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Abstracts

Keynote Session

- K.1. Rainwater Harvesting and Climate Change
Dr (Ms.) Tanuja Ariyananda,
- K.2. Implementation of Rainwater Harvesting in Malaysia
Ir. Ahmad Husaini Sulaiman
- K.3. Promotion of RAIN CITIES in Korea –Policies and Case Studies
Professor, Mooyoung Han
- K.4. Capacity Building and Technology for Rainwater Harvesting Systems
D. Brett Martinson
- K.5. Rainwater Harvesting as Supplement to Water Supply
Ir. Dr. Hasnul Mohamad Salleh & Ir. Noor Azahari Bin Zainal Abidin
- K.6. Implementation of Rainwater Collection and Utilization System (SPAHE)
Tan Choo Lan
- K.7. Research and Development of Rainwater Harvesting Systems
Ir. Ahmad Jamalluddin Shaaban
- K.8. Urban and Rural Rainwater Harvesting Systems
Prof. Ruslan Hassan
- K.9. American Rainwater Catchment Systems Association and the Dynamics of the USA Rainwater Industry (ARCSA)
Jason Kerrigan

1. Rainwater Harvesting, Human Health and the Environment

- 1.1. Importance of Rainwater Harvesting in Human Health
C.S. Weeraratna* & Tanuja Ariyananda**
- 1.2. The Holistic Design of Rainwater Harvesting Systems in Three Urban Projects
L. Ng* & E. Syariffudin*
- 1.3. Regional Climate Observation and Simulation of Extreme Temperature and Precipitation Trends
M.K. Sammathuria & L.K. Ling
- 1.4. The Application of Flat Ultra-Filtration for Rainwater Reuse
C. H. Liaw*, J. Kuo**, C.Y. Shih***, C. H. Wang***

2. Innovation in Rainwater Harvesting Systems

- 2.1. First-flush Rainfall Operation Strategy for the Rainwater Utilization System Design
Shih-Chi Lee * & Hsien-Te Lin*
- 2.2. The Advanced Technologies for Water Uses by Photovoltaic Energy in Small Scale Reverse Osmosis
Takeyama Kouichi*
- 2.3. A Management and Operational Plan for Improving Cisterns Efficiency in Brazil
L. Palmier¹ & A. Schwartzman²
- 2.4. Proposed rainwater harvesting system for the rest and service area, Kawasan Rehat Perasing, Kemaman, East Coast Highway, Malaysia.
Ir ismail Abd Rahman¹, Ir Ellias Saidin²

3. Rainwater Harvesting, Human Health and the Environment / Small Island Rainwater Harvesting Systems

- 3.1. Optimization of Stormwater Harvesting and Controlling System According to Different Proposals
J. L. Wang*, W. Che*, J. Q. Li*, G. Q. Pan**, H. X. Yi***
- 3.2. Effects of Roof Sizes on Reliability Analysis for Rainwater Harvesting
Prof. Ruslan Hassan, PhD, P.E.
- 3.3. Study on The Quantitative Feasibility of Rainwater Harvesting in Small Islands
Jaehong Ki¹, Mooyoung Han²

4. Rainwater Harvesting in Watershed for Soil Erosion Control and Management

- 4.1. Rainwater Harvesting in Integrated Watershed Management for Climate Change Adaptation
J.C. Salas
- 4.2. Experimental Simulation Technique of Rainwater Harvesting Modes Optimization on Small Watershed of Loess Plateau in China
J.E. Gao*, S.W. Yang*, H. Shao*, Y.X. Zhang*, M.J. Ji *
- 4.3. System Integration over Watershed Rainwater Harvesting for Topsoil Run-off Reduction to Conserve Beautiful Coral Eco-System in Okinawa Province, Japan
J. Matsushita*, A.R. Nafisah*, A. Okada, K. Suenobu**

5. Policy, Planning and Institutional Aspects

- 5.1. Comparison of Relevant Aspects in Rainwater Harvesting Practice between Two Metropolises: Tokyo & Selangor
A.R. Nafisah* & J. Matsushita*
- 5.2. Sustainable Construction Within The Built Environment: Malaysian Construction Industry Initiatives
Zuhairi Abd. Hamid¹, Mohd Khairolden Ghani², Maria Zura Mohd Zain³
- 5.3. Rainwater Harvesting – Comparing Apple to Apple
Mohamad Asari Daud
- 5.4. Policy, Planning and Institutional Aspects of Rainwater Catchment and Management in the Rural Area of Semi-Arid Brazil for Climate Change Adaptation
J Gnadlinger*

6. Modeling for Impacts of Rainwater Harvesting

- 6.1. Modeling and Reliability of Rainwater Harvesting System at Educational Institution
Thamer Ahmad Mohammad, Abdul Halim Ghazali, Megat Johari Megat Mohd. Noor
- 6.2. Using SimCLIM to assess the risks of climate variability and change to de-centralised water harvesting systems
R.A. Warrick* & P.B. Urich**
- 6.3. Quantifying The First-Flush Phenomenon: Effects Of First-Flush On Water Yield And Quality
D. B. Martinson* & T.H. Thomas**
- 6.4. Application of Continuous-Lumped Hydrology Model to Urban Long-Term Water Balance Analysis
Chao-Hsien Liaw, Yu-Chan Chia, Wei-Min Hua

7. Policy, Planning and Institutional Aspects / Capacity Building

- 7.1. Socio-Legal Effects of Compulsory Rainwater Harvesting in Malaysia
M.S. Othman *, S.A. Rahman*, R.M. Khalid** & F.M. Shahwahid***
- 7.2. Policy and Implementation of Rainwater Harvesting in Putrajaya, Malaysia
Akashah Hj. Majizat,
- 7.3. Building Capacities from University to Society
J. A. Gleason*, F. Córdova* & J. A. Demerutis*

8. Rainwater Harvesting as a Supplement to Water Supply and Irrigation

- 8.1. Conceptualization of Rain Water Harvesting Structures in Delhi, India
D.K.Chadha
- 8.2. Pilot Rainwater Harvesting Study, Ireland
L. Mccarton*, S. Ohogain*, A. Reid* And N. Mcintyre**, J. Pender**
- 8.3. Rainwater Harvesting in Burkina Faso: an Alternative for Areas with High Water
H. Kambou

9. Socio-Economic Aspects

- 9.1. Coping with water scarcity in water-rich environments: an integrated assessment of rooftop rainwater harvesting in the hills of Nepal
L. Domènech*, H. Heijnen** & D. Saurí***
- 9.2. Focused Evaluation of Rainwater Harvesting: A Case Study in Sandakan, Sabah, Malaysia
A. I. Che-Ani¹, N. Shaari¹, H. Yahaya², M. Jamil¹, N. Mohd-Tawil¹, M.F.M. Zain¹
- 9.3. Rainwater - A Feasible and Economic Solution to the Acute Drinking Water Shortage of the Slam Dwellers of Dhaka City
Islam, M. M.¹, Kabir, M. R.² & Chou, F. N.-F.¹
- 9.4. Evaluation of Required Capacity of Rainwater Harvesting System to Mitigate Typhoon-Induced Water Shortage in Southern Taiwan
Chou, F. N.-F.¹, Islam, M. M.¹ & Liaw, C.-H.²

10. Urban and Rural Community Rainwater Harvesting Systems

- 10.1. Flood Mitigation Using Building Rooftop Catchment in Taiwan
K.F. A. Lo* & K.C. Chih**
- 10.2. Integrated Roof Top Rain Water Harvesting In Saline Aquifer System, North West Rajasthan, India
Deesha & D.K.Chadha

11. Socio-Economic Aspects

- 11.1. Thai Schools Find a Solution to Turn Rainwater into Clean, Safe Drinking Water
Ruben Van Beek
- 11.2. Effectiveness of Rainwater Harvesting System at Office Building in Coping with Climate Change
Ir Dr Mohd Nasir Mohd Noh*, Norasman Othman**, Kamarul Azlan Mohd Nasir***, Mardhiah Farhana Binti Omar***, & Ellya Hayati Binti Omar ***
- 11.3. Building an institutional rainwater harvesting framework; the RAIN model and its challenges
K.Neke*, A. Schoemaker*, B. Jantowski and R. Meerman*
- 11.4. Adaptation to Climate Change through Rainwater Harvesting in Nepal
Dr Indira Shakya

- 11.5. Contaminants of Rainwater Harvesting Systems (RWHS) in Eastern & Southern Australia
A.C. Morrow*, R.H. Dunstan* & P.J. Coombes**

12. Urban and Rural Community Rainwater Harvesting Systems

- 12.1. Rain City Initiative Proposed by Suwon City, Korea
Won Jeung Yeon**• Mikyeong Kim***• Mooyoung Han**
- 12.2. A Crucial Need for Rainwater Harvesting in Rural Schools in Ethiopia
Girma H.Gode
- 12.3. Harvesting Rainwater, an Innovative Approach to Easing Urban Water-Energy Dilemma
Y.R Chiu*, C.H. Liaw**, Y.L. Tsai***
- 12.4. A Study of Rainwater Harvesting Systems Installations at Three Residential Houses in Malaysia
Ellias Saidin

KEYNOTE SESSION

K.1. Rainwater Harvesting and Climate Change

Dr (Ms.) Tanuja Ariyananda,

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Climate change and global warming has become the most concern of the 21st Century. Meteorological observations demonstrate that 11 of the past 12 years (1995-2006) are among the warmest years on record in terms of the average temperature of the Earth's surface. And associated with increasing temperatures of the atmosphere and the oceans is a proportionate increase in the content of water vapor in the atmosphere (for each degree Celsius of this increase, the air can theoretically absorb about 7% more water vapor). This causes numerous long-lasting climatic changes of regional and continental significance. Already world is recording the occurrence of extreme heat waves and intensive showers increased and it is predicted that this trend will continue. Serious dry spells (droughts) have affected vast regions of Europe, Asia, Canada, western and southern Africa and eastern Australia. The number of heavy floods (100-200 year floods) also increased significantly during the second half of the 20th century.

In the 20th century, however, humanity reached a degree of development that allowed it, knowingly or unknowingly, to change the water cycle to an unprecedented extent, and these changes, caused by human activities (along with many other factors) have clearly occurred and are still occurring. The old paradigm, which considered water as an eternally renewable resource, has failed, the truth being that water is only a renewable resource as long as the water cycle is functional. A new paradigm is therefore needed which will carefully protect the fragile equilibrium of this water cycle.

In the new water paradigm, the water balance at all levels—on the territory of individual communities, within cities, in forests, on agricultural land—is the central theme. The new water paradigm means developing, utilizing and supporting overland rainwater harvesting and conserving rainwater in watersheds so that ecosystems can "produce" enough good quality water for humanity, food and nature, can purify polluted water, can reduce the risk of natural disasters like floods, droughts and fires, can stabilize the climate and strengthen biodiversity and can become a component of economically sustainable development programs. What the new water paradigm offers is promotion and support for such a culture of land use which will permanently renew water in the water cycle through saturation of the soil with rainwater. The new water paradigm means a return to a natural responsibility for the state of water in one's region, but can also bring a new dimension of solidarity and tolerance between people and communities in watersheds.

K.2. Implementation of Rainwater Harvesting in Malaysia

Ir. Ahmad Husaini Sulaiman

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Rainwater harvesting has attracted considerable attention recently as an alternative method that helps store rainwater for other usage. It is the nation's most untapped resource, clean, abundant and reliable. With average precipitation of 3000 mm per year, Malaysia has a lot of potential in utilizing this

system for both potable and non-potable usage. Non-potable usage like flushing and cleaning toilets, washing cars and other vehicles as well as watering plants are some popular use while potable use, which requires special treatment, is still not being explored thoroughly. The Department of Irrigation and Drainage (DID) has implemented about 20 projects over the country and the number still growing year by year.

This paper discusses on the national policy, strategic direction and some implemented projects that have been done as well as future ventures by DID to ensure this program moves continuously. DID involves in the policy formulation as working committee among various agencies and recently published “Rainwater Harvesting Guidebook – Planning and Design”; explains step by step approach that needs to be taken by planners, designers and implementers in order to comply the requirements that fulfill water quantity and water demand needs. The strategic direction is tailored towards the overall stormwater management needs, which breaks into stormwater utilization program before scale down to rainwater harvesting activities.

Keywords: Rainwater harvesting, non-potable, water quantity control, demand management, strategic direction

K.3. Promotion of RAIN CITIES in Korea –Policies and Case Studies

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Due to climate change, flooding and drought are becoming worldwide problem. Considering that both flooding and drought are related to rainwater, we can reduce the risk of both natural disasters by proper rainwater management.

The main idea for a short term climate change adaptation is the change of rainwater management paradigm, which is to collect rainwater instead of drain rainwater. However, there are lack of scientific and engineering data about the rainwater characteristics and design methods.

The purpose of this paper is to show the scientific and engineering research results of the characteristic of rainwater in the context of urban water management, and to show the progress being made in many cities in Korea, which announced to become Rain City and to introduce several case studies in Korea. The policies and case studies such as Star City Rainwater System and Rain City Promotion project in Suwon City will be discussed.

K.4. Capacity Building and Technology for Rainwater Harvesting Systems

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On the surface, rainwater harvesting seems a simple technology to implement – just build a rainwater tank, connect it up and water will flow. But rainwater systems still fail for a variety of reasons and the vast potential for rainwater harvesting to contribute to the Millennium Development Goals and free

people from drudgery remains largely untapped. This paper looks at rainwater harvesting technology, and in particular, how this technology interacts with workers at different levels as well as users. It is argued that the apparent simplicity of rainwater harvesting can act against it with many promoters considering implementation of rainwater harvesting as the provision of full water coverage through the act of building tanks; with consequent failures in other areas and high costs. The paper goes on to consider how this record can be improved and penetration of rainwater systems expanded by considering a hierarchy of capacity building measures and also borrowing ideas from the emerging rainwater harvesting market in high-income countries and from the sanitation sector; e.g., wide coverage through market-based dissemination, simple, low-risk entry routes by providing choices in both size and quality of the system, and improved reliability by allowing potential users to access trained and accredited labour who focus on the whole rainwater system rather than its components.

Keywords: capacity building, systems, technology, technology transfer.

K.5. Rainwater Harvesting as Supplement to Water Supply

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As defined by Wikipedia, the free web based encyclopedia, Rainwater Harvesting is the gathering, or accumulating and storing, of rainwater for the purpose of providing drinking water, water for livestock, water for irrigation or to refill aquifers in a process called groundwater recharge. Rainwater harvesting can take place on many levels including large scale landscapes such as commercial sites and small scale landscape such as individual households. A typical system would collect the rainwater from the roof or pavement and by using course mesh, large debris are prevented from entering the system.

The purpose of rainwater harvesting is to either augment existing water supplies, remote and localised water supply, groundwater recharge or to provide water where other sources are either not available or would entail prohibitive development costs. The aim of any rainwater harvesting is to capture water in sufficient quantity and of suitable quality for intended use.

The catchment area of any rainwater harvesting system is an area that is reasonably impermeable to water which can be used to produce runoff. Some examples are :

- i. natural surfaces such as rock outcrops;
- ii. surfaces developed for other purposes such as paved highways, aircraft runways, or rooftops;
- iii. surfaces prepared with minimal cost and effort such as those cleared of vegetation or rocks and smoothed, or both smoothed and compacted;
- iv. surfaces treated chemically with sodium salts, silicones latex or oils;
- v. surfaces covered with asphalt, concrete, butyl rubber, plastic, tarpaper or sheet metal.

The quality of water from most surface treatments is usually adequate for livestock, but filters are needed in most cases if the water is for human consumption.

The economics of water harvesting have never been fully documented, particularly over the long term. The need is for a better understanding of the economic viability of different methods in different economic environments, particularly in developing countries.

There are many methods of rainwater harvesting and what is appropriate depends on the site condition, rainfall distribution and water requirement. With a combination of demand management, recycling water and harvesting rainwater it is possible to achieve sustainable water supply from small houses to large colonies. With a structured, scientific approach it is possible to maximize the benefits of rainwater harvesting . A detailed study helps in drawing the maximum benefits.

K.6. Implementation of Rainwater Collection and Utilization System (SPAHE)

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A United Nation study , published in 1997 has indicated that by 2025, the world's population will be affected by moderate to severe water shortage. Even a country that has abundant supplies of water such as Malaysia is not spared of the impending water crisis. Who could have imagined that such a tropical country with abundant rainfall would have to face water shortages as it had occurred around Klang Valley area in 1998 ? Increasing water demand as a result of population growth and industrialisation result in the need to manage the finite water resources more efficiently and effectively. To add problem is the growing trend towards unbanisation as highly populated areas impose tremendous toll on the water supply capacity. A proactive step must be taken to avoid acute water shortages in the future. One of the solutions, which has been given due consideration by the Government is the implementation of Rainwater Collection and Utilization System (SPAHE). It is basically collecting rainwater from main rooftops, and storing it for later uses. The system lies, perhaps, in its simplicity. Rainwater is relatively clean, freely accessible as Malaysia receives huge volumes of it all year long. The Rainwater Collection and Utilization System usage can be expanded to overcome the water supply shortage in our country. The stored water can be used for non-drinking purposes and as a back-up water supply. Adding to these benefits the Government is willing to make it compulsory for new selected buildings to implement SPAHE during the building plan submission stage. However old buildings are encouraged to install SPAHE. New guidelines will be published to provide the local authorities with some level of understanding on incorporating the SPAHE system during the approval of building plans.

K.7. Research and Development of Rainwater Harvesting Systems

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With the population of the world increasing rapidly, coupled with dwindling readily available water resources, alternative technologies to fulfill sustainable and adequate freshwater supplies to meet societal equitable access to water is the most urgent and significant challenge faced today. Among the various technologies to augment freshwater resources, rainwater harvesting and utilisation as a decentralized approach, is one of the alternatives to cope with this situation and also to provide environmentally sound solutions to the environmental problems often associated with conventional large-scale projects using centralised approaches.

The utilisation of rainwater harvesting should not be restricted to providing a dependable and locally-controlled water supply but also commensurate to provide tremendous environmental benefits and other aspects of living like flood mitigation, enhanced food and water security, feasible environmental rehabilitation, and the ever growing need for coping with climate change. Preventing runoff from going into sewers or storm drains instantly during storms and thereby reducing the load on treatment plants, flooding and erosion is certainly an added advantage. Capturing rainfall and replenishing it slowly to the aquifers is one of the ideal solutions that can contribute to improving the quality of groundwater. It cannot be denied that the rainwater harvesting approach is a sustainable and also very cost-effective in the long run. Rainwater harvesting has been identified as a system with the potential of contributing immensely for coping with the extremities as a consequence of impending climate variability, through reducing and mitigating more frequent floods or droughts predicted for the future. Research on the impact of rainwater harvesting to the environment like flood reduction, and local hydrological cycle and ecosystem restoration, should not be restricted to on-site impact only but has to be extended to the urban community level and the regional river basin scale.

Appropriate application of rainwater harvesting technologies plays an important role in encouraging people to harness rainwater as a complementary freshwater resource. The technologies can vary from the very simple and economical ones to those that are complex, expensive but efficient. There is a complex set of interrelated circumstances or factors that have to be considered when choosing the appropriate technology for such systems. However, what is appropriate in one situation may not be appropriate in another locale and all aspects must be pondered upon before making the final selection.

Nevertheless, appropriate technology and related system designs should include a complete set of robust system components such as roof, gutters, downpipes, filters, leaves-guard, storage tanks and distribution systems etc. Factors such as cost, climate, water quantity or volume, water quality or health concern, building structures, aesthetics, environmental concerns, social-political elements etc are also important and pertinent parameters that have to be taken into consideration to develop the eventual choice of system to be adopted for that particular situation.

Therefore, research and development on these circumstances for the various rainwater systems for different purposes and activities such as supplements to domestic water supply, as non-potable use that may include landscape irrigation, golf course irrigation, general cleaning, toilet flushing, cooling

water for power plants and air conditioning systems, fire fighting, agriculture, industry, construction, and even for potable use as safe drinking water where the situation warrants, are of utmost importance and must then be carried on to help the people to address and alleviate the challenges associated with water supply provision faced by the world. A flexible but adaptable and of economically viable technology that can widely be applicable and acceptable to the richest and the poorest societies, and from the wettest to the driest regions of the world, has to be developed by researchers and scientists.

Keywords: Climate change, Environmental benefits, Rainwater harvesting, Research and development

K.8. Urban and Rural Rainwater Harvesting Systems

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In this paper, a revisit of the issues pertaining to the rainwater harvesting installations in the urban and rural areas is made. These two different settings are also facing the two extremes in weather patterns. The former is facing demands exerted by an increase in population, industrial, institutional and commercial needs. The latter, is facing the needs from basic water supply to the conflicting needs of mega structures for irrigation and power sources. There were challenging times in meeting the two extremes of weather patterns. At times there were floods followed by dry and drought phases in the next. A typical water use in a home in an urban setting is for toilet flushing (30%), clothes washing (13%), outdoor (7%), and cleaning (8%), amounting to 58% of household water which can be replaced by rainwater harvesting. There are already other users such that in market place, commercial buildings, factory buildings, hostels, mosque, schools and double storey terraced-house which have benefited from the use of this alternative source with the payback periods ranging from 4 to 13 years. Whereas in the rural, the needs are typically for meeting the daily drinking supply and requiring continuous support from the Government of the day. The rainfall patterns combining with optimisation for storage for different regions showed the reliabilities could range from 23.71% to more than 50% only. Against these backdrops, several measures are proposed for mainstreaming the rainwater harvesting systems. The RWH systems should be incorporated in the design stage for aesthetic and functional reasons, a legislation with rewards system be instituted and a shared community storage RWH pool in the housing schemes to be undertaken. Data base and monitoring of changes in weather patterns manned using the best available technology be set-up. In the urban areas, it is hoped that more Green Buildings, with the water efficiency as an important component to the certification process, can pull the market forces aligned towards this direction. For rural areas, innovations such as rainwater collecting system using fused used plastic bags, is proposed. Finally, the paper will address issues with respect to regional and internationalisation to help sustain the RWH efforts.

K.9. American Rainwater Catchment Systems Association and the Dynamics of the USA Rainwater Industry (ARCSA)

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As the United States is being highly affected by the global recession with many industries shrinking in size; one industry is gaining momentum, that being the rainwater industry. Rainwater Catchment

Systems in North America are rapidly increasing in popularity. This can be seen through the increase in membership numbers of the American Rainwater Catchment Systems Association (ARCSA) and the increase in the activity through media channels, such as the New York Times, NBC News, National Public Radio and the Associated Press. The critical need for water resources has encouraged educational programs, university extension and research, plus municipal governments to address rainwater harvesting as a viable option to decrease shortages. This has increased businesses related to the rainwater industry and encouraged adoption of rainwater technologies by individuals and commercial enterprises.

1. RAINWATER HARVESTING, HUMAN HEALTH AND THE ENVIRONMENT

1.1. Importance of Rainwater Harvesting in Human Health

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Water used for drinking and other purposes may contain elements such as arsenic, cadmium or anions such as fluoride, and nitrates at toxic levels. Drinking of such contaminated/polluted water can cause considerable health problems. Arsenic in water causes many health problems collectively referred to as Arsenicosis. Cadmium in toxic levels cause Chronic Renal Failure. Excess fluoride in water cause dental and skeletal Fluorosis., and high levels of nitrates result in a condition called Methemoglobinemia. The facilities to purify water effectively are not adequate in most countries. Hence, a large number of people in many countries have to drink unpurified water resulting in numerous diseases, some of which are incurable. Water obtained directly from rain ie. Rainwater harvesting is the best alternative to prevent occurrence of such diseases.

Keywords: arsenic; cadmium, fluorides; nitrates, rainwater harvesting.

1.2. The Holistic Design of Rainwater Harvesting Systems in Three Urban Projects

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This paper aims to address the benefits of rainwater harvesting specifically in urban contexts with their unique requirements. Here, rainwater harvesting plays an important role in contributing to a city's stormwater management system by retaining water locally to ease downstream accumulation and prevent flooding. It is also crucial in ensuring long-term ecological sustainability by removing unnecessary and costly burdens on a city's freshwater provision.

Keywords: cleansing biotopes, rainwater harvesting, river restoration, urban stormwater management.

1.3. Regional Climate Observation and Simulation of Extreme Temperature and Precipitation Trends

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An unprecedented increase of 0.74°C in global averaged surface temperatures and increase in extreme rainfall events over most land areas are indicated in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). Regional climatic trends for Southeast Asia are consistent with the above findings from the AR4. Significant increase in regional climatic temperatures for

Malaysia, resulting in extreme surface temperature records correlate well with strength of the El Niño events. The signature of the El Niño Southern Oscillation (ENSO) for rainfall is more prominent for East Malaysia compared to Peninsular Malaysia. This is reflected by the fact that most of the severe dry spells in East Malaysia being recorded during El Niño years, is not the case with Peninsular Malaysia. Future regional climate projections for the 21st century were obtained for the Southeast Asian region using the Providing Regional Climates for Impacts Studies (PRECIS) regional climate model (RCM). A relatively consistent increasing trend of annual average maximum and minimum daily surface temperature is obtained for all the three regions considered, namely the Peninsular Malaysia, Sabah and Sarawak. Significant variation in annual rainfall trends between the three regions is evident during the second half of the century (2051 – 2099) compared to the first half (2001 to 2050). Throughout the century, a deficit in annual rainfall is generally simulated for all the three regions with an exception towards the end of the century (2084 to 2095). Decrease in annual rainfall projection is most clearly defined for Sabah, compared to Peninsular Malaysia and Sarawak. Simulation of ENSO like signatures are also investigated using the temperature and precipitation trends obtained.

Keywords : Annual; extreme; temperature; rainfall; ENSO; regional climate simulation.

1.4. The Application of Flat Ultra-Filtration for Rainwater Reuse

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Precipitation is a major source of valuable water resource on the Earth. The distribution, depth, and frequencies of precipitation are extraordinary due to the global climate change. Therefore, the level of application of precipitation depends on the functions of collecting and treatment systems. The filtering unit has been one of most important component of the water treatment procedures. However, filtering along is not enough to meet the standard.

The latest technical features of membrane were applied in this research. The flat UF membrane with pore diameter of 30nm is used. The SS in the precipitation was removed and the total coliform was reduced from more than 16 MPN/100 mL to 'Not Detected' (N.D.), and the application of recycled rainwater is broader. The ultimate target is to reach fully application of precipitation and to provide a convenient and cheap scheme of precipitation recycling.

Keywords: Precipitation recycling; filtration; UF membrane

2. INNOVATION IN RAINWATER HARVESTING SYSTEMS

2.1. First-flush Rainfall Operation Strategy for the Rainwater Utilization System Design

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Usually, the First-flush Rainfall contains more pollutant by the air pollution and silt from the automobile or the factory's discharges, especially in metropolis area or industrial region. It becomes the main influence factor for peoples do not want to use rainwater resources.

A long-term rainwater quality monitors data at Hsin-Chu Science-based Industrial Park region were applied for this appraisal analysis. The result showed that approaches 85% pollutant will wash out and enter to the rainwater treatment system in front of 2mm effective rainfall. In physical property aspects of this case, the change of chromaticity and turbidity is most obvious. On the other hand, SO_x quantum which by the air pollution has approaches 90% change quantity. If we can remove this rainwater volume, it will be able to reduce the funds and equipment establishment space of the rainwater treatment system in the new architectural design. This datum has bought into the country architectural design law (green building design norm) since 2007 in Taiwan.

On the other hand, we also test some simply filter material (stones, charcoal...), and the treatment effective of cant cube system on sedimentation procedure. The result shows that when comparing the original water quality with the water generated from the first-level non-woven fabric flume, the elimination of SS is able to achieve around 80% of the efficiency. Moreover, the chromaticity treatment efficiency implies that given the percentage of sands exist in water is the primary critical factor, the solid suspension filtered by the first-level non-woven fabric shows that 65% of the chromaticity has already been reduced. As the result, the selecting simple filtering materials to perform rainwater filtering can greatly enhance the rainwater quality and also provides the development reference of non-energy pipe disposal system for first-flush rainfall. Finally, with the operation strategy, this study showed a practical case of rainwater utilization system of the green building project in Taiwan.

Keywords: Green Building; First-flush Disposal System; Rainwater Interception Equipment.

2.2. The Advanced Technologies for Water Uses by Photovoltaic Energy in Small Scale Reverse Osmosis

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The many advanced technologies have been developed against frequent droughts or floods, as well as the many traditional rainwater harvests as the terraced paddy fields or dam- constructions in sloping area as well as many reservoirs, ponds or rivers. But self supply ratio of foods of Japan is about 40% with the fact that major use as two of thirds as 55 billion m³/year is agricultural water use. Now some

effective methods for amelioration of water quality, contributes sustainable water uses as the clarification by coagulation chemicals as the Artificial Zeolite synthesized, gained from coal fly ash, which showed much effect on clarification of water with water holding ability as slope protection. And aeration with more smaller “micro” size air bubbles increased oxygen in longer time into anoxic water area. With such advanced soil improvement material a highly-qualified farmer contributed to develop some high-level irrigation tools as spray water evenly and succeeded much products of marsh grass and water melon. And this paper deals with tool for gaining better drinking water, by small scale “home use water softner” using Reverse Osmosis membrane with tap water and pumped water, which power was afforded with comparisons with commercial charge and mobile photovoltaic sheet charge into batteries, from brackish raw water, and this small system s with 2 car batteries (12V×2) charged by charger from commercial power source, photovoltaic power charger, and the new 18W(12V) thin film solar panel were added to make comparisons, with 60PSI DC pump, proved some effective “soft water” gaining from brackish water as 1.0, 0.5, 0.25, and 0.1% salinity, and EC:0.6 mS/cm ground water supply at tap supply, showed much effect for gaining fresh and safe water, even in emergent condition as well as in apprehended water quality.

Keywords : Water amelioration; high-level irrigation tool; RO membrane ; Desalination, photovoltaic charge.

2.3. A Management and Operational Plan for Improving Cisterns Efficiency in Brazil

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The domestic roofwater harvesting has been used as a water supply alternative for human consumption in Brazil. An impressive initiative has been recently put into operation, which is Federal Government “One Million Cisterns” Program, aiming to provide water to families in the country’s semi-arid region. In spite of the current knowledge and latest developments on the topic, there are further difficulties to be overcome, related to water quality and quantity and costs issues. Some proposals are described in this paper so that to make the cisterns a more secure alternative for water supply. The absence of a systematic maintenance of the cisterns may result in their abandon and one obstacle for a wider use of cisterns in Brazil is the lack of a specific legislation and a management and operational plan that may ensure a greater performance. It is important to monitor the quantity and quality of the water which is stored and directly consumed by the beneficiaries and also to provide regular inspections in order to verify the necessity of repairs in each cistern as to increase its useful life. A preliminary version of a cistern management and operational plan is presented and be discussed in this paper.

2.4. Proposed rainwater harvesting system for the rest and service area, Kawasan Rehat Perasing, Kemaman, East Coast Highway, Malaysia.

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The Public Works Department of Malaysia is encouraging sustainable practices to be incorporated into projects undertaken by the Department. The Perasing Rest and Service area located near Kemaman along the East Coast Highway is a traveller's rest-stop with parking, shops, restaurants and large toilet facilities within the complex. A Rainwater Harvesting system is proposed for the water supply to the urinal and WC's of the Public Toilets, which make up more than 30% of the total water demand of the complex.

The catchment surface is the concrete roof-tile of the toilet building and walkway of approximately 1,000 m². The rainwater is conveyed via the UPVC gutter and rainwater down piping system to be discharged into the slightly elevated storage tank at the rear of the toilet building. The HDPE rainwater tank is of capacity 24,000 litres, which is ½ times the daily demand of the toilets. A 150mm dia UPVC first-flush diverter system is incorporated before the rainwater is discharged into the storage tank. An automatic topping up inlet pipe is provided for water from the public mains to fill up the storage tank when stored rainwater has been drawn down. The water is pumped and delivered through a pressurized steel piping system, delivering water to the Hush valve toilet system. Galvanised screens and nettings are provided to keep pest and insects from entering the storage tank.

The system is estimated to provide 27% of the toilet flushing water requirements and with about 56% of the total available rainwater captured and utilized.

3. RAINWATER HARVESTING, HUMAN HEALTH AND THE ENVIRONMENT / SMALL ISLAND RAINWATER HARVESTING SYSTEMS

3.1. Optimization of Stormwater Harvesting and Controlling System According to Different Proposals

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Rainwater harvesting may increase local water resources quantity, store and regulate the flood peak flow or to reduce runoff, improve the urban water cycle and the ecological environment. Therefore storage tank volume is a pivotal question for designing a rainwater harvest system. Several approaches were investigated for analysis storage and control volume optimization according to different proposals. Several methods and criteria were discussed in this paper, which including water demand method, design rainfall method, water quality control method and criteria, water quantity control method and criteria. Manly case studies were analyzed according to the proposed method in China. Results of the comparison provide guidance to the design of more efficient system associated with stormwater harvesting and control.

Keywords : Urban; Rainwater harvesting; Economical volume; Volume Optimization

3.2. Effects of Roof Sizes on Reliability Analysis for Rainwater Harvesting

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Rainwater Harvesting and utilisation are both commercially and environmentally attractive. However, the low storage capacities of rainwater systems may not be able to provide water in prolonged dry period as well as the inability of the roofs not able to capture rainwater effectively. A comparative study on the roof areas for different buildings in three regions, namely the Northern (Butterworth), Middle (Klang Valley) and the Southern (Johore) has been carried out. The objective is to determine the relationship between the roof sizes and the reliability of the system with respect to each rainfall pattern using a manual method and the NAHRIM Tank software and its simulation. For the simulation, results on reliability ratio, rainwater utilisation, storage efficiency, the time when the tanks are empty, rainwater capture and total rain delivered will be presented. A total of six (6) rainwater harvesting systems was analysed for their reliabilities. The reliabilities ranged from 23.71% to more than 50%. Finally, the optimum roof size for the rainwater collection for each region will be discussed and recommended.

3.3. Study on The Quantitative Feasibility of Rainwater Harvesting in Small Islands

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Many islands in Korea have problems related to water source security and supply. Especially, water supply condition is worse in small islands remote from inland. Couples of alternatives are developed and suggested to supply water to islands including water hauling, groundwater extraction, and desalination. However, these alternatives require high energy, cost and consideration in installation and operation processes. Rainwater harvesting is sustainable option that supplies water with low energy and cost. Lack of quantitative study in rainwater harvesting system hinders the promotion of the system. Therefore, this research studied quantitative feasibility of rainwater harvesting as a water supply option in islands. Operation of rainwater harvesting system was estimated with computer simulation and the method to determine system design is suggested based on the simulation result. The method applied to condition of existing island and required capacity of the system was found to be in acceptable extent. That rainwater harvesting is estimated to be a feasible water supply option under Korean climate, which is unfavorable condition for rainwater harvesting, implies high potential applicability of rainwater harvesting technology for other regions over the world suffering from water shortage.

4. RAINWATER HARVESTING IN WATERSHED FOR SOIL EROSION CONTROL AND MANAGEMENT

4.1. Rainwater Harvesting in Integrated Watershed Management for Climate Change Adaptation

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The paper presents a case study of the Tigum-Aganan Watershed and its problem of water supply. In 1993, attention was brought to the Maasin Watershed as only 35% of the city's population was serviced with potable water. A projection showed a decline in the water supply of the Tigum River because the watershed was denuded and farmed. A reforestation proposal was implemented and a decade later, the watershed experienced further reduction of water supply. This decrease of water supply was further exacerbated by a typhoon and flooding in the watershed which caused massive erosion yielding 2,100,000 m³ of soil and 71,000 uprooted trees. The recent presentation of a local utility firm estimated a further loss of water supply by 55% and soil erosion of one cubic meter of silt everyday from its de-silting pond. In response to these series of problematic events, a rainwater harvesting program in the Tigum-Aganan Watershed was initiated to help farmers and households cope with the limited supply of water. The problem of a degraded ecosystem and the impact of climate change led the stakeholders to meet in a series of assemblies and made recommendations, among which was rainwater harvesting in the catchment. How the program was implemented and what was the result is presented in the paper.

Keywords: Rainwater harvesting; integrated water resource management; watershed management; soil and water conservation; climate change adaptation.

4.2. Experimental Simulation Technique of Rainwater Harvesting Modes Optimization on Small Watershed of Loess Plateau in China

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Aiming at how to optimize rainwater use on small watershed of the loess plateau in China by experiment simulation, a design means and experimentation technology and its verification test were given based on similarity theory and hydrodynamic principles of rainfall, runoff and infiltration. The model is one of Kangjiagou small watershed of the loess plateau of China. It complied with the similarities of geometric, rainfall, flow, erosion production sediment transport and bed deformation etc. The verifying experiment results indicated that the movements of rainfall, flow, and production sediment and bed deformation agreed to the practical situation. It is concluded that the bad water erosion appeared in July to September and were caused by four to six heavy rains. Centralizing rainfall is an advantage for rainwater harvesting to prevent drought and water erosion. The similarity

experiment is an efficient tool for laboratory forecast. It can be used to optimize rainwater utilization mode and control soil erosion and utilize water and soil resource effectively.

Keywords: Rainwater harvesting; small watershed; simulative experiment; design and verification.

4.3. System Integration over Watershed Rainwater Harvesting for Topsoil Run-off Reduction to Conserve Beautiful Coral Eco-System in Okinawa Province, Japan

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The conservation of coral seas in the tropical/subtropical regions is a matter of an international concern, since the coral eco-system is fragile against environmental impact due to human disorderly activities and due disruptions in its habitat. This paper deals with appropriate measures against topsoil run-off from farmlands in Okinawa Island, the sub-tropical southern province of Japan which boasts of abundance in its coral species. Analysis was made on adaptation of the standardized watershed rainwater harvesting (RWH), which had been workable so far for flood mitigation and/or water demand control in rapidly urbanized river basins in Japan. As a result, it was clarified that system integration is desired with both application of RWH and stimulus schemes based on beneficiary-pay-principle combined.

Keywords: Conservation of coral eco-system, topsoil run-off reduction, system integration, watershed rainwater harvesting

5. POLICY, PLANNING AND INSTITUTIONAL ASPECTS

5.1. Comparison of Relevant Aspects in Rainwater Harvesting Practice between Two Metropolises: Tokyo & Selangor

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Rainwater Harvesting (RWH) has become one of the recent trend as a sustainable approach for supplementing public water supply as well as for serving several other purposes such as flood mitigation, emergency water supply etc. Tokyo starts off the RWH practice in urban area few decades ago. In consequence, Tokyo is known for her well-developed RWH practice. Whereby, Selangor, the most developed nation in Malaysia is far lack behind in implementing RWH since up till now, only several buildings are equipped with Rainwater Harvesting System (RWHS). This study aims to investigate the well-developed RWH practice in Tokyo from several aspects which are policy & planning, design, technology, and social matters. Subsequently, this study compares Selangor's efforts on such aspects for proposal of betterment.

Keywords: Design aspect; policy aspect; rainwater harvesting; social aspect; technological aspect.

5.2. Sustainable Construction Within The Built Environment: Malaysian Construction Industry Initiatives

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The construction industry and its related activities are responsible for a substantial amount of global resource use and waste emissions. As buildings and other structures are planned to last for 50 to 100 years, future changes in climate change derived from these constructions should be given a high priority. Through anticipating future climatic developments, engineers can minimize their negative effects and benefit from their positive impacts. The combination of efforts from sustainable and built environment and all actions derived from construction will protect the earth from manmade disaster. Construction sector could not be marginalized from the issues on environment. Creating a sustainable construction in Malaysia requires a strategic approach that will benefit the country's current and future consideration looking issues related to economic, social, environment and quality of life. Construction Industry Development Board (CIDB) Malaysia is obliged to take this issue on board through its Construction Industry Master Plan initiatives under Strategic Thrust 3: Strive for the highest standard of quality, occupational safety and health and environmental practices. This paper discusses the role played by CIDB Malaysia to set out an agenda and a strategy for action to attain current and future sustainable construction in the built environment.

Keywords: construction industry, built environment, strategic, sustainable construction.

5.3. Rainwater Harvesting – Comparing Apple to Apple

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Rainwater harvesting has not made much inroads in the Malaysian water consumerism. The advocators have been working very hard and have made some great findings and achievement. The peak of it is the announcement by the Prime Minister of Malaysia giving the green light for rainwater utilization to be incorporated in the building bye-laws. That is a big achievement, congratulations! How much it has moved from there?

This paper is looking at the predominant conventional thinking among water players in the water industry. Even engineering textbooks have not considered categorically rainwater harvesting as a water resource which undoubtedly it is.

To succeed in the promotion of rainwater harvesting, particular in Malaysia, is by bringing about paradigm change. It has to go right to the basic thinking that rainwater is a viable source of water, at least for the future. It is not just about saving few drops of water but it is saving the millions of Ringgits in developing major infrastructural facilities to meet the same objectives. In doing so, apple to apple comparison is vital.

This paper will touch on few aspects:

- Water quantity
- Water quality
- Cost of supplying water to consumer, economy
- Regulation
- Reliability
- Sustainability
- Indirect benefit of rainwater harvesting

In the final analysis this paper will propose strategies to path the way to gain acceptance of industry players in Malaysia. Otherwise promotion of rainwater harvesting will be analogous to the rainwater itself. It evaporates from the sea, condensed and falls as rain then flows back to the sea without being harvested by anyone, or as the famous Malay proverb says: ‘Like pouring water on to the yam’s leaf’.

Keywords: Conventional, Rainwater, Resource, Cost

5.4. Policy, Planning and Institutional Aspects of Rainwater Catchment and Management in the Rural Area of Semi-Arid Brazil for Climate Change Adaptation

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This paper deals with rainwater catchment and management programs to adapt to the semi-arid climate and to climate change in the rural area of semi-arid Brazil, a region with 969,599 km² and 9 million inhabitants in the rural area. In this region rainwater management has its origins in NGO initiatives, first for drinking purposes and later also for agriculture. These initiatives are being canalized by ASA the Brazilian Semi-Arid NGO Network into two programs, called P1MC and P1+2, which take rainwater catchment and management as integrated part of Living in Harmony with the Semi-Arid Climate. The goal of P1MC the One Million Cisterns Program is to supply safe drinking water for 1 million rural households. More than 261,000 cisterns with 16,000 liters have been constructed until now through the program.

P1+2 - the Program One Piece of Land and Two Types of Water, signifies that every rural family should own one piece of land (1), large enough to guarantee sustainable livelihood and have two (2) types of water, one for human consumption (already supplied by P1MC) and the other one for food production (all types of vegetables, corn, rice, beans or fruit trees). In 2007 and 2008, 1500 rainwater catchment systems, mostly underground cisterns with 52,000 liters for protective irrigation, rock cisterns and subsurface dams, have been constructed by the P1+2, and the implementation of another 1500 systems is underway in 2009. These rainwater catchment technologies are completed by green water conserving methods such as contour tillage, vegetative soil protection and use of manure.

The paper focuses on policy, planning and institutional aspects of these rainwater catchment and management programs: conception and planning, involvement of rural communities, organizing of a network of 1000 NGOs through awareness building, qualification of labor and of experts in Integrated Land and Water Management and the challenge of the construction of a partnership between governmental organizations and the implementing NGOs with different objectives, problems of the bureaucratic process, the discontinuity of the programs, the different interests of the stake-holders.

Keywords: rainwater catchment and management programs, sustainable development, public-NGO-partnership, semi-arid regions, climate change preparedness.

6. MODELING FOR IMPACTS OF RAINWATER HARVESTING

6.1. Modeling and Reliability of Rainwater Harvesting System at Educational Institution

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In the present study, a rainwater harvesting system is installed at the Faculty of Engineering, University Putra Malaysia and data for 24 different rain events is collected from the system for analysis. The collected data include rain depth and rainwater volume. It is found that the rainwater volume ranges from 0.027 m³ to 4.03 m³. The data is used to produce an empirical model for predicting the collected rainwater volume. Calibration and validation processes are conducted to the proposed model and T-test shows that the model prediction is within 95% level of confidence.

Furthermore, the water consumption for toilet flushing is monitored using water meter. Reliability of the installed rainwater harvesting system for toilet flushing is computed. It is found that the system reliability ranges from 26.61 % to 100 % depending on daily water demand and recorded rainwater depth.

Keywords: Rainwater harvesting, system modeling, assessment, reliability.

6.2. Using SimCLIM to assess the risks of climate variability and change to de-centralised water harvesting systems

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The purpose of this paper is to describe the SimCLIM modelling system and to demonstrate its potential application for assessing risks of climatic variability and change to domestic water harvesting systems. The paper describes the key features of SimCLIM, including its climate scenario generators and tools for examining climatic variability and extremes. A simple water tank model within SimCLIM is then used to spatially assess the risks of system “failure” over a region southeast Queensland, Australia, under both current climate and future change. It was found that a steep east-west gradient of risk exists under current climate, and that a future scenario of drier conditions portends an extension of the higher risk areas. Using SimCLIM, the paper then examines options for reducing the risks, including increasing tank storage or runoff area, decreasing average water consumption, and raising the tolerable threshold level for periods without tank water through preparedness. Each option is examined individually in terms of the extent of adaptation required to

maintain or achieve a goal of low level of risk, for two sites – a moderate risk site and an extremely high risk site. For areas of moderate risk, this goal is viable with any of the range of options examined. For areas of high risk, simply increasing tank storage is quite impractical given the large requirements, while the same level of low risk could be achieved through modest reductions in average water consumption. This exploratory analysis demonstrates the viability of assessing climate change impacts and adaptation through simulation tools like SimCLIM.

Keywords: Adaptation; climate change; impacts; water harvesting; simulation models

6.3. Quantifying The First-Flush Phenomenon: Effects Of First-Flush On Water Yield And Quality

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First-flush diversion is increasingly recognised as a useful intervention to reduce both suspended and dissolved contaminate loads in rainwater systems. Such first flush systems rely on the early rain to wash the roof before water is allowed in the store. While there is almost universal acceptance that this is beneficial, there is no agreement on just how much water is to be diverted and the reset of the device rarely considered. In a paper delivered at the 12th IRCSA conference the authors presented a number of field measurements and derived an exponential decay constant for the first-flush phenomenon based on rainfall depth. This paper builds on these results by applying this decay constant, and a time constant for debris accumulation derived from the same data, to a water-balance model. The results show that most current first-flush devices used in the field have a poor performance; however it is possible to remove up to 85% of incoming material while retaining 85% of the water if the device is designed carefully. Better material removal performance is possible but only at the expense of lower water yield; similarly water yield can be improved by reducing overall material removal. The key to good performance is found to be to use a slow device reset combined with a large water diversion, though not as large as had been initially feared. A design procedure is discussed along with practical technical constraints, possibilities and currently available techniques.

Keywords: Accumulation; mass balance; first-flush; wash-off; water quality; water yield.

6.4. Application of Continuous-Lumped Hydrology Model to Urban Long-Term Water Balance Analysis

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Due to excessive urban development and population growth, both impervious area and water demand in urban area increases dramatically. Consequently, less water is infiltrated into the ground and water conservation capability is worsen. Therefore, water balance in urban are interrupted and more frequent flooding are increased. In order to restore the water balance in the urban area, the long-term water balance model to assess the environment impacts by installing rainwater harvest facilities and porous pavement is needed.

This research collects and analyzes the researches performed in the areas of urban water cycle modeling, hydrology model, evapotranspiration estimation and the strategies of water environment improvement. The lumped distribution concept, which divided land use into pervious and impervious part, was used to establish the theoretical framework of "Urban Water Environment Decision System" using the language of Microsoft Visual Basic 6.0.

To evaluate the feasibility of this model, the watershed of Liu-guan pumping station of Datung district in Taipei city is selected for the study. Sensitivity analysis of parameters in the model, model calibration and verification are carried out using the established window-based model using data from years of 2005 and 2006. The simulation results show that the adaptability of "Urban Water Environment Decision System" is suitable for the long-term simulation and the roof rainwater catchment system decreases the water supply system demand, and obtain the benefit of flood mitigation. The porous pavement alternatives which include five different types can effectively improve the ability of infiltration, evapotranspiration, and runoff reduction in the study area.

The model developed is capable for assessing any impacts to urban water cycle due to land use changes and provides as an useful tool for urban planners.

Key words: Urban water environment, lumped hydrology model, roof rainwater catchment system, porous pavement.

7. POLICY, PLANNING AND INSTITUTIONAL ASPECTS / CAPACITY BUILDING

7.1. Socio-Legal Effects of Compulsory Rainwater Harvesting in Malaysia

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Voluntary rainwater harvesting failed to promote rainwater harvesting in Malaysia as only few agencies have adopted the system since its introduction in 1999. Hence the move by the government to make rainwater harvesting compulsory is applauded. This however would result in some implications on the existing social and legal provisions. Compulsory rainwater harvesting also requires amendment of certain laws since it attracts some planning, environmental and health issues. For instance, as design and requirement of a building are legislated under the Uniform Building By-laws 1984, it will be the most affected laws and has to be amended accordingly. This paper shall analyse any affected legal provisions once rainwater harvesting is made compulsory, and to propose solutions to impediments that may arise in the process. A method of content analysis has been used to achieve reliable results. The findings shall be useful in remedying any defects once rainwater harvesting is made compulsory in Malaysia.

Keywords: Compulsory rainwater harvesting, legal provisions, Malaysia.

7.2. Policy and Implementation of Rainwater Harvesting in Putrajaya, Malaysia

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Being the local authority for Malaysia's new Federal Government Administrative Centre of Putrajaya, Putrajaya Corporation has made a proactive effort in encouraging the application of rainwater harvesting concept to be considered in all its planning, development and post-development phases. The 600 hectares of the Putrajaya Lake and Wetlands, serving as a big detention pond storing an estimated volume of 24.5 million cubic metres, is one of the rainwater harvesting concepts which has been constructed in stages as early as in 1997. Having the big lake in place, which also acts as a natural climate moderator and cooling system for Putrajaya, will require a water quality and quantity management enhancement and thus making this concept even more important. Furthermore, the reduction of the lake water volume could be managed or controlled in prolonged drought events with the implementation of this concept. The slowing down of surface runoff flowing into the lake from the

city (surface) and the gradual seepage of the rainwater into the ground as groundwater recharge enables the water quality enhancement process to occur.

For that purpose, Putrajaya Corporation implements the rainwater harvesting concept as recommended in the guidelines on “*Installing a Rainwater Collection and Utilizing System*” introduced by the Housing and Local Government Ministry in 1999 for residential houses as well as commercial and government offices in Putrajaya.

The application of rainwater harvesting in Putrajaya serves its purpose in terms of the water quality improvement aspects such as the prevention of rubbish, debris, chemical agents and other pollutants entering the Putrajaya Lake. The Putrajaya Lake will thus receive most of the inflow water that is naturally purified which in turn improves the lake water quality to its best condition.

7.3. Building Capacities from University to Society

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The purpose of this paper is to share experience in teaching rainwater harvesting systems as a mean of building capacities at two universities of Guadalajara, Mexico. Rainwater Harvesting is taking on a higher relevance at Mexico. Last semester we implemented some strategies in two universities: University of Guadalajara (public university) and ITESO (private university). At University of Guadalajara started an academic reform in hydraulic and sanitary programs of architecture carrier. This reform consists in teaching new approaches in the design of hydraulic and sanitary systems, transforming the traditional approaches that included the mixed drainages to sustainable approaches. Now the proposal consists in teaching the idea to separate the wastewater and rainwater because in Mexico it is very common mixing the both waters. At ITESO was implemented a new Rainwater Harvesting Course to Engineering and Architecture carriers. Finally, there was organized a Rainwater Harvesting Conference at University of Guadalajara last march, which they were, gathered several universities, governments, high schools, enterprises, and media. These experiences were very useful and let us know the best ways to teach rainwater harvesting systems and spread the knowledge initialing at universities and then to the rest of society.

Keywords: Building Capacities; Teaching; Academic experience.

8. RAINWATER HARVESTING AS A SUPPLEMENT TO WATER SUPPLY AND IRRIGATION

8.1. Conceptualization of Rain Water Harvesting Structures in Delhi, India

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Rain water harvesting has become imperative and included in States' byelaws to use the non-committed monsoon runoff to supplement the available water resources and increase the sustainability of aquifers. Delhi has a total demand of 4.0 MCM per day for a population of 1.5 million but the total availability from surface and ground water resources is less than 3.6 MCM per day. It is estimated that 65.6 MCM is available for artificial recharge which can be harvested by constructing different types of recharge structures like check dams and combination of pit/trench with recharge wells. On the basis of geomorphology and drainage, five distinct artificial recharge environments have been classified, they are :1-Development and recharging of 97 sq Km of Yamuna flood plain having utilizable potential of 78 MCM up to 4m depth ; 2-Roof top rain water harvesting for effective recharge of 6 MCM per year;3-Ridge area, of 145 sq km has a runoff potential of 6.79 MCM for recharge each year;4-Surplus of canal water during monsoon having storage potential of 40 MCM for recharging depleted aquifers; 5-Surplus of Najafgarh drain estimated as 58 MCM for recharge of depleted aquifers in West Delhi. The cost of roof top water harvesting structures is between Rs. 1.60 to Rs. 7.0 per m³. The impact assessment of 7 roof top schemes show recharge of 5000 m³ and 8 roof top and pavement schemes show 8500-20000 m³ of recharge in a year.

Keywords: Artificial recharge Potential; Flood Plain; Monsoon Runoff; Ridge; Rooftop.

8.2. Pilot Rainwater Harvesting Study, Ireland

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There are no National Water Quality Standards for Rainwater Harvesting supply in Ireland. The Development Technology Centre (DTC) at the Dublin Institute of Technology was commissioned by the National Rural Water Monitoring Committee in 2005 to assess the feasibility of using rainwater harvesting to supplement treated mains water for non-potable uses. The project involved the design, installation, commissioning and monitoring of rainwater harvesting facilities for rural domestic and agricultural water supply. This paper will present the results from the domestic pilot rwh project. A dual water supply system was designed and installed to use rainwater collected from the roof surface to supplement mains water supply for toilet flushing and out door uses. A series of flow meters and a data logger system were installed to monitor micro component household water usage. Over the 19 month monitoring period, rainwater harvesting resulted in a saving of 20% of the total mains water

supplied to the house. Harvested rainwater was tested monthly for physico-chemical and microbiological parameters. All samples complied with EU bathing Water Regulations. Compliance with the more stringent Drinking Water Regulations was achieved for ten of the nineteen sampling dates. Laboratory experiments were conducted using a variety of water related bacteria to determine time required to reduce a bacterial population by 90% at a given temperature. The laboratory experiments showed that hot water systems maintained at adequately high temperatures (60 0C) for 5 minutes effectively reduced the bacterial load from E.coli, Enterococcus faecalis, Pseudomonas sp and Salmonella to zero.

Keywords: Demand management; health; hotwater systems; rainwater.

8.3. Rainwater Harvesting in Burkina Faso: an Alternative for Areas with High Water

H. Kambou

During the last decade, the level of groundwater in Burkina Faso has dropped in several areas due to climatic vagaries and overexploitation of ground water and surface water for the benefit of irrigation and communities' Potable Water Supply. Indeed apart from big urban centres, the population is supplied with water through boreholes and wells. Yet the realisation of these types of water facilities is sometimes impossible in some areas with very difficult hydro-geological conditions (hard rock or ground without water). In addition, in recent years, we've noted that toxic minerals such as arsenic and nitrate have contaminated the water of some wells and boreholes. Indeed a study in the northern region of Burkina Faso found that water from several boreholes and wells is contaminated with arsenic. The measures taken by the authorities to fix this problem were the outright closure of the contaminated water to prevent poisoning of consumers. However no alternative water supply has been offered to these communities. They are abandoned to themselves and obliged to have recourse to traditional water sources such as ponds and streams where the water is of poor quality. The poor quality of water from these sources causes serious health problems, with women and children spending a lot of time on this daily burden as far as they are responsible for collecting water for the household. This disturbs economic activity, education and quality of life. Access to drinking water is an important condition for improving millions of lives in the Sahel areas.

To solve the water problem of communities from these localities in Burkina Faso (with very high water stress) a programme for rainwater harvesting is being implemented since 2006 by NGOs with the support of the RAIN Foundation. The programme is very well appreciated by the beneficiaries (often disfavoured by the nature) and who feel a great relief from a problem that delayed their development for years. However the Government of Burkina has not yet recognised the collection of rainwater as a source of drinking water supply for communities. Thus the rainwater water harvesting programme coordinated by a Centre of Expertise for Rain Water Harvesting (CECEPA) constituted by the international NGO WaterAid and the National Representation of the Regional Centre for Low cost Water and Sanitation Technologies (RN / CREPA) has built more than 400 facilities for the collection of rainwater. The programme is also doing a lot of advocacy work to influence the Burkinabe authorities in recognising the technology.

9. SOCIO-ECONOMIC ASPECTS

9.1. Coping with water scarcity in water-rich environments: an integrated assessment of rooftop rainwater harvesting in the hills of Nepal

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During the rainy season, rooftop rainwater is the most convenient drinking water supply alternative for many Nepalis. For communities high up the hill sides, it is often the sole source of drinking water. Since 1996 more than 11,000 household rainwater harvesting tanks have been built in the rural areas of Nepal to supply drinking water to communities facing acute water scarcity. The NGO sector has been the main promoter of these technologies. This paper aims to elaborate an integrated assessment of the socioeconomic, institutional and environmental aspects that stimulate or hamper the successful introduction of this technology. Special attention has been devoted to user practices and perceptions since users are responsible for managing rainwater quantity and quality. Data have been gathered from 10 rural communities of Nepal through household survey, group discussion and water quality testing. Key sector stakeholders were also interviewed. This paper shows that harvested rainwater makes indeed an important difference to its users. Significant impacts on health and livelihood improvement are reported. To further promote rational use of rainwater, an enabling policy and stronger local governance are needed. This will facilitate the scaling up of rainwater harvesting in rural Nepal and enhance water security, livelihood and community health.

Keywords: Rooftop rainwater harvesting; integrated assessment; public perceptions; Nepal.

9.2. Focused Evaluation of Rainwater Harvesting: A Case Study in Sandakan, Sabah, Malaysia

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Rainwater harvesting (RWH) plays an important role in providing quality of live for peoples in Sandakan, Sabah. Unlike other places in Malaysia, the rainwater system in Sandakan has a successful story. The system can only be found in their landed residential property. The bye-law's requirement imposed by Sandakan Municipal Council, plus the stringent enforcement makes the rainwater harvesting become the successful one. In relation to that, this study conducts a focused evaluation to the residents experience towards the effectiveness of RWH system, in term of minimizing the

environmental problems, the benefit of RWH as well as the implementation issue in relation to RWH. The research conducted among 25 respondents from Sandakan. The methodology adopted is using the personally-assisted questionnaire survey and the data is analyzed using the SPSS, in identifying their level of agreement towards the effectiveness measures. The main finding reveals that the implementation of RWH can reduce the problem of water crisis, reduce water bill and among the problems highlighted is not enough professional to design the RWH system, particularly for the housing scheme. The impact of this study is to the design professionals and Malaysian government, as to seek better solution in promoting the RWH in Malaysia.

Keywords: building system, focused evaluation, rainwater harvesting, resident experience, sustainability

9.3. Rainwater - A Feasible and Economic Solution to the Acute Drinking Water Shortage of the Slum Dwellers of Dhaka City

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The shortage of safe drinking water sources is increasing whole over the world. A good many prominent people have recently forecasted that wars of the 21st century will be fought over water not on oil. Thus, water as a safe drinking water as well as some other important uses like cooking, dishwashing etc. is a very important component for daily life. But the safe water for the above mentioned uses is not always available due to shortages of surface water, groundwater contamination (arsenic, manganese and uranium contamination), groundwater depletion and so on. A research work had conducted to collect and store the rainwater for medium term in a ferro-cement storage tank. To examine the quality of the stored rainwater, some physical, chemical and bacteriological parameters were tested once in every 15 day throughout the storage period. The quality of stored rainwater was within the acceptable range for drinking purposes up to three months. After that period a few numbers of total coliform was detected. A cost-benefit analysis was performed to compare the installation and maintenance cost of the rainwater harvesting system with the existing water supply system and found that the rainwater system was more economic. From the quality and the economic point of view, a questionnaire survey study was conducted on four slum areas of Dhaka City to get the dwellers opinion on rainwater system. The study revealed that the rainwater was acceptable to the slum dwellers not only economic point of view but also quality point of view.

Keywords: Cost-benefit analysis; feasible; ferro-cement; rainwater; storage tank.

9.4. Evaluation of Required Capacity of Rainwater Harvesting System to Mitigate Typhoon-Induced Water Shortage in Southern Taiwan

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The water shortage of today's world is one of the most challenging problems and the world is looking for the best solution to reduce the crisis. Some human made causes and also natural causes such as less rainfall, economic development, rapid urbanization, natural hazards (typhoon, earthquake), structural failures and repairs, etc., are liable for the shortage of the existing water supply system. In Taiwan, especially during summer time, a lot of typhoons occurred and during that typhoon period, the turbidity of raw water increases beyond the treatment capacity of a treatment plant and the plant cannot supply required amount of water. To cope with the system, a couple of days are needed and during that period, there would be insufficient supply towards demand for a few days which causes shortage. The purpose of this study is to cope with this emergency shortage problem. A dual-mode Rainwater Harvesting System (RWHS) was used in this study as a supplemental to the existing water supply system to support some selected secondary/non-potable components such as toilet flushing and urinal flushing. This system was able to supply water both for ordinary uses and for emergency uses. An optimal design algorithm for this research work was developed. YAS (yield after spillage) and YBS (yield before spillage) both of the behavioral models were considered to evaluate the best suited for this system. The efficacy and reliability of the system were also evaluated from this study.

Keywords: 1Dual-mode system; emergency uses; non-potable demands; rainwater; shortage.

10. URBAN AND RURAL COMMUNITY RAINWATER HARVESTING SYSTEMS

10.1. Flood Mitigation Using Building Rooftop Catchment in Taiwan

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She-Zih is a low-lying area in Taipei city and has been classified as a flood retention district with strict inhibition to development in the early days. However, due to recent changes in environmental conditions, local residents have questioned the need for restriction and wanted urban development in this area. This study, therefore, attempts to gather necessary hydrologic information through scale-down rooftop simulation experiments and to evaluate the appropriate rainwater management strategies for flood mitigation in this study area. Study results indicate that rainwater catchment may substantially reduce flood peak and prolonged flow concentration time near residential areas. However, to comprehensively control floodwater, other low-impact runoff retardation technology such as dry ponds and wet ponds are also suggested to increase its storm water storage capacity.

Keywords: Low impact runoff retardation facility, storm water collection, flood peak depression, rainwater utilization.

10.2. Integrated Roof Top Rain Water Harvesting In Saline Aquifer System, North West Rajasthan, India

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Rain water harvesting being the best management options to cope with climate variability & to supplement the resources, especially in the regions where the actual rainfall is for a limited period of 15-30 days in a year. In the semi arid areas of North West Rajasthan, particularly in the Chirawa block where ground water is the only source to mitigate the water demand of various users' sector but it's over development than the dynamic recharge has resulted in continuous decline of water levels, quality deterioration & higher energy inputs. The present study area has annual rainfall of about 400 mm with unfavourable Hydrogeological conditions (aquifers are saline & at places with high concentration of fluoride & marked with sand dunes) roof top rain water harvesting and storing the water in Tankas (under ground stone masonry structure, circular in shape & stores runoff from the roof tops) emerged as the best option. The Ismailpur village has 130 house holds out of which 101 households have taken up roof top rain water harvesting and collected water in Tankas of different capacities with full community participation. The total system of Tankas was then integrated through pipelines and surplus if any, over & above the capacity of Tanka is diverted to a reservoir. This

approach has contributed towards socio-economic benefits and transfer of water custodianship from individual to community for effective management & utilization of conserved water.

Keywords: Climate variability; Management options; saline aquifers; socio-economic benefit; Tanka.

11. SOCIO-ECONOMIC ASPECTS

11.1. Thai Schools Find a Solution to Turn Rainwater into Clean, Safe Drinking Water

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Netherland/Thailand

Millions of children worldwide attend schools without access to clean, safe drinking water. This is not only true for schools in developing countries but also for some in industrialised and developed parts of the world.

The main reason for this is that networked water distribution systems are, particularly in rural areas, either nonexistent or inadequate. There is therefore a greater reliance on individual, private water sources. Rainwater Harvesting (RWH), despite its natural and sustainable benefits, is not used so extensively as tube wells, which are the most commonly used source of drinking water.

Over the past decade interest in the use of Rainwater, as a primary source of drinking water, has grown internationally. Various international organisations, such as WHO and NGO's, as well as national governments show increased interest in the potential for rainwater as a sustainable source of (drinking) water. An international movement has emerged for the promotion and development of Rainwater Harvesting. It includes such organisations as the IRCSA (International Rain Catchment Systems Association), established in 1989, the IRHA (International Rainwater Harvesting Alliance) and the International Rainwater Partnership.

Internationally, nationally and regionally, organisations are active in promoting of and gaining recognition for Rainwater Harvesting as a major, sustainable source of water for household use and drinking..

11.2. Effectiveness of Rainwater Harvesting System at Office Building in Coping with Climate Change

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Rapid socio-economic development has begun to put a strain on Malaysia's water supply and drainage facilities. Climate change has also caused higher intensity rainfall and prolonged drought. Rapid development has not only caused frequent flash flooding, but also has caused deterioration of water quality in the receiving water bodies. Climate change has caused some area to experience shortage of water supply due to drought. This water stress came to the fore on the back of the 1998 drought induced water shortages, which brought unpleasant water supply disruptions for 1.8 million residents in the Klang and Langat Valley. So, in order to overcome the water supply shortages problem, domestic roof water harvesting could be carried out in water stress area and areas that are experiencing prolonged dry period. Therefore, a case study of rainwater harvesting system for non-

potable use at JPS Raub Office, Pahang was conducted. The system includes the catchment's area, gutter, underground storage tank, elevated tank, pump and water meter. The instruments that were used for the data collection is rain gauge, level logger and water meter. The data collection program commences from 1st June 2008 until 1st June 2009 at JPS Raub. Historical rainfall data from 1990 until 2008 was analyzed for continuous dry period. Rainfall collected from the roof will flow via gutter while surface runoff at the pervious area will flow into the drain and stored in underground storage tank. Collected rainwater pumped into elevated tank and distributed to the toilet for flush, standpipe and landscape via gravity. Rainwater storage tank design is checked with recorded data. Four water meters were installed in JPS Raub to determine rainwater consumption. Average weekly rainwater usage is 16m³ where 72% is for toilet, standpipe at 3.2% and 2.4% for landscape. The result shows the utilization of the RWH system can reduced the usage of treated water by as much as 45% based on the monthly water bill..

Keywords: Rainwater Harvesting System, Underground storage tank, Continuous Dry Days, Climate Change, non-potable, water consumption,

11.3. Building an institutional rainwater harvesting framework; the RAIN model and its challenges

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Building and/or strengthening an institutional setting focusing on rainwater harvesting (RWH) plays a crucial role in ensuring successful and sustainable RWH implementation. NGOs, governmental organizations, universities, private sector, consultants and research institutes are important players, being able to manage and coordinate implementation activities, promote knowledge exchange, optimise technologies, best practices and ensure integration of RWH into policies and plans. An important element is to build up and strengthen capacity on all levels; from local capacity to governmental capacities. These capacities on RWH can be generated amongst others by providing training- and awareness sessions, exchanging knowledge and experience from elsewhere, having a national multi-stakeholder group discussing the needs and approach regarding the integration of RWH into policies and governmental programmes, how to integrate it into wider IWRM practices and how to operationalise this. Next to this, capacity development is paramount for stimulating local management and encouraging financial self-sufficiency of users. Ideally, all these actors should collaborate, being able to act on a country scale, as well as bottom-up, to respond to user specific needs. A multiplier effect is achieved when there are strong linkages among education and research institutions, NGOs and public and private extension services (Wanjohi, 1996).

Keywords:Capacity building; institutional RWH setting; rainwater harvesting, implementation network, policy influencing;

11.4. Adaptation to Climate Change through Rainwater Harvesting in Nepal

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program Co-Ordinator, Bsp-Nepal Rhcc

Access to safe water is an important condition for sustainable development for millions of people round the world. Rainwater harvesting systems offer a sustainable, simple and low-cost solution for the water shortages in many developing countries, like Nepal. Nepal is listed as the country that is only second to Brazil in terms of water resources. However, the dilemma is that even in this century only 13 percent (CBS, 2006) of its people has access to some sort of water supply. The quantity available amounts to mere 12 litres per head. Being one of the poorest countries in the world, Nepal is not in a position to afford expensive, effective and comprehensive water supplies for their rural citizens at present economical scenario. The other remarkable constraints are geographical structure and scattered settlements. This has further made the piped community or municipality water supplies not economically feasible in most part of Nepal. Consequences of these facts have tremendous implications in the lives of Nepalese people especially women and girl children who are forced to spend hours in fetching water for their daily need. Rainwater harvesting has proven to be a very effective solution in addressing the problem and will help these deprived rural people in improving their livelihood through multiple benefits due to availability of water and energy source at their doorsteps, if not, at least in their vicinity.

This study presents the implication of integrating RWHS with biogas for enhancing the livelihood of the rural population in Nepal; research findings and case studies of schools, indicate the exploitation of students in carrying the water to fill the school water tanks for drinking as well as cleaning purpose. This problem is not limited to the rural areas alone; this dilemma is on the rise even in the urban areas. The study has been conducted in 5 districts of the country thus strengthening the findings from the field.

Keywords: Rainwater Harvesting; rural population, adaptation to climate change, livelihood enhancement; implementation modality

11.5. Contaminants of Rainwater Harvesting Systems (RWHS) in Eastern & Southern Australia

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Maximum economic and environmental benefit associated with the use of roof-harvested rainwater is gained through its utilisation for a variety of internal applications including showering, bathing, clothes washing, and toilet flushing, as well as outside garden-watering applications. Widespread use of harvested rainwater for these purposes has not been adopted in urban settings until recently, partly due to concerns over the quality of harvested rainwater. This is despite the fact that roughly 3 million Australians rely on rainwater for domestic purposes, with no reported epidemics or widespread health impacts. This study analysed samples from rainwater tanks in different locations of Australia to determine the effects of tank type on elemental composition of roof-harvested rainwater. The results from this preliminary investigation suggested that tank type has little effect on the concentrations of most elements present in stored rainwater, with the exception of 3 elements present in relatively low levels in harvested rainwater: strontium, molybdenum, and arsenic. Samples collected from concrete tanks contained higher concentrations of these 3 elements than samples collected from plastic tanks ($P < 0.05$). Rainwater samples were also analysed for indicators of both anthropogenic and biogenic organic contamination, including hydrocarbons, phthalate esters, fatty acids, and polycyclic aromatic hydrocarbons (PAHs), as well as sterols indicating possible faecal contamination. Results indicated that straight-and branched-chain hydrocarbons, fatty acids and sterols were common organic components of stored rainwater, all of which were most likely sourced from biogenic processes.

Keywords: Rainwater Quality, Organic / Inorganic Contaminant

12. URBAN AND RURAL COMMUNITY RAINWATER HARVESTING SYSTEMS

12.1. Rain City Initiative Proposed by Suwon City, Korea

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Korean people learned how to overcome the natural disasters caused by irregular rainfall trend, which results as the frequent flooding and drought, and geological condition, with their philosophy and technology. The priority of the sustainable city is water management, shown in a single character 洞 meaning village. The character combines characters meaning water(水) and same (同), thus imply village people depend on same water: teaching village people why water should be conserved. This character also implies water status should remain the same even after the development. The reason for rainwater management is hidden in this single letter.

For the purpose of scientific water management, the first rain depth measurement gauge was invented in 1441 by King Sejong the Great, and the rainfall data has been recorded through the nationwide rain gauge network. Many decentralized ponds and reservoirs were built throughout the country with rainwater management to encourage agriculture.

Name of Suwon is derived characters meaning source of water; however, Suwon does not have a big river or dam thus always short of water. With the rapid industrialization, and city development, water source was contaminated and underground water and water sources were exhausted. It became clear Suwon faced a problem of securing the water source. Suwon city, “literally” the water origin, recently recognized the origin of water is Rain, and took initiative to make Rain City by every stakeholder, including City Mayor, City Council, Citizen group, Academic and Business sector.

In this paper, the current regulatory activities and on-going projects, like Rainwater Showcase project in Suwon Sports Complex and Rainstreet Project in Gwanggyo Central Business District, the vision, and strategy of Suwon City will be presented.

12.2. A Crucial Need for Rainwater Harvesting in Rural Schools in Ethiopia

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Freshwater is indispensable for the sustenance not only of all lives on mother Earth, but also of the livelihoods of the vast majority peoples, especially in the developing world. A multitude of evidences reveal that freshwater is dwindling alarmingly worldwide in general and in arid and semi-arid lands (ASAL) in particular. The situations in these areas have been worsened by factors attributed to the ongoing global climate change. Therefore, it is high time that humankind treats this finite, precious and versatile resource differently, with utmost sensitivity and care.

Ethiopia is a relatively vast country with over 1.13 million sq km of area and a population of 70 million. Out of its total landmass, some 55% falls under the ASAL category. Available statistics indicate that the country's economy has been growing steadily over the past decade. Along with the growth of the economy, there has been tremendous expansion of school infrastructures across the country, both in the urban and rural settings. Likewise, the size of the school population has been on the rise. Especially, the country has made a stride in narrowing the male-female ratio or gap in schools.

However, despite the enormous expansion of schools and increase in school enrollment in the last decade, many of the schools, especially in the rural areas, are either without or have meager water supply and sanitation facilities. Existing estimates reveal that about 75% of the schools in the rural areas lack water supply facilities and some 85% of them do not have sanitation facilities. Needless to say, water in schools is as much essential as it is in residential, production and service delivery establishments. Depending on the amount of supply available, water in schools can be needed for a variety of purposes: drinking, cooking, sanitation/hygiene, watering different fields (vegetable/horticultural gardens, tree nursery and plantation sites, flower strips, etc). All of these functions are basic in two main aspects: a) meeting the biological and sanitary needs of the school population and b) enhancing the teaching-learning process through practical demonstration fields set up in the school compounds. Evidently, the importance of these outcomes is more felt in schools located in ASAL rural areas than anywhere else.

Compared with other sources, rainwater harvesting appears to be the most feasible alternative to meet the dire needs especially of schools located in ASAL rural areas for safe water supply. The present paper attempts to outline the necessity of RWH projects and their basic features in rural schools in Ethiopia.

Keywords: natural resources; rainwater harvesting; schools.

12.3. Harvesting Rainwater, an Innovative Approach to Easing Urban Water-Energy Dilemma

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Trend of rapid urbanization has increased the number of hilly communities around many large cities and raise both water and energy consumption, as modern water supply systems heavily depend on energy supply. Locally available rainwater was examined in this study as a potential approach for urban water-energy conservation scheme. Using hilly communities of Taipei Metropolitan as a case study, this study proposed a GIS-based rainwater harvesting design system incorporating spatial technologies, hydraulic simulation and economic analysis to explore how rainwater harvesting systems (RWHs) can be a cost-effectively tool in urban water-energy conservation planning. The results clearly indicate that the economic feasibility of RWHs was significantly enhanced when water and energy savings are both considered. RWHs can cost-effectively contribute to a 21.6% savings in domestic water use and an annual energy savings of 138.6 (kWh) per family. Furthermore,

the cost of unit energy saving of 85.5% of RWHSs is lower than that of solar PV systems. Hence, well-designed RWHSs can ease the water-energy dilemma caused by rapid urbanization.

Keywords: Rapid urbanization; Hydraulic simulation; Economic analysis; Water-energy dilemma.

12.4. A Study of Rainwater Harvesting Systems Installations at Three Residential Houses in Malaysia

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The sustainable practice of Rainwater harvesting in urban residential area is rarely encountered in Malaysia. This paper describes and reviews the Rainwater Harvesting Systems installed in 3Nos. residential houses in Bukit Rimau(Shah Alam), Sungai Buloh and Putrajaya, which are located within the urbanized Klang Valley in Malaysia. The installed components of the RWH systems consisting of the capture surface, conveyance systems, screening, storage and delivery systems at each location are described. A study of the potential rainwater capture, water demand and the efficiency of each system are discussed. The rainwater consumed at the installations is compared to the total water consumed at the premise.

Recommendations to encourage increase in RWH practices are discussed for successful implementation of RWH projects for residential units in Malaysia.