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Excerpted Abstracts of the 7th Water Efficiency Conference 2022

Theme: "Water Resources Resilience for Small Island Developing States (SIDS)" 24th-16th December 2022

Kemi Adeyeye [a] and Kiran Tota-Maharaj [b]

[a] Water Efficiency Network Lead, c/o Department of Architecture and Civil Engineering, University of Bath, UK; Email: k.adeyeye@bath.ac.uk

[b] Department of Civil Engineering, School of Infrastructure & Sustainable Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, UK; Email: k.tota-maharaj@aston.ac.uk

Abstract: *In an increasingly uncertain world, water is constant and central to most things: the economy, energy, transport, agriculture, health, leisure, wellbeing, social and cultural life. The 7th Water Efficiency (WATEF) Conference 2022 was, for the first time, held outside Europe in the Caribbean, at the Faculty of Engineering, The University of the West Indies, Saint Augustine Campus, Trinidad and Tobago on 14th-16th December, 2022. Many challenges reflect the changing climate, increasingly unpredictable weather, and the efforts towards sustainable development necessary for social equity and economic growth. Proactive partnerships and collaborations across civil society is necessary to succeed in this effort. A conference on water efficiency and resilience is justified in the face of these challenges and during an energy, cost-of-living, food, and other crises. The WATEF-2022 Conference's theme was "Water Resources Resilience for Small Island Developing States (SIDS)". Trinidad and Tobago has a relatively high reliable water infrastructure (including desalination plants) for its population but in recent times water resources have been impacted by unforeseen climate change events. This twin-island republic was best suited for this conference, geographically and technically. Parallel with invited keynotes and feature speeches, technical presentations and panel discussions were made addressing various topics and areas associated with the conference's theme. This paper contains a total of 28 abstracts excerpted from the Conference proceedings that address towards collaborative solutions to the water and resilience challenges faced globally and experienced more intensely by SIDS.*

Keywords: Water efficiency, resources, resilience, SIDS, WATEF, Trinidad and Tobago

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1. Optimal Design Storm Frequency for Flood Mitigation

Vishwanath Maraj[1], Vincent Cooper[2], and Matthew Wilson[3]

[1]CIVENT Limited, No. 28 Union Park East, Gopaul Lands, Marabella, Trinidad and Tobago, West Indies; Email: vishmaraj@civent.org

[2] Department of Civil and Environmental Engineering, The University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies; Email: Vincent.Cooper@sta.ui.edu

[3] Geospatial Research Institute, University of Canterbury, New Zealand; E-mail: matthew.wilson@canterbury.ac.nz

Abstract: *Determining the right amount of money or budget to be spent on flood mitigation works has always been a challenge in developing countries. Recent work has identified a recommended budget based on the value accepted for flood mitigation works in developed countries, measured as the Cost per Inhabitant. In addition to this approach, the industry also utilises the hydroeconomic analysis (HEA) to determine an optimal design storm frequency that yields the most economical budget and design approach to flood mitigation works. This study investigates both economic approaches to determine the level of protection or the optimal design storm frequency for flood mitigation works. These economic approaches were executed for flood mitigation works within the North Valsayn community of Trinidad. To facilitate these economic assessments in determining the optimal design storm frequency, flood hazards were identified using a calibrated 2D hydraulic model done in LIS-FLOODFP. A Flood Damage Curve was used as a measure of the community's vulnerability using data collected from social surveys. Flood mitigation works were identified for the various design storm frequencies and the associated life cycle costs were determined. Upon execution of both economic approaches, the HEA indicated that it is most economical to maintain the existing flood condition as the annual cost of mitigation works far outweighs the annual damage cost. On the contrary, when implementing the Cost per Inhabitant approach, flood mitigation works performed for a design storm frequency of 1 in 50years was found to be optimal or comparable to the recommended budget. The study shows a disparity in defining a project's budget and the Optimal Design Storm Frequency using both approaches for decision/policy makers, and various stakeholders although both are acceptable.*

Keywords: *Storm Frequency, Flood Mitigation, Hydroeconomic Analysis, Trinidad*

2. The Value of Hydrometry in Reducing Fluvial Flooding Footprints across The Caribbean – A Case Study in Dennery, Saint Lucia

Fazir Khan[1] and Fey Mohammed[2]

[1,2] AEDL - Alpha Engineering & Design (2012) Ltd., Trinidad, West Indies

Emails: fazirkhan15@gmail.com; alphaeng.feymohammed@gmail.com

Abstract. *The work reported in this paper was initially carried out by Alpha Engineering and Design (2012) Limited (Alpha) for the Government of Saint Lucia (GOSL) on a World Bank (WB) Disaster Vulnerability Reduction Project (DVRP) for Flood Mitigation. Part of the scope involved setting up rainfall and streamflow gauges in the Dennery Watershed to observe rainfall depth and river stage for a limited period congruent with the engineering consultancy contract, to guide the selection of hydrological parameters and calibrate hydraulic models. Alpha then sought to extend the observation period so that larger datasets could be captured to improve the reliability and utility of the data. The aim of this paper is to present the real-world benefit of investing in hydrometric instrumentation to increase one's capacity when Analysing the hydrological and hydraulic impacts of storm events in Caribbean Watersheds and improve reliability in flood mitigation analyses for more resilient solutions. This is done through a case study in Dennery Village, Saint Lucia. This paper briefly presents the challenges associated with setting up and maintaining gauging stations, describes the technology used, lists the high benefits for the comparatively low cost of the investment, and finally the analyses of the data using standard methodologies in engineering hydrology and hydraulics to generate catchment-specific information relating to rainfall and runoff especially in terms of flooding, such as the role of antecedent moisture content on the severity of floods and the impact of rainfall structure, in space and time, on a flood hydrograph for specific catchments..*

Keywords: *Rain-Gauge, Streamflow-Gauge, River Stage, Stage Discharge, Flood Hydrograph, Hydrological Parameters, Watercourse baseflow, Irrigation*

3. Considerations for Use of Permeable Pavement Systems within Urban Settings across Caribbean Small Island Developing States

John J. Monrose[1], and Kiran Tota-Maharaj[2]

[1]AECOM, San Fernando, Trinidad and Tobago, West Indies; E-mail: john.monrose@aecom.com;
[2] Department of Civil Engineering, School of Infrastructure & Sustainable Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, UK; Email: k.tota-maharaj@aston.ac.uk

Abstract. *Increasing imperviousness caused largely from urban development coupled with global warming, sea-level rise and change in weather patterns contribute immensely to frequent flooding events across numerous urban municipalities across Caribbean Small Island Developing States (SIDS). Existing conventional drainage systems fail to meet stormwater runoff peak flow and volume demands generated by today's changing environment. Land or service constraints often restrict expansion of these drainage systems. Despite those challenges, Caribbean SIDS authorities and drainage engineers continue to recommend and use conventional drainage systems as the dominant infrastructure for the collection and conveyance of stormwater away from urban areas. Sustainable Urban Drainage Systems (SUDS) or Low Impact Development (LID) practices such as porous or Permeable Pavement Systems (PPS) are designed to effectively manage stormwater runoff at the source as opposed to conventional drainage systems. PPS reduce urban runoff and peak flows via development of on-site temporary storage measures for potential water reuse and minimisation of impervious areas. Water quality benefits of PPS include thermal mitigation and reduced pollutant loadings of suspended solids, heavy metals, hydrocarbons, and some nutrients to receiving natural waters. It is recommended that SUDS such as PPS be incorporated within urban drainage systems across Caribbean SIDS to help mitigate the frequent flooding events being experienced annually. PPS installations must be fit for purpose and this paper discusses key considerations for use of PPS within urban settings across Caribbean SIDS.*

Keywords: *Permeable Pavements, Stormwater Management, Sustainable Urban Drainage Systems (SUDS), Small Island Developing States (SIDS), Surface runoff*

4. Analysing Climate Gentrification in Coastal Neighbourhoods: A Case Study of Lagos, Nigeria

Godson Chizara Wogu[1], Kemi Adeyeye[2], Alex Copping[3]

[1,2,3] Department of Architecture & Civil Engineering, University of Bath, UK; E-mail: gcww20@bath.ac.uk; k.adeyeye@bath.ac.uk; a.copping@bath.ac.uk

Abstract. *The concept of climate gentrification emerged to redefine our understanding of how climate change impacts (sea-level rise, flooding, water storms, tsunami) and adaptations drive inequality in human settlement and probable displacement of low-income households through changes in housing property value. However, the concept of climate gentrification lacks adequate parameters for application in diverse coastal locations. In response, this qualitative case study proposes a climate resilience integrated approach (framework) for identifying the parameters to analyse climate gentrification in the coastal neighborhoods of Lagos (Nigeria). In doing so, a pilot investigation was conducted using naturalistic observation to explore events and lived experiences of residents in Lagos coastal neighborhoods. Findings indicate a preference for built/engineered resilience infrastructures and higher return on physical asset investments as core variables driving climate gentrification patterns in Lagos coastal neighbourhoods.*

Keywords: *Climate Change, Sea Level Rise, Flooding, Climate Gentrification, Housing Displacement*

5. Multi-Step Flood Forecasting in Urban Drainage Systems Using Time-series Data Mining Techniques

Farzad Piadeh[1], Kourosh Behzadian [2], and Amir M. Alani [3]

[1,2] School of Computing and Engineering, University of West London, St Mary's Rd, London, W5 5RF, UK; E-mail: alphaengtt@gmail.com
[3] Faculty of Engineering, Computing and the Environment, Kingston University, River House, 53–57 High Street, Kingston upon Thames, Surrey KT1 1LQ UK; E-mails: Amir.Alani@kingston.ac.uk;

Abstract. *While early warning systems are recognised as the most cost-effective solution in urban flood risk management, highly accurate flood forecasting is limited to short-term timesteps, usually less than a few hours especially for prediction of*

overflowing in urban drainage systems. This study aims to provide a framework for more accurate overflow predictions for longer lead times by using data mining models applied to time series data for multi-step flood forecasting. The framework including event identification, feature analysis and developing models is demonstrated by its application to a pilot study in London. All numerical rainfall data and water levels in urban drainage systems are first turned to the categorical events on which 6 common weak learner models are developed. Then, three new time-series models, including overflowing-based, non-overflowing-based, and accuracy-based, are developed based on these models to predict overflow states among all identified events. Three weak learner models, i.e. discriminant analysis, naive Bayes, and decision tree are considered as the best models based on accuracy, total overflowing detection and total non-overflowing detection. Furthermore, while the accuracy of these models is changed between 95 to 85% from 1 to 12-step ahead of prediction, these models can detect the non-overflow conditions better than overflow detection. To cover this gap, new time series developed models could significantly reduce the overestimation and underestimation of water levels, including correct predicting of 50% of the total events after 12-step ahead by overflow-based model. This result shows the potential of using time-series data-demanding models for effective and highly accurate predictions of overflow events..

Keywords: *Data mining; Drainage system; Flooding classification; Multistep prediction Overflow prediction*

6. Suitability of the SCS Type Temporal Distributions for Local Rainfall in Trinidad and Tobago, West Indies

Queena Edwards[1], and Vincent Cooper2

[1.2] Department of Civil and Environmental Engineering, The University of the West Indies, St. Augustine, Trinidad and Tobago; West Indies; Email: queena.edwards@my.uwi.edu; Vincent.Cooper@sta.uwi.edu

Abstract. *Stormwater management facilities are intended to convey the peak flows generated by some critical storm. A major feature of that storm controlling the resulting peak flow is its temporal distribution, that is, how the rainfall depth is distributed in time. The chosen distribution should be representative of the rainfall observed in the local vicinity of the facilities, and this is obtained by Analysing fine temporal resolution records (between 5 minutes to 1-hour intervals) collected from local rainfall stations. Often, the only records available are ones collected on a daily scale, which are too coarse for the small watersheds that typify small island states. For estimating design peak flows, designers frequently refer to the temporal distributions published within the SCS peak flow estimation procedure. The problem is these temporal distributions were developed for the United States and they may be markedly different from local distributions. This study analysed fine resolution data from a few stations in Trinidad. It found that the representative temporal distributions were bi-modal, unlike the strong uni-modal distributions in the SCS procedure. A comparison of peak flows derived from the various distributions found that the NRCS distributions over-estimated peak flows by more than 100%. Although this may suggest the possibility of oversizing infrastructure for drainage, caution is required in realising that while not frequent, from time to time, recorded storms have mimicked the SCS curves. Clearly the work needs to be extended to consider longer rainfall series, from a larger number of rainfall stations across the country.*

Keywords: *Rainfall temporal distribution; SCS hydrologic procedure; oversizing infrastructure; HEC-HMS; Trinidad and Tobago*

7. Examining the Feasibility of GeoAI and IoT for Smart Flood Early Warning Systems for Local Communities in Caribbean Urban Spaces

Mark Codling [1], Bheshem Ramlal [2] and Dexter Davis [3]

Department of Geomatics Engineering and Land Management, The University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies; [1] Email: mark.codling@my.uwi.edu; [2]E-mail: Bheshem.Ramlal@sta.ui.edu; [3]E-mail: Dexter.Davis@sta.ui.edu

Abstract. *Over the last few decades, flooding has resulted in many problems that significantly impact countries in the Caribbean. This has been especially challenging in urban areas where widespread damage has occurred. In addition, given that over 50% of the world's population lives in urban areas, these locations are deemed to be vulnerable to climate-related disaster events that would further exacerbate the challenges in the region. These urban spaces in the Caribbean have limited access to real-time flood monitoring data for formulating and supporting policies for disaster practitioners to coordinate timely preparedness and mitigation efforts. While flooding is complex, with a series of negative impacts on social and economic sectors, it is essential to provide a basis to support decision-making information on vulnerability and resilience through early warning systems (EWS). However, the main obstacle in creating early warnings in the Caribbean is the suitability and*

availability of data for real-time flood prediction. Consequently, there is a research gap from the perspective of short-term forecasting for sudden rainfall events in urban spaces in the Caribbean. Given the early warning system culture in the Caribbean has an environment of real-time data of scarce resources, it is necessary to forge an approach for real-time forecasting flooding impact in urban spaces. The paper will provide a preliminary analysis of the feasibility of machine learning and IoT use in supporting EWS in Caribbean urban spaces.

Keywords: *GeoAI, Machine Learning, Internet of Things, Early warning systems (EWS), Caribbean*

8. Advancing Solar Energy Driven Heterogeneous Photo-Fenton Processes for River Water Remediation

Kiran Tota-Maharaj [1] and Simeon Keates [2]

[1] Department of Civil Engineering, School of Infrastructure & Sustainable Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, UK; Email: k.tota-maharaj@aston.ac.uk

[2]Office of Deputy Vice-Chancellor (Research), University of Chichester, College Lane, Chichester PO19 6PE, UK; Email: s.keates@chi.ac.uk

Abstract*. Water is essential for life. Many of the countries across the globe that have poor management of potable water resources and lack critical infrastructure for managing wastewater. As the population of the Earth grows exponentially, the demand for water increases. More than 1 billion people across the world do not have access to potable water and they are struggling with epidemic level disease outbreaks, limited water supply among other large-scale public health risks. Large-scale critical infrastructure chains are required in order to produce potable water from raw water sources, and developing countries continue to struggle economically and cannot afford the same treatment chains as the developed world. This research project evaluated the feasibility of two photocatalytic and photo-Fenton solar reactors on their capabilities to breakdown water contaminants present in natural hydrosystems and freshwater resources namely rivers. The approached adopted to achieve this was the photo-Fenton reaction and solar-photochemical reactors designed constructed and tested for the removal efficiencies of Chemical Oxygen Demand (COD), ammonia, nitrates, nitrites and phosphates via LCK curvette tests, in addition to turbidity and colour. The water quality analysis and results showed that oversaturation of the photo-Fenton reagents reduces the effectiveness of the reaction, and that finding the correct chemical balance has a greater impact on the removal efficiencies of the five pollutants than the use of UV light catalyst. The difference in the reactor builds was their diameter, and the results showed that the reactor of smaller diameter achieved the best removal efficiency across all five pollutants.*

Keywords: *Photo-Fenton, Heterogeneous Fenton, Photochemical treatment, Solar Energy, River Water, Detoxification, Drinking water, Solar radiation*

9. Potential Impact of Oil Spills in Coastal Waters on Water Supply

Portia Felix

Department of Civil and Environmental Engineering, The University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies; E-mail: portiafelix30@gmail.com

Abstract. *It is apparent that oil exploration poses an inherent risk to water resources and water quality. This is exemplified by oil spills resulting from broken pipelines, underwater blowouts and oil transport vessel accidents. In these instances, water is usually the first casualty, as some form of water body is vulnerable to spilled oil, resulting in oil contaminated water. The freshwater resources of Small Island Developing States (SIDS) are often said to be stressed from anthropogenic pollution, which can lead to freshwater scarcity. In an effort to ensure the sustainability of freshwater resources resilience in SIDS, desalination is increasingly being used to provide potable water. Hence the quality of seawater deserves serious consideration. It is in this light that oceanic oil spills are of significant relevance to the provision of a guaranteed supply of potable water. For an oil producing small island developing state as Trinidad and Tobago, which has considerable oil and gas activities on land and in shallow waters along its coasts, the island's oceanic water can become increasingly stressed from oil spills, possibly leading to the shutting down of seawater intakes in the desalination process. A real-life seawater surface oil spill in the Gulf of Paria, south-west coast of Trinidad, not far from the largest desalination plant in the Caribbean, is investigated and its behaviour modelled, using numerical mathematical modelling techniques to produce trajectory plots. These plots are analysed to infer the potential impacts of the oil behaviour in the coastal waters on the island's domestic water supply.*

Keywords: *Small Island developing states (SIDS), oil spills, coastal water quality, freshwater resources, desalination, numerical mathematical modelling, Gulf of Paria, Trinidad*

10. The Impact of Climate Change on the Navet Reservoir, Trinidad

Ravi Baboolal [1] and Vincent Cooper[2]

[1] The University of Trinidad and Tobago, San Fernando Campus, Trinidad and Tobago, West Indies; E-mail: ravi.baboolal@utt.edu.tt
[2] Department of Civil and Environmental Engineering, The University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies; E-mail: Vincent.Cooper@sta.uwi.edu

Abstract. *A hydrologic study of the Navet reservoir and its catchment was conducted to investigate and evaluate the potential impacts of climate change on it, using the Soil Moisture Accounting algorithm in HEC-HMS to perform continuous simulations. The catchment is partially gauged, with a single rainfall gauge located within it and with the absence of a stream gauge, stage data from the reservoir was used to evaluate catchment response. The selection of model parameters was based on previous work done on the nearby Nariva catchment and were improved on by a manual optimisation technique. The model was subject to a split-sample test with a calibration period of 24 months (2003, 2004) on a daily time-step followed by validation over a period of 60 months (2005-2009). Upon successful validation, the model was used to evaluate the system's response to climate change. The meteorological data for this was generated by the PRECIS software for this region. The model was subject to three scenarios based on the SRES A1B scenario. The results of simulations for the period 2030-2096 showed that for successful operation, production rates at the Navet reservoir requires a 40% reduction of present values for two of these scenarios and by 30% for the most optimistic scenario.*

Keywords: *Continuous Hydrologic Modelling; Soil Moisture Accounting; HEC-HMS; Navet Reservoir*

11. Cumulative Fatigue Damage of Small-Bore Piping Subjected to Flow Induced Vibration

Rajesh Ragoobir[1], and Richard Bachoo[2]

[1,3] Department of Mechanical and Manufacturing Engineering, The University of the West Indies, St Augustine, Trinidad and Tobago, West Indies; [1]E-mail: rajesh.ragoobir@my.uwi.edu; [2]E-mail: Richard.Bachoo@sta.uwi.edu

Abstract. *The structural fatigue of a vertically oriented small-bore connection due to flow induced turbulence emanating from an upstream piping manifold is experimentally investigated. Dynamic strain measurements are taken at two perpendicular locations on a small-bore connection and the method of rain flow counting is used to determine the cumulative damage incurred. The influence of a number of factors on the cumulative damage are investigated and explained. These include the effects of (1) single phase and multiphase flow, (2) the upstream flow path through the manifold, and (3) steady-state and transient conditions. Specifically, key observations that may be useful to piping designers and engineers are observed and reported. For instance, for single phase water or air the largest bending stresses are due to the out-of-plane vibration of the small-bore piping, whereas the pulsating characteristics of the multiphase flow results in significantly larger in-plane bending stresses. It is also observed that under certain manifold outlet conditions, transient effects upon pump start-up can produce more than 300 times the cumulative fatigue damage compared to steady-steady operation.*

Keywords: *Cumulative damage, Fatigue, Flow induced vibration, Rainflow counting, Small bore connections.*

12. Improving Monetary Valuation Methods Used in Cost Benefit Analysis of Water Infrastructure Projects

Dino Ratnaweera

Department Doscon AS, Østre aker vei 19, 0581 Oslo, Norway; E-mail: dino@doscon.no

Abstract. *An assessment of social utility and project benefits in the water sector should include financial, environmental and socioeconomic impacts that are comparable over the same unit in an analysis. Cost benefit analysis (CBA) is a decision support tool that can cover impacts identifiable within these three impact categories. However, most water sector CBA are only invested in forecasting future financial cost-benefits, while environmental and socioeconomic impacts are assessed by environmental impact assessments (EIA), life cycle assessments (LCA) and other qualitative assessments, or entirely ignored. Studies identify a need for more guidance on application of relevant monetary valuation methods to water infrastructure specific project impacts. This is feasible if a more approachable and implementable CBA framework tailored for the sector is*

made available. This paper suggests a universal set of umbrella categories for wastewater treatment plant (WWTP) impacts across the five project phases that comprise a project lifespan. The paper identifies literature on accessible and relevant monetary valuation methods for each impact category typical to a WWTP infrastructure project. The findings originate from literature on current practices in the water sector, academic innovations theoretically applicable to water sector projects, and methods borrowable from comparable sectors. These origins are the building blocks for consolidating knowledge of monetary valuation methods relevant to the water sector, which we tabulate in a reference matrix.

Keywords: *CBA, WWTP, roadmap, monetary valuation methods*

13. Rainwater Harvesting Design Approaches

Jeremy Gibberd

CSIR, Meiring Naude Rd, Brummeria, Pretoria, South Africa and Nelson Mandela University, Gqeberha, South Africa; E-mails: jgibberd@csir.co.za; itshose@gmail.com

Abstract. *Different approaches have been developed to design rainwater harvesting systems. However, these have not been widely applied in schools and are not well understood. This paper presents findings from a study in which different rainwater water harvesting design approaches are selected and applied to a case study school. The approaches are introduced and the results of their application to the case study school are critically evaluated. The study finds that the methodologies have different strengths and weaknesses. A critical analysis of the results indicates that one approach may be too simplistic and provide misleading results. Another approach does not provide adequate outputs to fully design rainwater harvesting systems. A third methodology is complex to apply and requires data that is difficult to obtain. Based on the study, recommendations are made on how the selected approaches can be improved to enable these to be used more easily to design school rainwater harvesting systems.*

Keywords*: Schools, rainwater harvesting, rainwater harvesting modelling and calculators*

14. School Water and Rainwater Use Modeller

Jeremy Gibberd

CSIR, Meiring Naude Rd, Brummeria, Pretoria, South Africa and Nelson Mandela University, Gqeberha, South Africa; E-mails: jgibberd@csir.co.za; itshose@gmail.com

Abstract. *With climate change, schools in hot and dry areas are increasingly experiencing water shortages. This can affect the health of students and teachers, disrupt education and in the worst case, lead to school closures. Rainwater harvesting can help address water shortages by providing a safe alternative source of water. However, there is limited research and guidance on how rainwater harvesting systems can be applied to schools. A lack of guidance and knowledge has meant that schools are not aware of the potential of rainwater harvesting systems and do not adopt these systems. There is a need, therefore, for a simple tool that can be used by schools to understand the potential of rainwater harvesting systems at schools. This study aims to address this gap by developing the School Water and Rainwater Use Modeller (SWARUM). The modeller is presented and applied to a case study school in a drought-stricken area of Southern Africa. The findings of the application and the modeller are critically evaluated. The study finds that the modeller can be used to show the potential of a rainwater harvesting system at schools and enables different scenarios to be modelled and understood. The study makes recommendations for the improvement of the modeller and its application.*

Keywords: *Schools, rainwater harvesting, School Water and Rainwater Use Modeller*

15. An Elementary Review of Wave Energy Potential at Mauritius Island

Antonia Chatzirodou[1] and Hugo Harel [2]

University of the West of England, Coldharbour Ln, Stoke Gifford, Bristol BS16 1QY; [1]E-mail: Antonia.Chatzirodou@uwe.ac.uk

Abstract. *During the last decade renewable energy sector has attracted a significant interest from a range of stakeholders. Ocean Renewables in specific are an attractive solution for covering countries' high energy demand with low or none*

environmental impacts. Within this context wave energy power generation potential around small islands has extendedly been investigated as well. Following that a review has been carried out in here, to compile existing research findings on wave energy potential, in specific around Mauritius Island. The island is geographically favored for ocean energy extraction in the context of energy extraction from offshore winds, waves and currents, and ocean thermal and saline energy. Mauritius relies on fossil fuels to cover its energy needs. But the island has set a target to be able to cover its electricity needs by utilising 35% from renewable energy sources by 2025. From the reviewed literature and a range of secondary calculations two sites come through as highly favorable locations for WECs (Wave Energy Converters) installation. Findings highlight that the wave source itself is abundant stressing out the need for further research to understand when and if WECs at the Mauritian sites could be fully commercialised in the future. For these sites and from the point of better understanding the spatial distribution of wave energy resource, high resolution wave transformation and hydro-morphodynamic numerical modelling is further suggested. Numerical modelling can support exercises to identify precise locations for WECs deployment along the coastline, prior to reaching any commercialisation.

Keywords: *Mauritius Island, Wave Energy Converter (WEC), Ocean Wave Energy, Renewable Energy, Small Island*

16. Digitalisation in the Water Sector: Opportunities and Challenges in the Next Decades

Harsha Ratnaweera

Norwegian University of Life Sciences, PO Box 5003, 1432 Aas, Norway; Email: harsha@nmbu.no

Abstract. *The water sector is undergoing rapid digitalisation providing new opportunities for improved, more efficient and economical services. Digitalisation may efficiently enable water utilities to overcome numerous challenges in the next decade by implementing, for example, real-time detection of water quality, process optimisation, efficient management of transport systems' rehabilitation, and reduction of utilities' physical and energy footprints. Many countries consider water supply and wastewater management critical services, and small islands are not an exception. Disruption of these services can lead to devastating consequences for the functioning of a society. In addition to natural catastrophes, the increasing number of manmade disruptions requires the earliest possible detection. The rapid digitalisation of the water sector has increased its vulnerability to cyberattacks, making it the third most attacked sector based on probability. Preparedness for immediate control of the attacks and the recovery actions after the incident is vital and should be planned. When a utility is under attack, identification is also critical, as man-made attacks can last several hours or days before being identified. This paper presents the emerging opportunities of digitalisation and the challenges associated with cyberattacks. Examples requiring increased preparedness, efficient detection, and the use of digital tools to minimise the impacts are outlined.*

Keywords: *Water utilities, Digitalisation, Remote control, Cyber risks*

17. Potential Implications for Deployment of Low Carbon Construction Materials in the Water Industry

Colin D. Hills[1], Nimisha Tripathi[2], Kiran Tota-Maharaj[3] and James E. Hills [4]

[1]School of Engineering, University of Greenwich, Chatham Maritime, Kent ME4 4TB; Email: c.d.hills@gre.ac.uk
[2] Indo: UK Centre for Environment Research and Innovation/ University of Greenwich, Chatham Maritime, Kent ME4 4TB UK; Email: n.tripathi@greenwich.ac.uk.
[3]Department of Civil Engineering, School of Infrastructure & Sustainable Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, UK; Email: k.tota-maharaj@aston.ac.uk
[4]Southern Water, Yeoman Road, Worthing, West Sussex BN13 3NX UK; Email: James.Hills@southernwater.co.uk

Abstract. *The introduction of sustainable and low-carbon construction materials into the built environment is one approach to reduce emissions of greenhouse gases to the atmosphere. By increasing the use of renewable energy and waste, new materials and processes can be incorporated into the materials supply chain. The present work relates to the mineralisation of anthropogenic CO_2 gas in construction materials, and their potential for use in water treatment, particularly in small island nations. We provide an overview of developments in this area of interest, with specific reference to the capture and use of point-source emissions, carbonate-able cementitious binders and waste in the manufacture of construction aggregates/monolithic products, including concrete and potential filter media. As the amount of construction materials used in new and existing water-related infrastructure is significant, there is potential for meaningful long-term carbon sequestration. In respect of this, we discuss the potential sustainability gains from replacing/reducing carbon intensive materials, quarried and crushed stone*

with low-carbon substitutes with particular reference to typical water supply and wastewater treatment facilities in the SE of England. Further, we estimate this potential more widely in order to gain a 'global' for carbon storage potential figure within fresh and waste water infrastructure.

Keywords: *Low Carbon Construction Materials, Water Industry, Water infrastructure, England*

18. Development of Sustainable Building Design in Hong Kong: Exploring Lean Capabilities

Edmond W.M. Lam[1], Albert P.C. Chan[2], Timothy O. Olawumi[3], Irene Wong[4], and Kayode O. Kazeem[5]

[1]College of Professional and Continuing Education, The Hong Kong Polytechnic University, Hong Kong, China; Email: edmond.lam@cpce-polyu.edu.hk;

[2,4,5]Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China; Email: albert.chan@polyu.edu.hk; irene.wong@polyu.edu.hk; Kayode.Kazeem@speed-polyu.edu.hk

[3]School of Computing, Engineering and the Built Environment, Edinburgh Napier University, United Kingdom; Email: T.Olawumi@napier.ac.uk

Abstract*. When a building design fails to meet the end-users' requirements after construction, it is regarded as a faulty design. Faulty designs often lead to renovation, demolition, and material waste. The need to implement innovative tools and systems that continuously provide designers with the end-users' design requirements and feedback in the built environment cannot be ignored. This study explores the potentiality of implementing a Lean Premise Design (LPD) scheme in Hong Kong to facilitate sustainability practices, ensure energy conservation, promote innovative green technologies and water efficiency, and reduce abortive works in high-rise residential (HRR) buildings. A comprehensive review of literature on concepts similar to the LPD scheme and sustainability practices in the design and development of high-rise buildings was undertaken. In addition, interviews were adopted to validate the identified barriers and drivers to the LPD scheme. These facilitated the identification of perceived barriers to the LPD scheme adoption in the local context. Furthermore, the relevant drivers that can promote its implementation were examined. The study focused on sustainable building design relating to users' behaviour patterns and expectations, social needs, green maintenance technologies, and government initiatives. About 77% of the experts affirmed the availability of comprehensive building codes and guidelines. Nevertheless, 62% of the experts confirmed the insufficiency of the current regulations to promote sustainable building design. Similarly, the literature review revealed that while there are many sustainable concepts in the development of high-rise buildings, little or none of these concepts focused on LPD.*

Keywords: *High-rise buildings; Lean Premise Design; Residential buildings; Sustainability, Waste; Hong Kong*

19. Higher Education Institutions in the Sustainable Transition: A Study at the University of Aveiro

Sara Bona[1], Armando Silva Afonso[2], Ricardo Gomes[3], Carla Pimentel-Rodrigues[4], and Fernanda Rodrigues[5]

[1,5] RISCO, Civil Engineering Department, University of Aveiro and Campus 2 Morro do Lena – Alto do Vieiro, 2411-901, Leiria, Portugal; E-mails: sara.cbona@ua.pt; mfrodrigues@ua.pt

[2,4] ANQIP, Civil Engineering Department, University of Aveiro and Campus Universitário de Santiago, 3810-193, Aveiro, Portugal; E-mails: asilva.afonso@outlook.pt; anqip@anqip.pt;

[3] INESC Coimbra and SMAS de Leiria, Civil Engineering Department, Polytechnic of Leiria; E-mail: ricardo.gomes@ipleiria.pt

Abstract. *In accordance with the United Nations 2030 Agenda for Sustainable Development, Higher Education Institutions (HEIs) play a key role in raising environmental awareness and implementing practices to contribute to the Sustainable Development Goals (SDGs), in a scenario of protecting the environment and promoting innovation and resilience – social, cultural, scientific, and technological. Considering HEIs as active agents of change in the global network for sustainability, the present study aims to present the main strategies and current initiatives of HEIs in the implementation and development of sustainable campus, regarding institutional physical interventions. Using the literature review, it is intended to identify the various contributions of HEIs in the Portuguese and European panorama for this emerging challenge, about the categories evaluation that include energy, greenhouse gas (GHG) emissions, waste, procurement practices and the built environment, mobility, biodiversity, water and food security, also highlighting the initiatives to increase environmental sustainability on the campuses of the University of Aveiro (UA). The conclusions of this research indicate that the HEIs, at the European level are implementing good practices in the management of the campus as a living and evolving laboratory, but there are potential interventions, still little explored, to make the operations of the HEIs more sustainable and effective.*

Keywords: *Sustainable Campus, Circular Economy, Higher Education Institutions, University of Aveiro.*

20. Nearly Zero Water Buildings: Contribution to Adaptation and Mitigation Processes in Urban Environments

Armando Silva-Afonso[1] and Carla Pimentel-Rodrigues[2]

[1,]University of Aveiro/RISCO (Portugal) and ANQIP (Portugal), 3810-193 Aveiro, Portugal and Standing Technical Committee on Water, World Federation of Engineering Organisations (WFEO), Paris, France; Email: asilva.afonso@outlook.pt;
2ISCIA (Portugal) and ANQIP (Portugal), 3810-193 Aveiro, Portugal and University of Aveiro/RISCO (Portugal) and ANQIP (Portugal), 3810-193 Aveiro, Portugal; Email: carla.rodrigues@ua.pt

Abstract. *Extreme weather events related to heat waves and heavy rainfall are expected to intensify in the coming decades in various regions of the planet as a result of climate change. The impacts of these events on urban environments will be particularly significant, given that, according to the United Nations, around two-thirds of the world's population will live in cities by 2050. Buildings and other urban infrastructures therefore have an important role to play in the processes of mitigation and adaptation to climate change. The implementation of nearly zero energy buildings (NZEB), for example, can contribute to very significant reductions in greenhouse gas emissions, which is why the European Union has established special requirements in new buildings. However, "nearly zero buildings" for all resources, not just energy, should employ integrated and enhanced construction solutions in the future, not only contributing to increasing environmental sustainability in urban areas, but also playing an important role in adaptation and mitigation in relation to climate change. In the case of "nearly zero water buildings", they can increase the resilience of urban environments in the face of extreme events such as prolonged droughts or extreme precipitation and, considering the water–energy nexus, can also contribute to a significant reduction in emissions. The "zero building" concept is not, however, similar for all resources. In the case of energy, the usual concept of NZEB does not mean a circular use of the resource, but rather that the total amount of resource used by the building is approximately equal to the amount of renewable resource produced or available on the site. In the case of water, part of the resource can be used in a circular way (water recycling), but renewable local sources alternative to the supply from the public network can also be considered. The design of "nearly zero water buildings" should be based on the 5R principle of water efficiency: Reduce consumption; Reduce losses and waste; Reuse water; Recycle water; and Resort to alternative sources (rainwater, salt water, etc.). It is obvious that water efficiency is of the utmost importance in the face of prolonged droughts, but the use of rainwater in urban areas has an additional known effect in dampening flood peaks. Considering the water–energy nexus, reducing water consumption in a building (the 1st R) also produces significant energy savings. This is a result of reducing the energy needs for domestic hot water, to pressurise water in buildings, and also in public systems, in pumping and treatment of water and wastewater.*

Keywords: *Climate change, Water efficiency, Zero building*

21. Interpreting the Technical versus the Physical as Drivers for Shower Water Use

Kemi Adeyeye[1], Kaiming She[2], Ines Meireles[3], Vitor Sousa[4], Tao Wang[5], and Dahmane Bairi [6]

[1] Department of Architecture and Civil Engineering, University of Bath, Bath BA2 7AY, UK; E-mail: ka534@bath.ac.uk
[2] University of Brighton, Lewes Road, Brighton, BN1 5EL, UK; Email: K.M.She@brighton.ac.uk
[3] Department of Civil Engineering, University of Aveiro, Aveiro, Portugal; Email: imeireles@ua.pt
[4] Department of Civil Engineering, Architecture and GeoResources, IST—University of Lisbon, Lisbon, Portugal; Email: vitor.sousa@ist.utl.pt
[5] Faculty of Art and Design, Beijing Institute of Technology, Beijing 100081, China; Email: wangt@cnu.edu.cn, taowang50@163.com
[6] Université de Paris, Laboratoire Thermique Interfaces Environnement (LTIE), Département GTE, Université de Paris, Ville d'Avray, France

Abstract. *Showering is informed by the person, their preferences and the affordances provided by the showering device and supporting systems. People shower for different reasons, including reasons of health, hygiene, wellbeing, leisure, relaxation among others. Studies have explored water use and efficiencies in showering in homes and other buildings. The lack of granularity of showering data can however mean that findings and deductions are typically made at the household or building level, rather than at the individual, shower end-user level. This study helps to address this gap about showering. This paper presents further analysis from an in-home trial with 12 adult participants: 6 male and 6 female, with a particular focus on interpreting the shower performance factors against the shower user. The findings highlight the contextual and physical characteristics e.g., shower positioning and user anthropometrics, and the showering needs (perceived shower functionality) as important drivers of water use.*

Keywords: *End-users, showerhead, showering, time, purpose, water efficiency*

22. Water Distribution Challenges in Northeast Trinidad and Tobago

Goldie Davis

Department of Mechanical and Manufacturing Engineering, The University of the West Indies, St Augustine Trinidad and Tobago; West Indies; E-mail: goldiedvs@gmail.com

Abstract. *Provision of a reliable supply of water with adequate pressures is a paramount challenge for the water distribution network in Northeast Trinidad and Tobago. Customers in this region, served by the Water and Sewerage Authority of Trinidad and Tobago often have trouble in obtaining a pipe borne supply of water as they reside on areas of high elevation or at the farthest end of the distribution system. These areas where water supply challenges are a problem are Oropoune Gardens Piarco, Upper Five Rivers Arouca, Windy Hill Arouca, Edna Hill Arouca, Lillian Heights Arouca, The Foothills Arouca and Bon Air North that is made up of Pineridge Heights Housing Development and Ridgeview Heights Housing Development. Sources of supply for these impacted areas are the North Oropouche Water Treatment Plant, the Hollis Water Treatment Plant, Tacarigua Highlift Station and the Arouca Wells. Challenges in the water supply are a consequence of obsolete pipelines, numerous leaks, failure of mechanical equipment and the shortened duration of supply to the respective areas. The aim of this paper is to identify the inefficiencies and challenges of the water distribution system in this region by simulating flow through pipes using ANSYS Fluent simulation and the Hazen-Williams equation and advocate prospective solutions that can alleviate or even eliminate the inadequate water supply experiences faced by customers in these highly elevated areas.*

Keywords: *ANSYS Fluent, Distribution pipelines, Hard-hit areas, Hazen-Williams Equation,Northeast Trinidad and Tobago, Transmission pipelines, Water distribution*

23. Impact of Climate Changes on Domestic Hot Water Consumption

Sandra Costa[1], Inês Meireles[2], and Vitor Sousa [3]

[1,2] RISCO, Department of Civil Engineering, University of Aveiro, Campus Universitario de Santiago, 3810-193 Aveiro, Portugal; Email2: smcosta@ua.pt; imeireles@ua.pt

[3]CERIS, Department of Civil Engineering, Architecture and GeoResources, IST - University of Lisbon, Av. Rovisco Pais 1049-001 Lisbon, Portugal; Email: vitor.sousa@ist.utl.pt

Abstract. *Domestic hot water consumption is the second largest source of energy consumption in residential buildings. Moreover, the growing trend towards more energy efficient buildings, from a thermal performance point of view, is increasing its relevance. As such, more accurate modeling of domestic hot water consumption is required, including the consideration of the impact of climate change. A new approach that accounts for the variability of the domestic hot water consumption and cold-water temperature throughout the months is used to forecast the amount of energy and carbon emissions associated. It was found that in climate change context, despite the forecasted increase in air temperature in the summer months, the decrease in the remaining leads to higher domestic hot water consumption and, proportionally, higher energy and carbon emissions.*

Keywords*: Domestic hot water consumption, energy consumption, carbon emissions, climate change*

24. Water Demand Modelling and Analysis United Kingdom, North American and Sri Lankan Data

Seevali Surendran[1] and Shelini Surendran [2]

[1]The Environment Agency, England, UK; E-mail: seevali.surendran@environment-agency.gov.uk

[2] School of Biosciences and Medicine, University of Surrey, Guildford, Surrey, GU2 7XH UK; Email: s.surendran@surrey.ac.uk

Abstract. *The aim of this research is to study real water consumption data to determine the most appropriate statistical distribution function to address the peak water demand. Moreover, the study is expected to contribute to finding a better fitting water demand model, which could apply to any water network. To achieve the objective, this study selected water usage of three different countries with diverse socio-economic backgrounds, climate, and geography to get an overall picture of water usage patterns. The countries selected for the analysis were United Kingdom, North America, and Sri Lanka. The most widely used probability distribution functions to represent a continuous random variable such as normal, log-normal, exponential, logistic, log-logistic, 3- parameter log-logistic and Weibull were applied to comprehend the suitability of fitting. The normal, log-*

logistic and 3- parameter log-logistic distributions are suitable to represent demand data with lower and high demand values and were selected for further analysis and is described here to provide their suitability for modelling water demand..

Keywords: *Uncertainty in water demand, log-logistic distribution, 3- parameter log-logistic distribution, probability distribution function, sustainable design*

25. Microbial Activity in Potable Water Storage Tanks of Barbados

Katelyn Long[1], Katherine Alfredo[2], and Elon Cadogan [3]

[1,2] College of Engineering, Civil & Environmental Engineering Department, University of South Florida, Tampa, FL 33620 USA; Emails: klong1@usf.edu; kalfredo@usf.edu

[3]Caribbean Community Climate Change Center, Barbados; West Indies

Abstract. *As water supplies are strained, distributed infrastructure can often help stabilise a water distribution system. Recently, the Barbados Water Authority, in collaboration with Caribbean Community Climate Change Center, installed 400, 450, and 1000-gallon potable water storage tanks to residential and school properties to increase the reliability of distributed drinking water to residents. However, there is minimal knowledge on the potential microbial impact of these storage tanks on water delivered to the tap. Preliminary data from this project confirmed that temperatures within these tanks can exceed 25 degrees Celsius, the lower threshold for increased growth of the premise plumbing pathogen Legionella. Inhalation and ingestion of Legionella pneumophila is known to cause Legionnaire's disease, a lifethreatening lung disease with pneumonia-like symptoms and tends to grow with long water stagnation periods, low disinfectant residuals and elevated temperatures. Seven sites located in the northern parishes of Barbados and one site located in a western parish were tested for temporal fluctuations of temperature, nitrate, total chlorine, total coliforms, and Escherichia coli (E. coli) with Legionella tested at select times of the day. Five of these sites were installed within the past year and three were installed up to four years prior to this study. All tanks showed values below the nitrate recommended range of less than 10 mg/L given by the USEPA. Only three tanks maintained the minimum chlorine residual of 0.2 mg/L given by the USEPA. Five sites showed positive total coliform tests and three sites showed positive E. coli tests and Legionella tests. With these results in mind, more quality assurance testing must be performed to ensure the true activity inside these tanks at various times of the year, location on the island and with continually flushed and finished systems. Unintended consequences from infrastructure upgrades are a threat, especially as climate change will continue to strain drinking water source supplies.*

Keywords: *Legionella pneumophila, water scarcity, potable, temperature, Barbados*

26. Biomass-based Sorbents for Stormwater Treatment

Nimisha Tripathi[1], Colin D. Hills[2], Kiran Tota-Maharaj[3] and James E. Hills[4]

[1]Indo: UK Centre for Environment Research and Innovation/ University of Greenwich, Chatham Maritime, Kent ME4 4TB UK; Email: n.tripathi@greenwich.ac.uk.

[2] School of Engineering, University of Greenwich, Chatham Maritime, Kent ME4 4TB; Email: c.d.hills@gre.ac.uk

[3] Civil and Environmental Engineering, Aston University, Birmingham B4 7ET UK; Email: k.tota-maharaj@aston.ac.uk;

[4] Southern Water, Yeoman Road, Worthing, West Sussex BN13 3NX UK; Email: James.Hills@southernwater.co.uk

Abstract. *Rapid urbanisation coupled with climate change necessitates the use of bespoke facilities to treat waste and stormwater to prevent contamination of ground and surface water. The contaminants of interest are wide-ranging including heavy metals, organic pollutants and micro plastics. There is mounting interest in the management of significant amounts of biomass waste available around the world and the exploration of utilisation potential. For example, large amounts of filter media including 'active' materials such as charcoal and plant based fibres are used. Nevertheless, the use of biomass-based sorbents and filter materials are of importance as they can offer both technical and economic advantages over traditional treatments. For example, studies are on-going on biomass-based sorbents coupled with conventional filter media such as graded sand and gravel gravity filters. The present work reviews developments in this area and introduces new potential materials for consideration, including biowaste from crustaceans, shells, and agriculturally derived biomass waste. With reference to example water supply and wastewater treatment facilities in the SE of England, the potential scale and benefits for resource recovery of biomass waste whilst also harnessing its water remediation potential will be discussed.*

Keywords: *Biomass-based Sorbents, biowaste, Stormwater Treatment, urbanisation*

27. Renewable Energy-powered Reverse Osmosis Desalination: Solutions and Opportunities for Large-scale Implementation

Mohamed T. Mito[1], Xianghong Ma[2], Hanan Albuflasa[3], and Philip Davies[4]

[1] Mechanical Engineering Department, College of Engineering and Technology, Arab Academy for Science, Technology and Maritime Transport, Abu-Qir, Alexandria, Egypt; E-mails: mohamed.mito@aast.edu; mohamed.mito@gmail.com

[2] Mechanical Engineering Department, School of Engineering and Technology, Aston University, Birmingham B4 7ET, UK; Email: x.ma@aston.ac.uk

[3] Department of Physics, College of Science, University of Bahrain, Kingdom of Bahrain; Email: halbuflasa@uob.edu.bh

[4] School of Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK; Email: p.a.davies@bham.ac.uk

Abstract. *Operating reverse osmosis (RO) systems using renewable energy (RE) is fundamental for meeting water security challenges, especially for small islands and developing states. Their integration requires RO systems to accommodate variations from RE sources to avoid reliance on backup systems. This study presents the outcomes of a research project that aimed to optimise the operation of RE powered RO by improving their variable-speed and modular operation for handling a wide range of RE variations. An industrial-scale pilot RO plant with 3.2 m3/h production capacity was designed, commissioned and tested at Aston University, UK, to be the basis for this project. It includes an isobaric pressure exchanger and delivers similar performance to large RO systems to develop solutions suitable to such scale. Several operation strategies were investigated for operating RO systems using RE. An advanced control system using Model predictive control was developed to control the RO power consumption based on RE variation. RE availability prediction using neural networks was developed for scheduling the startup/shutdown cycles of RO units during modular operation. The project concluded that operation at variable recovery and constant brine flowrate delivered the lowest specific energy consumption and widest operation range for systems using an isobaric energy recovery device. Model predictive control enhanced energy utilisation compared to a proportional-integral controller leading to a 2.35% improvement in permeate production for a defined power input. Overall, the solutions developed showed that RO systems can operate efficiently by direct RE using variable operation, which showcased the opportunities for further testing and development towards large-scale implementation.*

Keywords: *Reverse osmosis; renewable energy; variable operation; model predictive control; wind speed prediction*

28. Comparative Study of Solar-Enhanced Advanced Oxidation Processes for Water Treatment

Rikhi Ramkissoon[1], Krishpersad Manohar[2], and Kiran Tota-Maharaj[3]

[1,2] Faculty of Engineering, Department of Mechanical and Manufacturing Engineering, The University of the West Indies, St Augustine, Trinidad and Tobago, West Indies. Emails: ramkissoonrikhi@yahoo.com; Krishpersad.Manohar@sta.uwi.edu

[3] Department of Civil Engineering, School of Infrastructure & Sustainable Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, B4 7ET, UK; Email: k.tota-maharaj@aston.ac.uk

Abstract*. Water is an essential resource for human survival but in the 21st Century there is a lack of potable water in many parts of the world. In several developing countries people resort to consuming heavily polluted water obtained from rivers which contain life threatening diseases. The study used two methods, Photo Fenton and photocatalytic semiconductor as an advanced oxidation process to eliminate various water contaminants and provide an effective water treatment solution. Experiments were performed on polluted river water. Both methods were assessed by evaluating the physiochemical parameters that define the characteristics of safe water. The two methods successfully eradicated about 80-100% of pollutants that was measured in the river water samples. This shows the technology has potential in eradication of the contaminants.*

Keywords: *Titanium Dioxide, Solar Photo Fenton, Solar photocatalytic semiconductor, Photocatalysis*