Assessment of dry and wet weather pollutant fluxes in a small urban watershed of Belo Horizonte (Brazil)

Martin Seidl, Guido Petrucci, Catherine Lorgeoux, Nilo Nascimento

Assessment of dry and wet weather pollutant fluxes in a small urban watershed of Belo Horizonte (Brazil)

Martin SEIDL[1, 2 *], Guido PETRUCCI[1], Catherine LORGEOUX[1], Nilo NASCIMENTO[2]

[1]*Université Paris-Est, LEESU, UMR-MA 102-AgroParisTech, 6-8 avenue Blaise Pascal, Cité Descartes, 77455 Champs-sur-Marne, France*
[2]*Universidade Federal de Minas Gerais, Av. Antônio Carlos, 6627, 31270-901 - Belo Horizonte, Brazil*
**martin.seidl@leesu.enpc.fr*

ABSTRACT
This paper aims to present the evaluation of wet weather contribution to the total annual pollutant load in a residential watershed of 125 ha in Belo Horizonte, Brazil. The monitoring was done over a full hydrologic year, covering diurnal variations during dry periods and frequent samplings during rain events. The paper discusses the changes in fluxes of major pollutants and the contribution of selected micro pollutants. The results show that the concentrations of the major constituents are impacted by the discharge of untreated waste water, and that the values do not comply with the Brazilian legislation for water bodies. For most of the water quality parameters, the concentrations decreased during rain events due to dilution, with the exceptions of suspended solids and some heavy metals, which increased. This increased load is due to erosion and sediment resuspension.

KEYWORDS
pollutants, nutrients, heavy metals, organic micro pollutants, watershed, fluxes, urbanization, Brazil

INTRODUCTION
Brazil, as several other countries with rapidly developing industry and urbanization, suffers from environmental pollution, especially in the dense urban areas. Their fast growth is rarely followed by adequately developed systems for collection of wastewater and run-off. Cities with a dense hydrographical network like Belo Horizonte, the sixth larger city in Brazil, located between Rio de Janeiro and the capital Brasilia, suffer therefore from permanent sewer overflows, wet weather discharges and diffuse pollution in most of their urban rivers.
Research on the pollution generated by urban runoff has been developed since the last 20 years, with increasing focus on organic pollutants and modeling of their transfer. Most of the studies are done in industrialized countries, but in developing countries such as Brazil the works are still in the beginning (Campbell et al., 2004; Choe et al., 2002; Lee et al., 2007; Tomaz, 2007;).
The objective of this study is to contribute to the knowledge of urban run-off in developing countries by modeling the wet weather discharge of an urban catchment, evaluating the level of diffuse pollution and identifying the contribution of the wet weather to the total annual flux in order to treat the pollution locally (Seidl et al 2008).

METHODOLOGY

The study area is the Quaresma creek catchment, a small urban basin (125 ha) situated in the outskirts of Belo Horizonte, capital of Minas Gerais state in the south East of Brazil . The land use of the catchment is predominantly residential, with an estimated population of 15,000 inhabitants, consisting of low income households with relatively high unemployment and criminality (IBGE, 2000, in PSM/PBH, 2004/2007).

The urban creek Quaresma is situated at the south limit of the urban area of the city of Belo Horizonte and is a tributary of the more known creek of Vilarinho. The upper part of the creek is closed and canalised, whereas the lower part is open in semi natural bedding. The sampling station is situated at the upper end of the detention pond, about 1000 meter from the creek origin (Figure 1).

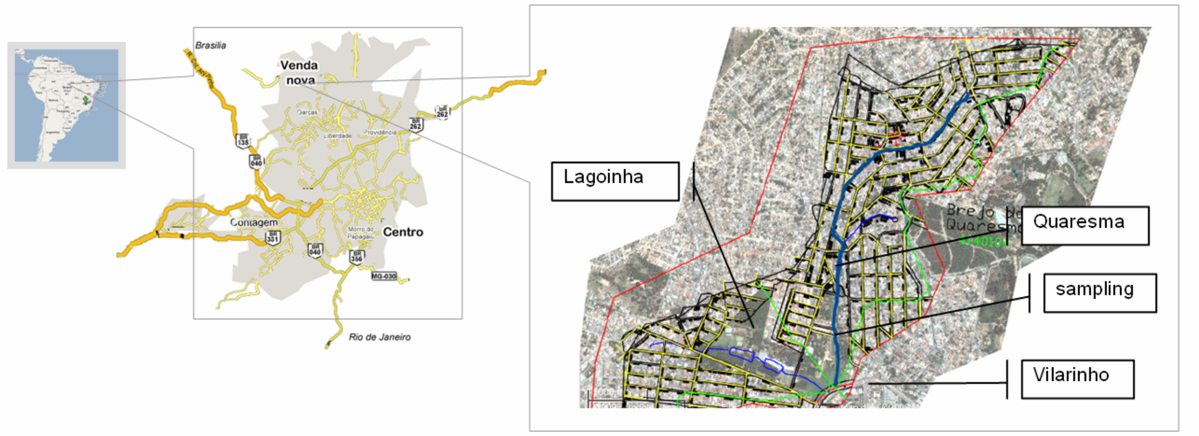

Figure 1: Position of the watershed and study area. The red line indicates the limits of the watershed .

Due to difficult socio-economic conditions of the sampling station (coordinates WGS86: -19.799212,-43.988883) situated in an informal settlement and local flooding zone, the sampling campaigns were fragmented and the use of a model was necessary to validate measurements and fill data gaps.
In 2007 and 2008 the rainfall was measured by Brazilian institute for meteorology, INMET, situated 8 kilometers from the sampling station. These data were consolidated by 15 minutes measurement of the university institute CDTN close to INMET. The topography and land use of the region are homogenous with altitude variations of less than 40 meters. From November 2008 onwards the precipitation was measured with 0.1 mm precision at the sampling site. To get more accurate rain data distribution for the wet weather events not measured on site, the rainfall values of the distant station were redistributed according to the median event values obtained for on-site measurements in 2009 for a series of 20 events.
The water level was registered till 2008 manually by a simple gauge. From 2008 on, the water level was measured automatically through level probe with 1 mm precision, at a rectangular weir and transformed to flow values using Kindsvater-Carter formula (ISO 1438). Flow simulations were performed using SWMM model version 5.0 (Rossman et al. 2004). The watershed was simulated with seven sub-basins, representing the hydrology and land cover, based on topography, satellite photos and field visit. The physical, hydraulic and hydrologic parameters adopted in the modelling were based on methods proposed by US Soil Conservation Service. The SWMM model was automatically calibrated with a set of 20 rain events through the procedure proposed by Petrucci et al. (2013).

Despite the difficult local conditions, five dry weather periods and five wet weather events were sampled between the end of 2007 and the beginning of 2010. Nutrients and pathogens (Viera et al, 2012) were followed to trace domestic pollution whereas heavy metals and PAHs were used as tracers of possible industrial activity. According to the work of Zgheib et al (2007) coprostanol was used as additional tracer of domestic pollution.
The water quality sampling was performed proportionally to time by an automatic sampler equipped with liquid actuator (ISCO3700). For each event 12 samples were analysed for main pollutants. For two representative wet events and two representative dry periods, 2 subsequent samples were mixed for analysis of organic micro-pollutants and heavy metals. All parameters were analyzed, following the recommendations of Standard Methods of APHA and AWWA (2005). The nutrients were analyzed by spectrophotometric methods. The total metal content was analyzed after HNO3/H202/HCl digestion by Inductively Coupled Plasma (ICP-OES). The organic micro-pollutants were analyzed on particulate matter retained by an oven cleaned glass filter (Whatman GF/F) with gaz chromatography coupled with mass spectrometry (GC/MS) on lyophilized solids after specific extraction and separation.
The annual fluxes are calculated from average event load normalized for the precipitation high and the annual precipitation.

RESULTS AND DISCUSSION

Hydrology

The accurate measurement of rainfall in 2009 at the water quality sampling station made it possible to construct a global relation between the rain high and the elapsed time for a median rain event. The empiric relation obtained (Fig. 2) was than used to distribute more accurately the total rain high obtained from the distant INMET station for wet weather events sampled in 2008.

The modelling of rainfall - runoff relation using SWMM resulted in a Nash efficiency above 0,8 for both calibration and validation, confirming the accurateness of the model. It was then possible to use the model to validate manual flow estimations antecedent to 2009 and to fill data gaps for flux calculation.

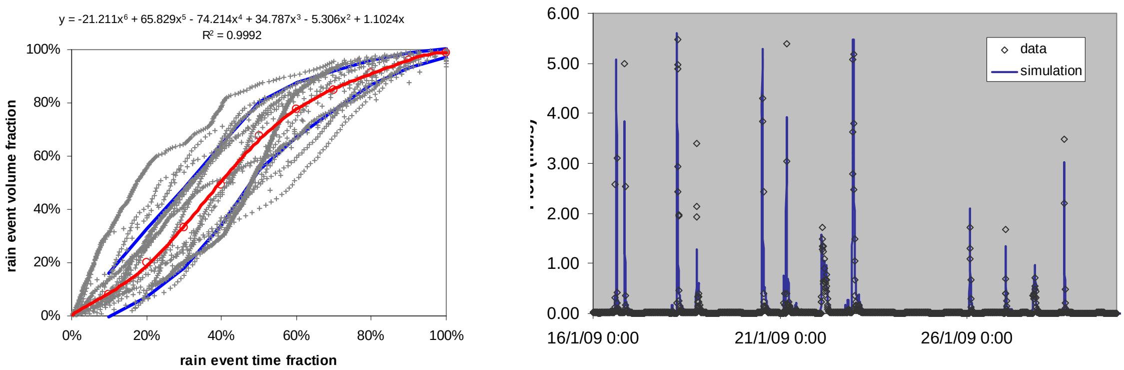

Figure 2: Rain event distribution of Vilarinho sampling station obtained in 2009 (Left) Measured and simulated flow data of the creek Quaresma (Right)

Water quality

During dry periods the water quality parameters show for the Quaresma creek a clear day-night cycle with the very high averages of 226 mg BOD5/L and 17.8 mg NH4-N/L. The impact of discharge of the waste water is underlined by the almost constant concentration of pathogens indicators like *E. coli* with a mean above 10^8 MPN/100 ml (Figure 3, Table 1).

Comparing the mean conductivities of the creek Quaresma (556 µS/cm) to those of a non impacted creek Lagoinha (274 µS/cm) and to waste water in Belo Horizonte (660 – 778 µS/cm) we can estimate that the proportion of waste water in the creek Quaresma is between 55% and 70% of dry weather flow. This result is coherent with another estimation based on the fact that no sewage system is collected in the catchment and thus most of the drinking water consumed (150 L/hab/day) returns to the creek as waste water. The latter estimation provides a proportion of waste water of 60%.

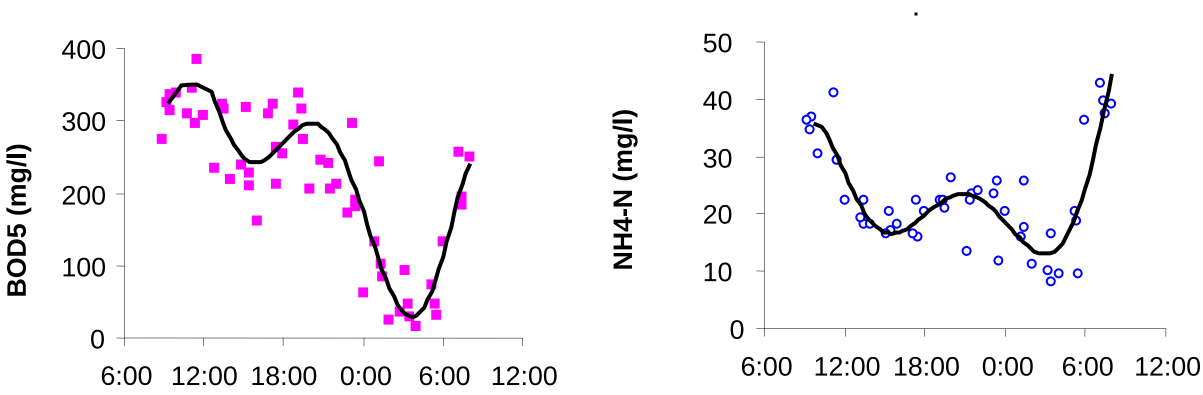

Figure 3 Water quality parameters for 5 dry weather campaigns of 24 hours. The solid line represents the polynomial regression.

The solids transported are about 58 % composed of organic matter, but without relation with the day / night cycle. The composition of the organic matter remains the same during the day, with about 50 % of the organic matter biodegradable. There is no correlation between organic matter content and its biodegradability. The N/P ratio is about 5.7.

Most pollutants show diurnal variation during dry period, illustrating the different processes occurring in the catchment area. This is the case for classical parameters like conductivity as well for faecal tracers following the usual diurnal evolution found in combined sewers (figure 3).

Table 1 – Concentrations observed in Quaresma creek. N=94 values for dry weather and N=48 values for wet weather

	EC µS/cm	TSS $mg.L^{-1}$	COD $mg.L^{-1}$	BOD $mg.L^{-1}$	NH_4^+-N $mg.L^{-0}$	NO_3^- $mg.L^{-1}$	P-total $mg.L^{-2}$	*E.coli* MPN. *$100ml^{-1}$*
Dry Weather								
Average	**566**	**235**	**394**	**186**	**20**	**1.03**	**2.7**	1.78E+09
std	102	125	177	95	8	1	1	**8.10E+08**
Rain Events								
Average	**326**	**582**	**148**	**70**	**3.6**	**1.9**	**1**	2.14E+08
std	117	477	77	44	3	1	1	**8.00E+07**

As well for the major elements as well for the micro pollutants most components are diluted and found in lower concentration during the wet weather. Though some, like suspended solids, heavy metals like chromium and lead or organic components like coprostanol show significantly higher levels during the rain event than during the dry weather. For suspended solids this is due to erosion processes occurring in the whole watershed For the micro pollutants this erosion is mostly due to resuspension of sediments accumulated in the river bed and due to wash off of pollution accumulated on urban surfaces (Figure 4). These pollutants may originate from activities like small scale metallurgy industry or cars reparation found in the water shed. The PAH, coming principally from atmospheric fall out are washed from the impervious surfaces during the rain events, but may also come from point sources like gasoline station or car mechanic, not treating the oil residues.

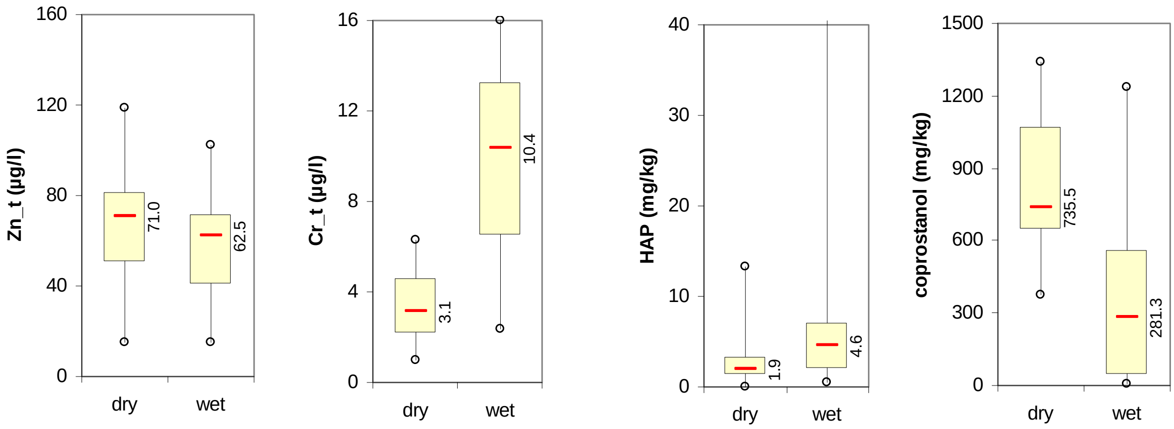

Figure 4: Micro pollutants in the watershed, average concentration and statistical distribution (n=12).

Coprostanol is like E. Coli a tracer of human excreta, though it's comporting differently. It can accumulate in the sediments and can be preserved from degradation, though no clear correlation was observed between both parameters.

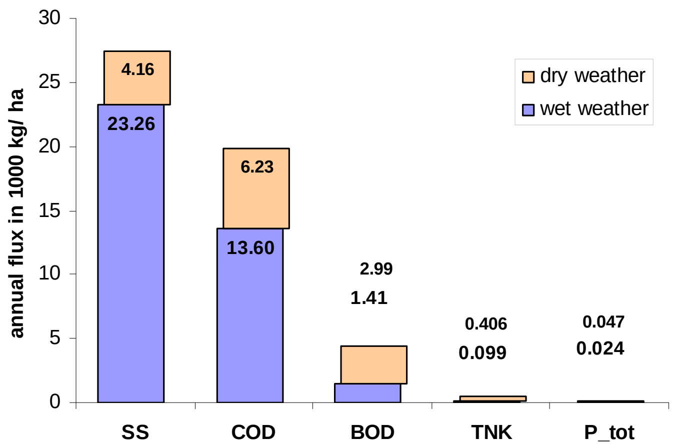

Figure 5: Pollutant fluxes in dry and wet weather periods

In terms of annual flows, in Belo Horizonte the rain events represented about 6.2 % of the duration of the whole hydrological cycle 2007/2008. The upscaling of results on an annual basis shows that the contribution of 528 hours of rain to the total flux of suspended solids and of COD was more important than that of the 343 remaining dry days.

The annual flux of zinc is about 1.2 kg/ha/year with 40% being transported during wet events. For the PAH it's rather the other way round, 25 g/ha/year with 80% during the rain period. Both values are higher, but in the same order of magnitude as data found in the metropolitan region of Paris. More sampling campaigns will be needed to confirm these results.

CONCLUSION

The high concentrations of organic matter (COD and BOD), nutrients (N and P) and suspended solids, together with the high densities of *E.coli* observed during dry weather show that the behavior of the Quaresma creek is strongly influenced by the domestic sewage discharged directly and indirectly into the creek.

The results of hydraulic simulation and measurements of pollutants put forward the importance of run-off in the annual load of many pollutants. The lack of urban planning is revealed by the extremely strong erosion of urban surfaces and by the consequent importance of suspended solids and organic matter entering the drainage system. Though the catchment might be considered as residential, non-negligible concentrations and fluxes of micro-pollutants can be detected during dry weather periods, most probably because of the presence of informal activities in the catchment.

REFERENCES

- APHA/AWW/WEF (2005).Standard Methods for the Examination of Water and Wastewater 21st edn, American Public Health Association/American Water Works/Water Environment Federation, Washington, DC, USA., 2005. ISBN: 0875530478.
- CHOE, J.S.; BANG, K.W.; LEE, J.H. Characterization of surface runoff in urban areas. *Wat.Sci.Tech.* vol. 45, p.249-254, 2002.
- LEE, H.; SWAMIKANNU, X.; RADULESCU, D.; KIM, S.J., STENSTROM, M. (2007). Design of stormwater monitoring programs. *Water Research*, vol. 41, pp.4186-4196.
- PETRUCCI, G., RIOUST, E., DEROUBAIX, J.F., TASSIN, B. (2013). Do stormwater source control policies deliver the right hydrologic outcomes? *Journal of Hydrology*, 485, 188-200.
- PSM/PBH. Superintendência de Desenvolvimento da Capital – SUDECAP. Grupo de Gestão em Saneamento. (2004). Plano Municipal de Saneamento de Belo Horizonte 2004/2007: "Saneamento para Todos". Belo Horizonte. (in Portuguese).
- ROSSMANN L.A. (2004). Storm water management model User's manual version 5.0. EPA, Water Supply and Water Resources Division, National Risk Management Research Laboratory, Cincinnati, OH, USA.
- SEIDL, M. et al. Instream treatment facility for creek revitalization, Belo Horizonte (Brazil) – setup and pollutant load. In: 11th International Conference on Urban Drainage (ICUD), Edinburgh, Scotland, UK, 2008. Organised by University of Sheffield, University of Abertay Dundee, Heriot Watt University and University of Exeter (www.icud.org), 2008a.
- TOMAZ, P. (2006). *Poluição Difusa.* Porto Alegre: Navegar Editora. (in Portuguese).
- VEZZARO, L., Ledin, A., Mikkelsen, P.S., 2012. Integrated modelling of Priority Pollutants in stormwater systems. Physics and Chemistry of the Earth, Parts A/B/C,

Estimating and representing uncertainty in applied hydrology, hydraulics and water quality studies 42–44, 42–51. doi:10.1016/j.pce.2011.07.002

- VIEIRA P.C. , M. VON SPERLING, M. SEIDL and N.O. NASCIMENTO (2012) Evaluation of water quality characteristics of an urban polluted stream during dry weather and rainy events. IWA World Water Congress 16 – 21 September 2012, Bussan Correa.
- ZGHEIB S., M.C. GROMAIRE, C. LORGEOUX, M. SAAD, G. CHEBBO, Sterols: a tracer of organic origin in combined sewers", proceedings of 5th international conference on sewer processes and networks, Delft, 28-31 August 2007

Oral Presentations

2517998

Assessment of Dry and Wet Weather Pollutant Fluxes in a Small Urban Watershed of Belo Horizonte (Brazil)

Martin SEIDL[1,2]*, Guido PETRUCCI[1], Catherine LORGEOUX[1], Nilo NASCIMENTO[2]

- [1]Université Paris-Est, LEESU, UMR-MA 102-AgroParisTech, 6-8 avenue Blaise Pascal, Cité Descartes, 77455 Champs-sur-Marne, France
- [2]Universidade Federal de Minas Gerais, Av. Antônio Carlos, 6627, 31270-901—Belo Horizonte, Brazil

Corresponding author
Email: martin.seidl@leesu.enpc.fr

Abstract
This article aims to present the evaluation of wet weather contribution to the total annual pollutant load in a residential watershed of 125 ha in Belo Horizonte, Brazil. The monitoring was done over a full hydrologic year, covering diurnal variations during dry periods and frequent samplings during rain events. The article discusses the changes in fluxes of major pollutants and the contribution of selected micropollutants. The results show that the concentrations of the major constituents are impacted by the discharge of untreated waste water, and that the values do not comply with the Brazilian legislation for water bodies. For most of the water quality parameters, the concentrations decreased during rain events due to dilution, with the exceptions of suspended solids and some heavy metals, which increased. This increased load is due to erosion and sediment resuspension.

Keywords
Pollutants, nutrients, heavy metals, organic micropollutants, watershed, fluxes, urbanisation, Brazil

2518041

Comparison of First Flush Quantification Methods in Tropical Catchments

Ha Song LE[1]*, Lloyd Hock Chye CHUA[1,2]

- [1]DHI-NTU Water & Environment Research Centre and Education Hub, Nanyang Environment and Water Research Institute, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798
- [2]Current Affiliation: School of Engineering, Deakin University, 75 Pigdons Road, Waurn Ponds, Victoria 3216, Australia

***Corresponding author**
Email: leha@ntu.edu.sg

Abstract
This study evaluates the first flush quantification methods in ten catchments of agricultural, residential and forest land uses in the Kranji Reservoir catchment, Singapore for seven parameters: TN, NO_3, NH_4, TP, TDP, OP and TSS. The four employed first flush quantification methods are: (i) b-value (Bertrand-Krajewski et al., 1998), (ii) maximum distance between cumulative load and cumulative runoff curves (Geiger, 1987), (iii) Cumulative mass delivered at 20 and 30% of cumulative runoff volume or FF20 (Deletic, 1998) and FF30 (Bertrand-Krajewski et al., 1998) respectively and (iv) Characteristic pollutographs (Bach et al., 2010). Among all first flush methods tested, the FF30 was the most stringent, followed by the FF20 method. Only the Bach et al. (2010) method detected first flush for TN, NO_3, TDP and OP. The results showed that the first flush was not pronounced in tropical catchments, probably due to the frequent rainfall in the area which limits the build-up of pollutants on surface. Interestingly, first flush for TSS was stronger in agricultural than urban catchments, which may be attributed to the high erodibility of rainfall energy in the area. In application of first flush quantification methods in tropical catchments, the b-value and the Bach et al. (2010) methods should be used with caution.

Keywords
First flush, tropical catchments, b-value, Geiger 1987 method, FF20 and FF30, Bach et al. (2010) method

2518109

Flood-Related Water Quality Assessment Using Water Quality Sampling and Household Survey in Can-Tho City, Vietnam

Maria Luisa B. SALINGAY[1,4]*, Peter van der STEEN[1], Assela PATHIRANA[1], Jeroen RIJKE[1], Nguyen Hong QUAN[2], Chris ZEVENBERGEN[1], Ky Quang VINH[3]

- [1]UNESCO-IHE Institute for Water Education
- [2]Instiute for Environment and Resources (IER)—Viet Nam National University Ho Chi Minh City, Vietnam
- [3]Climate Change Can Tho Coordination Office
- [4]Mindanao University of Science and Technology, Cagayan de Oro 9000, Philippines

***Corresponding author**
Email: salin9@unesco-ihe.org

Abstract
This study involves the water quality assessment of Can Tho City, Vietnam. It used water quality sampling in strategic surface waters and household survey in four communities vulnerable to floods. A majority of the 245 respondents were not satisfied with the water quality of the surface water in their neighbourhood. Their social perceptions were justified and verified by the water quality results, especially in the microbiological analysis. For total coliform the minimum average value obtained was in Nhon Nghia (N2) of 34,617 MPN/100 mL and the maximum average value was in An Hoa (H1) of 742,583 MPN/100 mL as against the maximum tolerable limit of Vietnam of 10,000 MPN/100 mL. For *E. coli* the minimum average value obtained was in Nhon Nghia (N2) of 3,079 MPN/100 mL and the maximum average value was in An Hoa (H2) of 83,083 MPN/100 mL as against the maximum tolerable limit of only 200 MPN/100 mL. It was so alarming that in Nhon Nghia, with or without flooding, the respondents used the surface water for cooking, drinking, bathing and washing of clothes. Greater water quality deterioration was observed in the sampling sites of An Hoa. These sites are the boundaries of two densely populated urban districts of Nien Kieu and Binh Thuy. This study concluded that domestic waste contributed so much to the bad quality of surface water. Responsible government agencies should look into effective measures on how to deal with this domestic waste. As the respondents were willing to pay to improve the quality of water and they were also unanimous in their responses that it is the responsibility of local and national government to improve the water quality of the surface water of the city.

Keywords
Household survey, Salmonella, sub-urban, total coliform, vulnerability

2518437

Identifying Relevant Pathogen Pathways into Surface Waters Used for Recreational Purposes

Silke RODER[1]*, Katharina TONDERA[1], Kassandra KLAER[1], Martin STRATHMANN[2], Johannes PINNEKAMP[1]

- [1]Institute of Environmental Engineering of RWTH Aachen University, Germany
- [2]IWW Rheinisch-Westfaelisches Institut fuer Wasser, Germany

***Corresponding author**
Email: roder@isa.rwth-aachen.de

Abstract
Pathogens responsible for illnesses enter surface waters from several "point-sources" (e.g., the effluent from wastewater treatment plants and sewer overflows) as well as "diffuse sources" (surface runoff).