Investigating the potential physical, chemical and microbiological impacts of treated wastewater effluent on a receiving river – a case study

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INTRODUCTION

Water is a guarantor of social and economic development, but inevitable climate and socio-economic changes will force developing countries like South Africa to adopt better wastewater management practices to protect aquatic environments. Impact studies may be useful to assess the performance of a wastewater treatment works (WWTW) and aid in the proper management thereof. The effects of failing WWTWs are well known[1,2]. Still, conventional wastewater treatment processes may not be effective to remove certain chemical and microbiological pollutants[3]. The potential impact of these micro-pollutants is of emerging concern. With an ever increasing use of various chemicals, pesticides as well as pharmaceuticals and personal care products (PPCPs), WWTWs employing conventional processes may not be able to efficiently remove these pollutants from wastewater. By-products of disinfection formed during treatment are of further concern as these may pose additional risk to the environment and subsequently human health.

OBJECTIVE

This case study investigated and evaluated the potential physical, chemical and microbiological impacts of treated wastewater discharged from a macro-sized WWTW (capacity >25Mℓ/day) on a receiving river. To add value to the study, the occurrence and prevalence of certain pollutants not routinely monitored and regulated for the WWTW, but of emerging concern, was also investigated and evaluated.

MATERIALS AND METHODS

Sampling and sample sites: grab samples were collected routinely from the raw influent to the WWTW, treated effluent from the WWTW as well as up-stream and down-stream from the point of discharge into the receiving river.
Historical data for the WWTW: chemical and microbiological data (2009 to 2014) from routine monitoring the WWTW were retrieved from the laboratory information management system (LIMS) system (LabWare, US) used by ERWAT Laboratory and evaluated.
Routinely monitored parameters: these included pH, electrical conductivity, ammonia nitrogen (NH_3), ortho-phosphates (PO_4^{3-}), nitrite and nitrate nitrogen (NO_x) and *Escherichia coli* (*E. coli*). Standard methods were employed for the measurement of these parameters while the Colilert®/Quanti-Tray®/2000 system (Idexx, US) was used for the detection and enumeration of *E. coli*.
Additional parameters investigated: these parameters are not routinely monitored or legally regulated for the WWTW, and included metals and heavy metals (As, Cd, Cr, Cu, Hg, Mn, Pb, Se and Zn), a wide range of volatile and semi-volatile organic compounds (VOCs and SVOCs) and enteric pathogens (*Salmonella enterica*, *Shigella* species and/or EIEC and toxigenic *Vibrio cholerae*). Metals were quantified using inductively coupled plasma atomic emission spectroscopy (ICP-AES), VOCs and SVOCs were quantified using gas chromatography mass spectrometry (GC-MS) and enteric pathogens were detected using real-time polymerase chain reaction (PCR) coupled with high resolution (HRM™) melt curve analysis.
Evaluation of analytical results: test results were compared, where applicable, to the discharge permit requirements for the studied WWTW (as issued by the Department of Water and Sanitation), the resource water quality objectives (RWQO) as well as to the target water quality ranges (TWQR) as stipulated in the South African Water Quality Guidelines[4] (SAWQG).

RESULTS AND DISCUSSION

Parameters routinely monitored and regulated for the studied WWTW

- Overall, the WWTW showed good compliance to the DWS permit requirements and did not appear to significantly impact the river water quality (**Figure 1**).

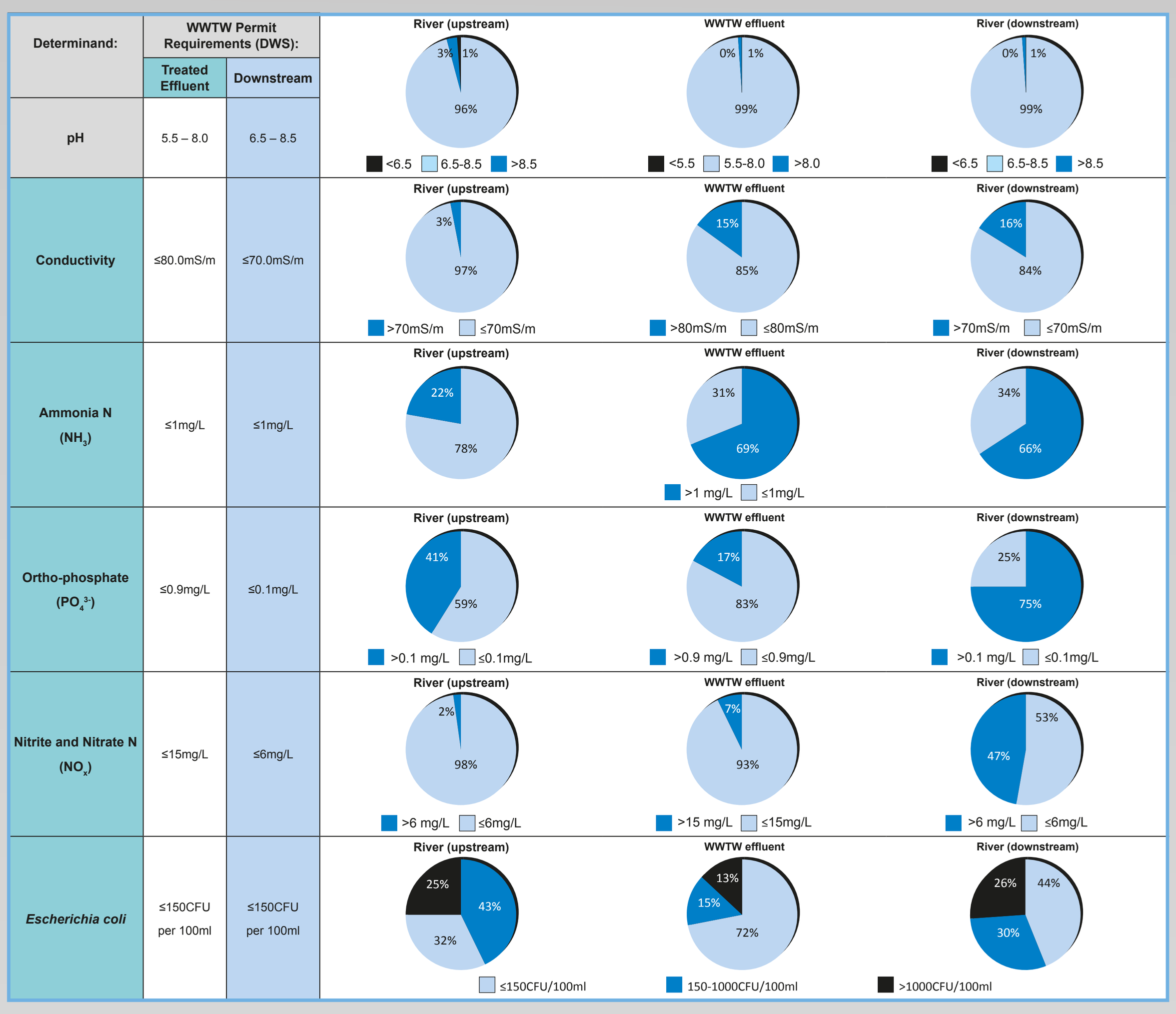

Figure 1: Compliance (%) of treated effluent, upstream and downstream samples with the DWS permit requirements for the studied WWTW

- However, results suggest some impact on the river with regards to conductivity and NH_3 in particular.
- Low compliance to the NH_3 limit showed that WWTW struggled with proper nitrification – this may be attributed to construction work at the WWTW during the study period.
- Results for pH, conductivity, NH_3, PO_4^{3-} and *E. coli* suggest that the river is already impacted by pollution events upstream of the WWTW.
- Pollution might arise from the various urban, industrial and agricultural settlements the river runs through.

Parameters not routinely monitored or regulated for the studied WWTW

Metals and heavy Metals

- Most metals, particularly Cr and Mn were readily removed during treatment at the WWTW (**Table 1**).

Table 1: Results for metal and heavy metal analyses performed for the studied WWTW

TWQR: (Aquatic)	Determinand:	Unit:	Sampling Date: 27 June 2014	02 July 2014	08 July 2014	16 July 2014	24 July 2014	01 August 2014	08 August 2014	13 August 2014	Sample Point:
≤10µg/L	Arsenic (As)	µg/L	0.81	3.05	1.66	0.81	0.67	1.06	0.67	0.82	Raw influent
			0.79	1.60	1.87	0.92	0.77	1.08	0.56	0.66	WWTW effluent
			0.67	0.76	1.55	0.50	0.64	0.76	0.58	0.55	River (downstream)
			0.55	0.51	1.33	<0.50	<0.50	0.51	0.50	0.58	River (upstream)
≤0.25µg/L	Cadmium (Cd)	mg/L	<0.10	0.24	<0.10	0.49	<0.10	<0.10	0.11	0.21	Raw influent
			<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10	WWTW effluent
			<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10	River (downstream)
			<0.10	<0.10	<0.10	<0.20	<0.10	<0.10	<0.10	<0.10	River (upstream)
≤7µg/L	Chromium (Cr)	µg/L	16.3	35.3	5.04	20.4	10.5	14.80	15.6	24.60	Raw influent
			<3.00	5.82	<3.00	4.92	3.11	5.64	<3.00	5.81	WWTW effluent
			<3.00	<3.00	<3.00	2.69	4.97	4.35	6.66	<3.00	River (downstream)
			<3.00	<3.00	<3.00	2.19	<3.00	3.58	<3.00	<3.00	River (upstream)
≤0.8µg/L	Copper (Cu)	µg/L	6.71	17.00	<0.10	9.05	8.80	6.83	6.31	8.04	Raw influent
			3.08	2.30	<0.10	4.28	4.54	3.79	<0.10	2.63	WWTW effluent
			2.55	1.74	<0.10	1.80	2.74	1.89	2.07	1.32	River (downstream)
			1.18	0.81	<0.10	<0.10	1.99	<0.10	<0.10	<0.10	River (upstream)
≤0.5µg/L	Lead (Pb)	µg/L	2.23	14.10	<1.00	1.76	1.17	1.51	1.25	1.43	Raw influent
			1.96	3.13	<1.00	1.96	3.00	1.40	<1.00	<1.00	WWTW effluent
			<1.00	1.04	<1.00	<1.00	<1.00	1.08	<1.00	<1.00	River (downstream)
			<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	River (upstream)
≤180µg/L	Manganese (Mn)	µg/L	130.00	127.00	99.45	78.90	145.00	117.00	59.80	90.20	Raw influent
			62.90	43.80	69.65	20.00	50.80	0.80	30.90	4.66	WWTW effluent
			138.00	111.00	0.49	9.10	1.24	0.67	2.58	5.00	River (downstream)
			0.61	1.87	0.46	0.13	0.62	0.36	0.64	0.13	River (upstream)
≤0.04µg/L	Mercury (Hg)	µg/L	<0.50	<0.50	<0.50	<0.50	7.84	0.64	<0.50	<0.50	Raw influent
			<0.50	<0.50	<0.50	<0.50	11.8	<0.50	<0.50	<0.50	WWTW effluent
			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	River (downstream)
			<0.50	<0.50	<0.50	<0.50	4.72	<0.50	<0.50	<0.50	River (upstream)
≤2µg/L	Selenium (Se)	µg/L	<2.00	9.14	2.61	<2.00	<2.00	5.18	<2.00	<2.00	Raw influent
			<2.00	4.35	2.75	<2.00	2.16	3.97	<2.00	<2.00	WWTW effluent
			<2.00	<2.00	2.21	<2.00	<2.00	2.96	<2.00	<2.00	River (downstream)
			<2.00	<2.00	2.67	<2.00	<2.00	2.37	<2.00	<2.00	River (upstream)
≤2µg/L	Zinc (Zn)	mg/L	<0.06	0.09	0.06	<0.06	<0.06	0.06	0.16	0.09	Raw influent
			<0.06	<0.06	0.06	0.06	<0.06	0.06	<0.06	0.11	WWTW effluent
			<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	River (downstream)
			<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	0.08	<0.06	River (upstream)
Result within the TWQR limit			Result exceeding the TWQR limit					Detection limit of method higher than TWQR limit			

Result within the TWQR limit *Result exceeding the TWQR limit* *Detection limit of method higher than TWQR limit*

- However, Cu, Pb, Hg and Se were only partially removed during treatment and were detected downstream of the WWTW at levels exceeding the TWQR for aquatic ecosystems.

Volatile and semi-volatile organic compounds

- Treated effluent and river samples were free from most of the VOCs and SVOCs tested for during the study.
- Trichloromethane ($CHCl_3$), a disinfection by-product, was detected in treated effluent and river samples downstream from the WWTW (**Figure 2**).

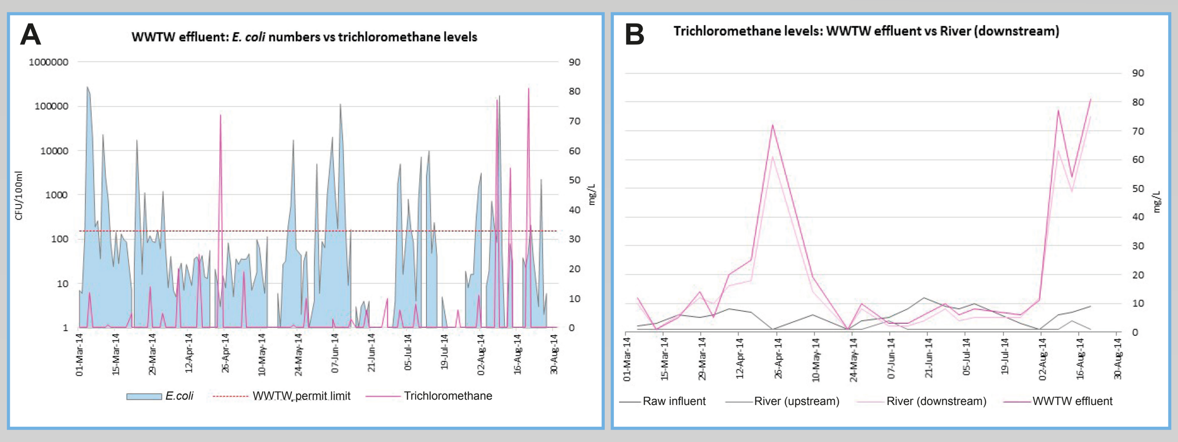

Figure 2: Trichloromethane levels compared to *E. coli* in treated effluent (A) and comparison of levels in treated effluent and river samples downstream of the WWTW (B)

- When *E. coli* numbers in effluent were lower, assumedly as a result of increased chlorination, levels of $CHCl_3$ appeared higher.
- The impact on the river was clear as downstream samples showed levels of $CHCl_3$ following a similar trend as for treated effluent samples.

Enteric pathogens

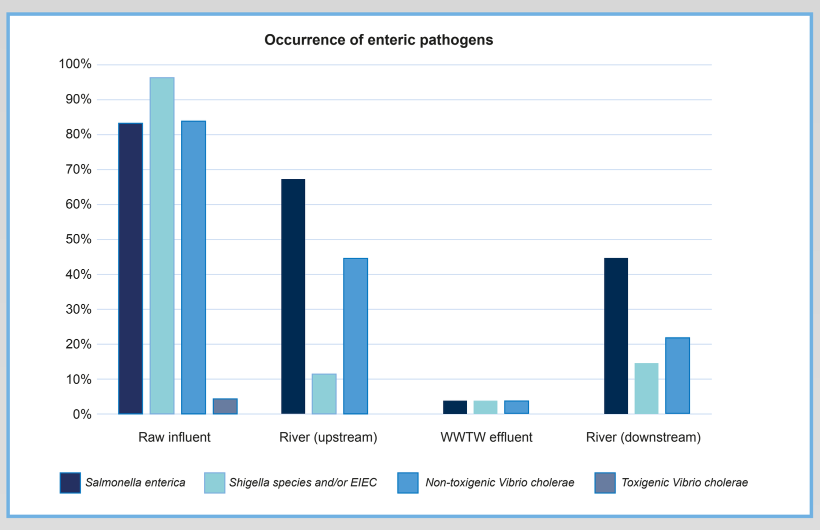

Figure 3: Enteric pathogens detected during the case study

- Enteric pathogens appeared to be removed effectively during treatment by the WWTW, with only 4% of effluent samples showing the presence of pathogens
- Most notably, river samples showed the presence of pathogens, emphasizing pollution events both upstream and downstream from the WWTW.

CONCLUSIONS

- Apart from NH_3, effluent from the WWTW did not seem to significantly impact the quality of the receiving river and performed well in removing phosphates and NO_x.
- The river is likely suffering from non-point source pollution events, both upstream and downstream from the WWTW, as evident from the PO_4^{3-}, NO_x, *E. coli* and enteric pathogen results.
- The AS process seem to lack in efficiently removing some micro-pollutants of emerging concern
- Some metals (Cu, Pb, Hg and Se) were not effectively removed - these metals might impact the receiving aquatic environment.
- The microbiological impact of the WWTW on the receiving river appeared to be insignificant and enteric pathogens did not seem to be discharged readily by the works.
- Although the studied WWTW complied well with the set *E. coli* limit, the detection of $CHCl_3$ (a by-product of chlorination) in treated effluent is of some concern
- It highlights the dual problem encountered by WWTW operators to limit by-product formation but ensure sufficient chlorination to reach strict *E. coli* limits imposed by DWS permits.

EXCELLENCE IN WASTEWATER

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