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Prevalence of enteropathogenic bacteria in treated effluents and receiving water bodies and their potential health risks

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HIGHLIGHTS

- Wastewater treatment plants failed to produce effluents of high microbial quality.
- Pathogenic bacteria in the effluents impacted on the receiving water body quality.
- Up to 93% of water samples showed *Salmonella* spp., *Shigella* spp. and *Vibrio cholera*.
- Daily combined risk of enteropathogen infection was above the WHO risk limit (10^{-4}).

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ABSTRACT

The failure of wastewater treatment plants to produce effluents of a high microbiological quality is a matter of great concern in terms of water resource pollution. A more serious concern is that this water source is used by communities in developing countries for multiple purposes, which include drinking, recreation and agriculture. The current study investigated the prevalence and potential health risks of enteropathogenic bacteria (*Salmonella typhimurium*, *Shigella dysenteriae* and *Vibrio cholerae*) in the treated effluents of three selected South African Wastewater Treatment Works as well as their receiving water bodies. Culture-based and polymerase chain reaction techniques were used to detect and identify the pathogenic bacteria. The conventional methods revealed that of the 272 water samples collected, 236 samples (86.8%) tested presumptively positive for *Salmonella* spp., 220 samples (80.9%) for *Shigella* spp. and 253 samples (93.0%) for *V. cholerae*. Molecular test results indicated that out of the randomly selected presumptive positive samples (145), zero to 60% of samples were positive for *S. typhimurium* and *S. dysenteriae* and 20% to 60% for *V. cholerae*. For the health risk assessment, the daily combined risk of *S. typhimurium*, *S. dysenteriae* and *V. cholerae* infection was above the lowest acceptable risk limit of 10^{-4} as estimated by the World Health Organization for drinking water. This study showed that the target treated wastewater effluents and their receiving water bodies could pose a potential health risk to the surrounding communities.

1. Introduction

Africa especially Sub-Saharan Africa faces severe challenges as its people have very limited access to basic sanitation (WHO/UNICEF JMP, 2012). With a population growth of almost 400 million people since 1990, the population without an improved sanitation facility has increased by 200 million people to 612 million in 2010. Over this period, it has been estimated that more than one in four people in urban areas relied on shared or public sanitation facilities. In other words, little over one in five people in Africa still practise open defecation, down from one in three in 1990. With only six percent of the population practicing open defecation in urban areas, this rate is fivefold in rural areas (32%) (WHO/UNICEF JMP, 2012). These figures clearly imply that the role of sanitation in the transmission of disease tends to be forgotten in developing countries by both consumers and managers of sanitation facilities. The challenges of an effective protection of water resources from the impacts of human wastes and domestic sewage disposal in peri-urban and rural areas are currently a matter of concern (Momba et al., 2006). In South Africa for example, uncontrolled sewage discharges and poorly managed wastewater treatment plants have been identified as two of the major sources of microbial pollution of water sources (Dungeni et al., 2010). The quality of the surface water is dubious because inadequately treated wastewater disposal and other non-point sources of pollution such as agricultural pollutants in the surrounding localities enter the scarce water resources of the country (Momba et al., 2006). This problem is exacerbated due to continuous population growth, as well as the implications of industrialisation and

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urbanisation (DWAF, 2004). In 2009, an assessment of 852 South African municipal wastewater treatment works revealed that only 449 (53%) plants were within the compliance limits set for water quality standards and only 203 (45%) of the plants assessed scored better than 50% in measurements against the stringent criteria set by the Department of Water Affairs (Dungeni et al., 2010).

Water source polluted with human and animal faeces contains microorganisms, which can cause deadly diseases, especially in rural areas and other informal settlement dwellers (Cabral, 2010). Among the pathogens disseminated in water sources, enteric pathogens such as *Shigella* spp., *Vibrio cholerae* and *Salmonella typhimurium* are the most frequently encountered and are usually transmitted to humans by the ingestion of contaminated water and foods (Momba et al., 2006). Diarrhoea caused by these pathogens is the second leading contributor to global burden of disease, ahead of heart disease and HIV/AIDS. Approximately 40% of childhood deaths from diarrhoea worldwide occurred in Sub-Saharan Africa by the year 2000. Moreover diarrhoea has been estimated to be responsible for 25 to 75% of all childhood illnesses in Africa with *V. cholerae* reported as the most frequent pathogen in this region (Dewaal et al., 2010). Cholera on the other hand has been well thought-out as an indicator of social stratum of communities, and Africa accounts for over 90% of all cholera cases (WHO, 2007). Unless people have access to basic services such as safe drinking water and improved sanitation infrastructures, efforts to prevent death due to waterborne pathogens are doomed to failure, especially to everyone who relies on direct use of effluents discharged into watercourses.

The risk of contracting the waterborne diseases has been articulated as the likelihood of adverse health effects (dose–response) and may depend on the magnitude, timing and duration of exposure to pathogenic microorganisms (ILSI-Risk Science Institute Pathogen Risk Assessment Working Group, 1996). The dose mounts up in due course each time a pathogen causes a risk of infection independently when others enter the host. However, multiple exposures to a single dose can generate the very same total risk as a single exposure that has the dose magnitude equivalent to the multiple exposures (Eisenberg et al., 2005; Atkinos and Wein, 2008; Pujol et al., 2009). According to NRC (1983), the dose–response relationship and exposure assessment are combined to describe the risk to subject persons. Therefore, health risk assessment and exposure assessment describe the probability of actual or anticipated human exposure to pathogenic microorganisms or microbiological toxins. It has been reported that the assessment of the probability of infection is related to the microorganism (virulence and infectivity, genetic material and/or dosage); human host (age, pregnancy, nutrition, overall health, medication status, concurrent infections, immune status and previous exposure history) and population characteristics (population immunity and access to medical care) (WHO, 1999).

The aim of this study was twofold: i) to investigate the prevalence of *S. typhimurium*, *Shigella dysenteriae* and *V. cholerae* in the treated wastewater effluents and receiving water bodies of the target wastewater treatment plants in peri-urban area of the City of Tshwane Metropolitan Municipality, Gauteng Province, South Africa; and ii) to assess the health risk of these enteropathogenic bacteria to surrounding communities of Sedibeng District Municipality and Soshanguve peri-urban area of the Tshwane Metropolitan Municipality, Gauteng Province. These selected areas have been used as an example to showcase issues occurring in most developing countries that are facing challenges for an effective protection of water sources and public health.

2. Materials and methods

2.1. Study sites

This study was conducted between August 2011 and May 2012 at four wastewater treatment facilities (Leeuwkuil, Meyerton, Rietgat and Sandspruit Wastewater Treatment Works) and their respective receiving water bodies (Klip, Vaal, Soutspruit and Sun Spruit Rivers) of the Sedibeng District Municipality (26.5000° S, 28.2500° E).and Soshanguve peri-urban area (25.5269° S, 28.1089° E) of the Tshwane Metropolitan Municipality situated in Gauteng Province, South Africa. Sedibeng District Municipality is located in the southernmost part of the Gauteng Province with a geographical area of 4 185 km^2. It is the only district of Gauteng that is situated on the banks of the Vaal River and the Vaal Dam. The economy of Sedibeng is dominated by heavy manufacturing (35.3%) and other important sectors including social services, trade, transport, electricity, construction and agriculture. Sedibeng District has a population of 805 168 and Emfuleni Local Municipality is the most populous with a representation of 80.9% of the entire population, followed by Lesedi (9.56%) and Midvaal (9.5%). During the past 15 years, the peri-urban or semi-urban outlook of the Sedibeng district has been altered to an urban lifestyle at a rate of 88.8% in 2008. Sedibeng District has a high level of water and sanitation service provision where 95.5% and 91.2% of the households are served, respectively. Sanitation service level is high in Midvaal (95.3%) and followed by Emfuleni (90.9%) and Lesedi (88.7%), where 1486 (6.7%), 11,212 (50.7%) and 9438 (42.6%) households lack these services, respectively (SDM, 2012). Leeuwkuil and Meyerton and Wastewater Treatment Works are located in Sedibeng District Municipality.

The Leeuwkuil wastewater treatment plant is one of the three wastewater works serving 23.5% of the households within the Emfuleni area of jurisdiction. The plant is located at the geographical coordinates of S26°40.382′ and E027°53.772′. It has been hydraulically overloaded during the wet season, though the operational capacity remained manageable during the dry weather. The Meyerton wastewater treatment works is one of the wastewater treatment plants serving approximately 83.13% of the households within the Midvaal Local Municipality and is situated at S26°34.919′ & E027°58.386′. Meyerton wastewater treatment plant was selected due to the existing and potential future capacity and current operational and maintenance constraints. This wastewater treatment facility is currently severely overloaded, and is discharging substandard effluent into the environment. This problem is exacerbated by a serious maintenance backlog, resulting in increased problems with the design capacity and deterioration of the quality of effluent which is being discharged (CoT, 2009).

Soshanguve is a peri-urban area established in 1974 and situated approximately 45 km north of Pretoria with a geographical area of 126,77 km^2. It is characterised by a rapidly growing population resulting in an increase of informal settlements. As one of the previously disadvantaged areas, Soshanguve is one of the most densely populated peri-urban areas (a population of 664,900) of the Tshwane Metropolitan Municipality. Currently, the water and sanitation backlog of the City of Tshwane Municipality comprises 69,987 households and Soshanguve contributes 13.93% (CoT, 2009). The Rietgat and Sandspruit wastewater treatment plants that serve Soshanguve peri-urban area are situated at the geographical coordinates; S25°26′32.6″ E028°05′49.4″ and S25°34′41.4″ E028°02′56.9″, respectively. Rietgat and Sandspruit wastewater treatment works discharge effluents to Soutspruit River and Sun Spruit Rivers, respectively. Both wastewater treatment plants have a design capacity of 20 M⁄/day. Rietgat and Sandspruit wastewater treatment plants were assessed because they have been showing an increasing risk trend when measured against the wastewater treatment works risk-rating criteria set by the Department of Water Affairs, South Africa (DWA, 2012).

2.2. Study population and sample collection

In this investigation, four wastewater treatment plants from which sixteen sampling points were identified for the whole sampling regime and a total of 272 samples (68 per site) were aseptically collected using 2 L sterile bottle. Prior to sample collection, sampling bottles were soaked in 10% nitric acid, rinsed thoroughly with distilled water and autoclaved at 121 °C for 15 min. For the chlorinated final effluent