, bisphenol A, and octylphenols) derived from sewage treatment plants (Carballo et al., 2005). Only in 18% of fish from one of the rivers (Guadarrama river) there were elevated levels of plasma vitellogenin, while neither abnormal gonadosomic index nor oocytes in the testis were found in any of the male fish examined.

Genotoxins (Mutagens). Genotoxic pollutants are introduced into the aquatic environment by wastewaters coming from different sources. Jolibois and Guerbet (2005) investigated the removal of genotoxicity at two wastewater treatment plants that consisted of pre-treatment, primary treatment by settling, and secondary (activated sludge) treatment in the Rouen, France. Genotoxins were detected in almost all influents (24 samples) with the Ames fluctuation test on Salmonella typhimurium strains TA98, 100, 102 with or without metabolic activation, while all of the tested effluents were non-genotoxic, indicating effective removal of toxins during the wastewater treatment processes.

Pharmaceuticals and Personal Care Products.

The occurrence of pharmaceuticals and personal care products in surface water and raw as well as treated wastewater is an emerging environmental and public health issue (Hileman, 2005). Schwab et al. (2005) reported human health risk assessments for 26 environmentally-relevant active pharmaceutical ingredients and/or their metabolites in the United States by developing acceptable daily intakes (ADIs) and using the PhATE model, an environmental fate and effects model. Ratios of measured environmental concentrations (MECs) to predicted-no-
effect concentrations (PNECs) were typically very low, indicating that no appreciable human health risk exists from the presence of trace concentrations of pharmaceuticals in surface water and drinking water.

The Stockholm County Council, the provider of public healthcare in Stockholm, Sweden has introduced a classification of pharmaceuticals commonly found in municipal wastewater and surface water according to their potential for biodegradation, bioaccumulation, and ecotoxicity (Wennmalm and Gunnarsson, 2005). In the first phase of the investigation, 10 out of 22 antibiotics and viral inhibitors were considered to pose risk to public health via surface water accumulation or to aquatic life.

Bioaerosols at Wastewater Treatment Plants

Inhalation of bioaerosols (endotoxins, airborne bacteria, and fungal spores) has been implicated in lung epithelial injury (i.e., toxic pneumonitis) among workers at wastewater treatment plants. Oppliger et al. (2005) investigated the seasonal variation of bioaerosol (airborne cultivable bacteria, fungi, and endotoxin) exposures in wastewater treatment plant workers in Switzerland. They found that only airborne fungi were present at significantly higher concentrations in summer (2331 ± 858 cfu, \( p < 0.001 \)) than in winter (329 ± 95 cfu) and that there were more bacteria in enclosed areas than in unenclosed areas. They also noted that the airborne bacteria found were mostly gram-negative bacteria in the Pseudomonadaceae and Enterobacteriaceae families, and that enteric bacteria such as \( E. \) coli were present generally at low numbers and were detected less frequently. Similar results were reported by Cyprowski et al. (2005) who investigated the occupational exposure to bioaerosols and chemical agents in a wastewater treatment plant in Poland.

Fernando and Fedorak (2005) reported the marked reduction of culturable airborne microorganisms at a wastewater treatment plant in Edmonton, Alberta, Canada. Modifications of the wastewater treatment plant included expansion and conversion of secondary treatment from a conventional activated sludge process to a biological nutrient removal system using fine bubble aeration, covering the grit tanks and primary settling tanks, and changing the design and operation of indoor automated sampling taps and sinks. Although these modifications were primarily made to reduce odor problems and improve treatment efficiency, they also contributed to the reduction of the number of airborne microorganisms.

It was reported that exposure to bioaerosols increased serum Clara cell protein (CC16) concentration in the wastewater workers, although no indication of work-related respiratory diseases was found (Steiner et al., 2005). Smit et al. (2005) used endotoxin exposure data and questionnaires of 468 employees from 67 sewage treatment plants in the Netherlands to investigate work-related symptoms in these workers. They found that the “lower respiratory and skin”, “flue-like and systemic”, and “upper respiratory” symptoms were more prevalent in workers exposed to endotoxin levels higher than 50 endotoxin units/m\(^3\).
Wastewater Reuse for Agricultural Irrigation

Raw and treated wastewater and sewage sludge that contain ample nutrients have been used for irrigation in agricultural activities for years. In many developing countries, however, the insufficient treatment of wastewater and sludge often causes the deterioration in surface water quality by microbial and chemical contamination, subsequently leading to contamination of crops and drinking water (Amoah et al., 2005). In order to alleviate this problem, the World Health Organization (WHO) developed *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture* in 1989. Carr (2005) reviewed the current activity to revise the WHO Guidelines based on new data from epidemiological studies, quantitative microbial risk assessments, and other information.

Raschid-Sally et al. (2005) identified and discussed common waterborne diseases related to agricultural irrigation using raw or partially treated wastewater, such as diarrhea, cholera, hepatitis A, paratyphoid and typhoid, polio, and helminthiasis. They suggested that anticipated health risks might vary among different groups of people, including farmers, consumers, and nearby communities. Health risks were also discussed in conjunction with other issues in agricultural irrigation using raw or partially treated wastewater, such as choice of crops, irrigation technologies, hydrology, and socio-economic issues (Huibers and Van Lier, 2005; Martijn and Redwood, 2005).

The health risks of agricultural irrigation using raw wastewater were investigated. In Faisalabad, Pakistan, Ensink et al. (2005) found that the farmers (and their children) using untreated wastewater for irrigation were at significantly higher risks ($p < 0.001$) of intestinal infection by hookworm (most prevalent), *Ascaris lumbricoides*, and *Trichuris trichiura* than the farmers using regular irrigation water. Amahmid and Bouhoum (2005) reported similar results found in Marrakech, Morocco.

It has been suggested that repeated applications of metal-enriched substances such as fertilizers, sewage sludge, and raw and treated wastewater to the agroecosystem might cause contamination and toxicity problems (He et al., 2005). Mapanda et al. (2005) reported accumulation of heavy metals (7 to 145 mg Cu/kg, 14 to 228 mg Zn/kg, 0.5 to 3.4 mg Cd/kg, <0.01 to 21 mg Ni/kg, 33 to 225 mg Cr/kg, 4 to 59 mg Pb/kg) in the soils that were irrigated with treated wastewater for 10 years compared to control soils in Harare, Zimbabwe. They warned that the heavy metal concentration might exceed the permitted levels within 5 to 60 years, which could pose potential environmental and health risks.

Greywater irrigation in households and small private farms is increasingly popular partly due to the notion that greywater is of better quality than raw wastewater (i.e., blackwater). However, it was shown that greywater may be of similar quality to wastewater in several parameters such as BOD and fecal coliforms, and even worse than the latter in terms of boron and surfactant concentrations (Gross et al., 2005). Thus, treatment of greywater before using it for irrigation may be recommended.
Wastewater and Sludge Disposal

Bloetscher et al. (2005) evaluated three wastewater effluent disposal alternatives, including deep well injection, ocean outfalls, and surface water discharge, in Southeast Florida. Among the three alternatives, deep well injection after secondary treatment appeared to pose lower health and urban ecological risks than the other two methods.

It has been recognized in recent years that land application of sewage sludge (biosolids) that contains human, animal, and plant pathogens poses important public and environmental health risks (Gerba and Smith, 2005). Godfree and Farrell (2005) discussed the processes for managing pathogens arising from land application of biosolids based on the concept of multiple barriers (proper treatment, crop restriction, and limiting application intervals) employed in the United States and Europe.

Avery et al. (2005) demonstrated the persistence of highly virulent E. coli O157:H7 in raw and treated sewage sludge, as well as other organic wastes from slaughterhouses, creameries, and farms (bovine slurry). Although the number of E. coli O157:H7 gradually declined during the storage at 10 °C, it was still viable in 77% of the wastes tested after 2 months. Thus, long-term storage of sewage sludge cannot be expected to completely eliminate this pathogenic strain of E. coli.

The leachate of a municipal sewage sludge that contains toxic metals and organic chemicals can contaminate surface water and groundwater and lead to serious health hazards. Tewari et al. (2005) investigated the sub-acute genotoxic effects of municipal sludge leachate in mice. A dose-dependent inhibition of mitotic index and induction of chromatid/chromosome fragments and breaks were observed among other genotoxic effects in the male mice that were orally given leachate (0.1 to 0.4 mL/mouse/day) for 15 days.

References

Amahmid, O. and Bouhoum, K. (2005). Assessment of the Health Hazards Associated with Wastewater Reuse: Transmission of Geohelminthic Infections (Marrakech, Morocco). Int. J. Environ. Health Res., 15, 127.

Amoah, P., Drechsel, P. and Abaidoo, R. C. (2005). Irrigated Urban Vegetable Production in Ghana: Sources of Pathogen Contamination and Health Risk Elimination. Irrig. Drain., 54, S49.

Avery, L. M., Killham, K. and Jones, D. L. (2005). Survival of E. Coli O157:H7 in Organic Wastes Destined for Land Application. J. Appl. Microbiol., 98, 814.

Berner, W. (2005). Trachoma Control in Łódź at the Time of the II Republic of Poland. Przegl. Epidemiol., 59, 173.

Bloetscher, F., Englehardt, J. D., Chin, D. A., Rose, J. B., Tchobanoglous, G., Amy, V. P. and Gokgoz, S. (2005). Comparative Assessment of Municipal Wastewater Disposal Methods in Southeast Florida. Water Environ. Res., 77, 480.

Boadi, K. O. and Kuitunen, M. (2005). Environment, Wealth, Inequality and the Burden of Disease in the Accra Metropolitan Area, Ghana. Int. J. Environ. Health Res., 15, 193.

Bofill-Mas, S., Clemente-Casares, P., Albinana-Gimenez, N., de Motes Porta, C. M., Hundesa Gonfa, A. and Girones Llop, R. (2005). Effects on Health of Water and Food Contamination by Emergent Human Viruses. Rev. Esp. Salud Pública, 79, 253.
Carballo, M., Aguayo, S., de la Torre, A. and Muñoz, M. J. (2005). Plasma Vitellogenin Levels and Gonadal Morphology of Wild Carp (Cyprinus Carpio L.) in a Receiving Rivers Downstream of Sewage Treatment Plants. Sci. Total Environ., 341, 71.

Carr, R. (2005). Who Guidelines for Safe Wastewater Use - More Than Just Numbers. Irrig. Drain., 54, S103.

Černáková, B., Sobotová, Z., Rovny, I., Bláhova, Š., Roivainen, M. and Hovi, T. (2005). Isolation of Vaccine-Derived Polioviruses in the Slovak Republic. Eur. J. Clin. Microbiol. Infect. Dis., 24, 438.

Costa, C. H., Werneck, G. L., Rodrigues, L., Jr., Santos, M. V., Araújo, I. B., Moura, L. S., Moreira, S., Gomes, R. B. and Lima, S. S. (2005). Household Structure and Urban Services: Neglected Targets in the Control of Visceral Leishmaniasis. Ann. Trop. Med. Parasitol., 99, 229.

Cyprowski, M., Szarapinska-Kwaszewska, J., Dudkiewicz, B., Krajewski, J. A. and Szadkowska-Stanczyk, I. (2005). Exposure Assessment to Harmful Agents in Workplaces in Sewage Plant Workers. Med. Pr., 56, 213.

Dods, P. L., Birmingham, E. M., Williams, T. D., Ikonomou, M. G., Bennie, D. T. and Elliott, J. E. (2005). Reproductive Success and Contaminants in Tree Swallows (Tachycineta Bicolor) Breeding at a Wastewater Treatment Plant. Environ. Toxicol. Chem., 24, 3106.

Eisenberg, J. N. S., Lei, X. D., Hubbard, A. H., Brookhart, M. A. and Colford, J. M. (2005). The Role of Disease Transmission and Conferring Immunity in Outbreaks: Analysis of the 1993 Cryptosporidium Outbreak in Milwaukee, Wisconsin. Am. J. Epidemiol., 161, 62.

Ensink, J. H. J., van der Hoek, W., Mukhtar, M., Tahir, Z. and Amerasinghe, F. P. (2005). High Risk of Hookworm Infection among Wastewater Farmers in Pakistan. Trans. Roy. Soc. Trop. Med. Hyg., 99, 809.

Fernando, N. L. and Fedorak, P. M. (2005). Changes at Art Activated Sludge Sewage Treatment Plant Alter the Numbers of Airborne Aerobic Microorganisms. Water Res., 39, 4597.

Gelting, R., Sarisky, J., Selman, C., Otto, C., Higgins, C., Bohan, P. O., Buchanan, S. B. and Meehan, P. J. (2005). Use of a Systems-Based Approach to an Environmental Health Assessment for a Waterborne Disease Outbreak Investigation at a Snowmobile Lodge in Wyoming. Int. J. Hyg. Environ. Health., 208, 67.

Gerba, C. P. and Smith, J. E. (2005). Sources of Pathogenic Microorganisms and Their Fate During Land Application of Wastes. J. Environ. Qual., 34, 42.

Godfree, A. and Farrell, J. (2005). Processes for Managing Pathogens. J. Environ. Qual., 34, 105.

Gross, A., Azulai, N., Oron, G., Ronen, Z., Arnold, M. and Nejdat, A. (2005). Environmental Impact and Health Risks Associated with Greywater Irrigation: A Case Study. Water Sci. Technol., 52(8), 161.

He, Z. L., Yang, X. E. and Stoffella, P. J. (2005). Trace Elements in Agroecosystems and Impacts on the Environment. J. Trace Elem. Med. Biol., 19, 125.

Hileman, B. (2005). Antiseptic Soaps under Scrutiny. Chem. Eng. News, 83(43), 14.

Huibers, F. P. and Van Lier, J. B. (2005). Use of Wastewater in Agriculture: The Water Chain Approach. Irrig. Drain., 54, S3.

Jolibois, B. and Guerbet, M. (2005). Efficacy of Two Wastewater Treatment Plants in Removing Genotoxins. Arch. Environ. Contam. Toxicol., 48, 289.

Klein, R., Bartel, M., He, X. H., Müller, J. and Quack, M. (2005). Is There a Linkage between Bioaccumulation and the Effects of Alkylphenols on Male Breams (Abramis Brama)? Environ. Res., 98, 55.
Mapanda, F., Mangwayana, E. N., Nyamangara, J. and Giller, K. E. (2005). The Effect of Long-Term Irrigation Using Wastewater on Heavy Metal Contents of Soils under Vegetables in Harare, Zimbabwe. *Agric. Ecosyst. Environ.*, **107**, 151.

Martijn, E. J. and Redwood, M. (2005). Wastewater Irrigation in Developing Countries - Limitations for Farmers to Adopt Appropriate Practices. *Irrig. Drain.*, **54**, S63.

Matsui, S. (2005). Protecting Human and Ecological Health under Viral Threats in Asia. *Water Sci. Technol.*, **51**(8), 91.

Matyasova, I. (2005). Poliomyelitis Surveillance in the Czech Republic from the Start of Vaccination to the Certification of Eradication in the European Region. *Epidemiol. Mikrobiol. Imunol.*, **54**, 16.

McMaster, M. E., Hewitt, L. M., Tetreault, G. R., Janoscik, T., Boyko, C., Peters, L., Parrott, J. L., Van Der Kraak, G. J., Portt, C. B., Kroll, K. J. and Denslow, N. D. (2005). Detailed Endocrine Assessments of Wild Fish in the Northern River Basins, Alberta, in Comparison to Eem Monitored Endpoints. *Water Qual. Res. J. Can.*, **40**, 299.

Moore, M., Lefkovitz, L., Hall, M., Hillman, R., Mitchell, D. and Burnett, J. (2005). Reduction in Organic Contaminant Exposure and Resultant Hepatic Hydropic Vacuolation in Winter Flounder (*Pseudopleuronectes Americanus*) Following Improved Effluent Quality and Relocation of the Boston Sewage Outfall into Massachusetts Bay, USA: 1987-2003. *Mar. Pollut. Bull.*, **50**, 156.

Moubarrad, F.-Z. L. and Assobhei, O. (2005). The Health Effects of Wastewater on the Prevalence of Ascariasis among the Children of the Discharge Zone of El Jadida, Morocco. *Int. J. Environ. Health Res.*, **15**, 135.

Oliver, J. D., Dagher, M. and Linden, K. (2005). Induction of *Escherichia Coli* and *Salmonella Typhimurium* into the Viable but Nonculturable State Following Chlorination of Wastewater. *J. Water Health*, **3**, 249.

Oppliger, A., Hilfiker, S. and Duc, T. V. (2005). Influence of Seasons and Sampling Strategy on Assessment of Bioaerosols in Sewage Treatment Plants in Switzerland. *Ann. Occup. Hyg.*, **49**, 393.

Paillard, D., Dubois, W., Thiebaut, R., Nathier, F., Hoogland, E., Caumette, P. and Quentin, C. (2005). Occurrence of Listeria Spp. In Effluents of French Urban Wastewater Treatment Plants. *Appl. Environ. Microbiol.*, **71**, 7562.

Raschid-Sally, L., Carr, R. and Buechler, S. (2005). Managing Wastewater Agriculture to Improve Livelihoods and Environmental Quality in Poor Countries. *Irrig. Drain.*, **54**, S11.

Sadowska, J. (2005). Sanitary and Epidemiological Conditions in the Łódź Region During the Period of the Second Polish Republic in the XIX and XX Centuries. *Przegl. Epidemiol.*, **59**, 163.

Schertenleib, R. (2005). From Conventional to Advanced Environmental Sanitation. *Water Sci. Technol.*, **51**(10), 7.

Schwab, B. W., Hayes, E. P., Fiori, J. M., Mastrocco, F. J., Roden, N. M., Cragin, D., Meyerhoff, R. D., D’Aco, V. J. and Anderson, P. D. (2005). Human Pharmaceuticals in Us Surface Waters: A Human Health Risk Assessment. *Regul. Toxicol. Pharmacol.*, **42**, 296.

Smit, L. A. M., Spaan, S. and Heederik, D. (2005). Endotoxin Exposure and Symptoms in Wastewater Treatment Workers. *Am. J. Ind. Med.*, **48**, 30.

Soares, S. R. A., Parkinson, J. and Bernardes, R. S. (2005). Analysis of Scenarios for Wastewater and Urban Drainage Systems in Brazil Based on an Integrated Modeling Approach. *Water Sci. Technol.*, **52**(9), 53.

Steiner, D., Jeggli, S., Tschopp, A., Bernard, A., Oppliger, A., Hilfiker, S. and Hotz, P. (2005). Clara Cell Protein and
Surfactant Protein B in Garbage Collectors and in Wastewater Workers Exposed to Bioaerosols. Int. Arch. Occup. Environ. Health, 78, 189.

Tewari, A., Chauhan, L. K., Kumar, D. and Gupta, S. K. (2005). Municipal Sludge Leachate-Induced Genotoxicity in Mice—a Subacute Study. Mutat. Res., 587, 9.

Ueki, Y., Sano, D., Watanabe, T., Akiyama, K. and Omura, T. (2005). Norovirus Pathway in Water Environment Estimated by Genetic Analysis of Strains from Patients of Gastroenteritis, Sewage, Treated Wastewater, River Water and Oysters. Water Res., 39, 4271.

Uzunovic-Kamberovic, S., Durmisevic, S. and Tandir, S. (2005). Environmental Risk Factors for Hepatitis A Infection in the Zenica-Doboj Canton, Bosnia and Herzegovina. Clin. Microbiol. Infect., 11, 145.

van den Berg, H., Lodder, W., van der Poel, W., Vennema, H. and Husman, A. M. D. (2005). Genetic Diversity of Noroviruses in Raw and Treated Sewage Water. Res. Microbiol., 156, 532.

Vethaak, A. D., Lahr, J., Schrap, S. M., Belfroid, A. C., Rijs, G. B., Gerritsen, A., de Boer, J., Bulder, A. S., Grinwis, G. C. M., Kuiper, R. V., Legler, J., Murk, T. A. J., Peijnenburg, W., Verhaar, H. J. M. and de Voogt, P. (2005). An Integrated Assessment of Estrogenic Contamination and Biological Effects in the Aquatic Environment of the Netherlands. Chemosphere, 59, 511.

Vine, E., Shears, J., van Aerle, R., Tyler, C. R. and Sumpter, J. P. (2005). Endocrine (Sexual) Disruption Is Not a Prominent Feature in the Pike (Esox Lucius), a Top Predator, Living in English Waters. Environ. Toxicol. Chem., 24, 1436.

Wang, X. W., Li, J., Guo, T., Zhen, B., Kong, Q., Yi, B., Li, Z., Song, N., Jin, M., Xiao, W., Zhu, X., Gu, C., Yin, J., Wei, W., Yao, W., Liu, C., Li, J., Ou, G., Wang, M., Fang, T., Wang, G., Qiu, Y., Wu, H., Chao, F. and Li, J. (2005). Concentration and Detection of Sars Coronavirus in Sewage from Xiao Tang Shan Hospital and the 309th Hospital of the Chinese People's Liberation Army. Water Sci. Technol., 52(8), 213.

Wennmalm, A. and Gunnarsson, B. (2005). Public Health Care Management of Water Pollution with Pharmaceuticals: Environmental Classification and Analysis of Pharmaceutical Residues in Sewage Water. Drug Inf. J., 39, 291.