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George A. Sorial

Jihua Hong

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**George A. Sorial
Jihua Hong**

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TABLE OF CONTENTS

INTRODUCTION

<i>George A. Sorial and Jihua Hong</i>	1
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PLENARY SESSION

Characterization of Atmospheric Particles from South America to Antarctic <i>Ricardo Henrique Moreton Godoi</i>	4
Groundwater-Surface Water Flux Measurements. <i>Carl G. Enfield</i>	5
Continuous Treatments of Endocrine Disrupting Chemicals (EDCs) by Artificial and Natural Oxidation Processes. <i>Yutaka Sakakibara</i>	6
Membrane Optodes for Heavy Metal Ions: Preconcentration and Quantification in Natural Waters <i>Gurijala Ramakrishna Naidu</i>	7

WATER POLLUTION AND WATER QUALITY

Rivers, Lakes and Estuary Systems/ Watershed Management

Water Management by YAN Technology, YAN Microorganisms (YANM) and Titanium Bio-Ball. <i>Ki Hae Yang, Mi-Sug Kim, And Jee-June Song</i>	9
Surveying the Problems in Developing Water Quality index in Iran. <i>Farzam Babaie Semiromi, A.H Hassani, A. Torabiyani and A.R. Karbasi</i>	15
Freshwater Harmful Algal Bloom Suppression: Solar-Powered Circulation and Current U.S. Policy. <i>Kenneth Hudnell, Joseph Eilers, Vic Lucero, Christopher Jones, Dennis R Hill, Amanda Williams</i>	21
Bacterioplankton Community in Highly Eutrophic Plateau Shallow Lake. <i>Mingji Lv, Yi Huang</i> Pilot Studies on Atmospheric Deposition in Mine Lakes Region Part I: Heavy Metals. <i>Jatau- Emeagha Glory Ladidi, Ufodike E.B.C.</i>	22

Water Resources and Assessment

Environmental Impact of Return Flow on Groundwater Quality at Azraq Basin, Jordan. <i>Yasin Al- Zu'bi , and Jarrah Al- Zu'bi</i>	24
A New Technique of Discharge Release from Dam Reservoir for Flood Control. <i>Yusei Kitada, and Tadashi Yamada</i>	30
Optimal Spatial Allocation of the Economical Crops in Saudi Arabia, According to the Comparative Advantage. <i>Ahmed M. Alabdulkader, Ahmed I. Al-Amoud, Fawzi S. Awad, Abdulrahman A. Alazba, Saad A Al-hamed, Ali S. Al-Tokhais, Jalal M. Basahi, bdulrahman M. Al-Moshailih, Yousef Y. Al-Dakheel.</i>	37
Performance Assessment of Water Management in the Old Land of Egyptian Delta. <i>Ahmed Mohsen Aly Mohamed, Ahmed M. ALY, Yoshinobu KITAMURA, Katsuyuki SHIMIZU</i> ...	43

Groundwater

Status of Arsenic Contamination in Groundwater of Southern Bangladesh: A Population-Based Survey. <i>Nepal C Dey</i>	51
Arsenate Removal from Simulated Groundwater by Donnan Dialysis. <i>Bin Zhao and Huazhang Zhao</i>	57

Residential Development Overlying a Complex Aquifer in Ontario, Canada - Science and Practice. <i>Prem Manicks</i>	57
Qualitative and Quantitative Assessment of Groundwater of Coalmining areas, India. <i>Prasoon Kumar Singh, Dipanwita Bhakat, Gurdeep Singh</i>	58
Assessment of Source Flows at a Mojave Desert Spring: Habitat to Endangered Species. <i>Luz Vargas, Barry Hibbs, and Mercedes Merino</i>	58
Groundwater Baseflows Contaminate Streams in Southern California Coastal Watersheds. <i>Barry Hibbs, Wynee Hu, and Rachel Andrus</i>	59
Non-point Sources	
Impact of Non-point Source Pollution on Bacterial Community Structure in River Water from a Densely Populated Watershed. <i>Mark Ibekwe, Richard M. Bold, Stephen. R. Lyon, and Menu B. Leddy</i>	59
Wastewater Discharge Management	
Biosolids as Foaming Reactive for Froth Flotation Processes. <i>Lorenzo Reyes-Bozo, Alex Godoy-Faúndez, Miguel Herrera and Rosanna Ginocchio</i>	61
Drinking Water	
Optimization Models for Monitoring Station Sitting in a Water Distribution Network. <i>Pei-Hao Li and Jehng-Jung Kao</i>	67
Monitoring of Source Water Supplied to a Treatment Plant to Evaluate Its Effect on Influent Water Quality. <i>April Nabors</i>	72
Spatial Variation of Haloacetic Acids in the Indoor and Outdoor Household Drinking Water in Kuwait. <i>Humood F. Al-Mudhaf, Mustafa I. Selim, Aleksander Astel, Abdel-Sattar I. Abu-Shady</i>	72
Identifying Carcinogenic Potentials of Drinking Water Disinfection Byproducts using Normal Human Colonocyte Cultures. <i>Anthony DeAngelo, Yue Ge, Michael George, Carlton Jones, Steve Kilburn, Sheau-Fung Thai, William Ward, and Ernest Winkfield</i>	73
Women's Role in Managing Household Water in Rural Bangladesh. <i>Nepal C Dey and AKM Masud Rana</i>	75
Pre-treating Microcystis-laden Raw Water by Silver Carp in Water Works. <i>Hua Ma, Fuyi Cui</i>	81
Hydrogen Peroxide with Potassium Permanganate to Replace Pre-Oxidant Chlorine in Drinking Water. <i>J. Cochran</i>	81
Reduction of Perchlorate from Contaminated Waters Using Zero Valent Iron, Palladium as a Catalyst, and UV Light. <i>Q. Amy Zhao, E. Sahle Demessie, and George Sorial</i>	82
Pipe Service Age Effect on Chlorine Decay in Drinking-Water Transmission and Distribution Systems. <i>A. O. Al-Jasser</i>	83
Water Quality Assessment/Management	
MRBC Dispersion Parameters Assessment by SA, GA and GNM Inverse Modeling. <i>V. P. Huggi, A. K. Rastogi</i>	93
Assessment of Particles and Trace Elements in Selected Reservoir of Curitiba – Brazil. <i>Ricardo Henrique Moreton Godoi, André Virmond Lima Bittencourt, Patricia Yassumoto Hirata, Ana Flavia Locateli Godoi, Eduardo Felga Gobbi, Luiz Fabricio Zara, Miguel Jafelicci Jr, Rafael Bini, Jorge Eduardo de Souza Sarkis, José Manoel dos Reis Neto, José Eduardo F. C. Gardolinski, René Van Grieken</i>	93
Innovative Non-Chemical, Electronic De-Scaling and Scale Prevention Technology for Heat	

Transfer Optimisation. <i>Philip Acquah</i>	94
Monitoring of Drinking Water Quality in Regional Laboratory Gombe Nigeria. <i>Bertha Abdu Danja, Jürgen Ertel and Otmar Deubzer</i>	95
The Fecal Coliform Pollution in the Lanzhou Section of the Yellow River, China. <i>Famin Liu and Lirong Wang, Weishou Shen</i>	101
Management of Organic Waste from an Agricultural Enterprise (Dairy Farm) In Botswana. <i>Gilbert Kabelo Mmolawa, G.K. Gaboutloeloe and K. Ramolekwa</i>	102
Dairy Enterprises Environmental Pollution Risk Assessment in Gaborone Agricultural Region, Botswana. <i>Gilbert Kabelo Gaboutloeloe, and C.M. Tsopito</i>	106
E.Coli Chromogenic Reagent Selection Based on User Perception for Use in Field Based Water Quality Tests. <i>Tahmina Ajmal, N.E. Scott-Samuel, Germinal Magro, R.E.S. Bain, R.L. Matthews, A.P. Davis and S.W. Gundry</i>	111
Contamination of Water Body Associated with Bird Nesting on Highway Bridges. <i>Rania Bashar, Veysel Demir, Sazzad Bin-Shafique</i>	117
Bacterial Indicators of Fecal Contamination in the Macagua Lake, Bolívar State, Venezuela. <i>Rosa Vásquez Lic, Nailec Valdiviezo, Tibisay Gómez, Hilda Centeno and Lenny Moya</i>	122
Utilizing the Water Quality Index as an Indicator of Surface Water Pollution: A Case of Damour River, Southern Lebanon. <i>May A. Massoud</i>	128
Optimizing Readability of Escherichia Coli Selective Fluorogenic Assay for Testing Water Quality. <i>Tahmina Ajmal, R.E.S. Bain, R.L. Matthews and S.W. Gundry</i>	132
Water Quality Processes at the Estuarine Interface of Upper Newport Bay, California. <i>Barry Hibbs, Cherylee Sevilla, and Maryam Taiedi</i>	132

Nitrogen-Phosphorus Wastewater Treatment / Sludge Treatment

Encapsulation of Electroplating Sludge - Its Mechanical Strength, Leachate Studies and Microstructural Analysis. <i>H. Dayananda, Lokesh K. S.</i>	134
Investigation of Organic Loading Rates and Inhibition of Thermophilic Digestion. <i>Sebnem Koyunluoglu-Aynur, and Rumana Riffat, Sudhir Murthy</i>	144

Municipal Wastewater Biotreatment

Biomedical Waste Prospective in India. <i>Kodamagudi Padmini and Gurijala Ramakrishna Naidu</i>	150
---	-----

Industrial Wastewater Biotreatment

Kinetic, Isotherm, Thermodynamic and Column Studies of Biosorption of Lead [II] by Modified Shells of Portunus Sanguinolentus. <i>TVN. Padmesh</i>	151
Use of Duckweed Lemna minor for Reduction of BOD in TimTek Process Water. <i>Lauren Heard Mangum, Hamid Borazjani, S.V. Diehl, M. L. Prewitt, and Dan Seale</i>	161
Design, Processing and Testing of Solid Waste Derived Microbial Support Material for a Wastewater Treatment System. <i>Lam Van Giang , Franz Furby C. Ramos, Jocelyn B. Toga-on, Ma. Catriona Devanadera, Nguyen Phuoc Dan, Ohtaguchi Kazuhisa, and Wilfredo I. Jose</i>	167
Biodegradation of Carbazole by the Pseudomonas sp. Strains. <i>Cui Zhao, Man DING, Donghui WEN, and Xiaoyan TANG</i>	174
Performance of Consortium of Blue-Green Algal Species in Bioremediation of Tannery Effluent. <i>V. Shashirekha, M. R. Sridharan, and Mahadeswara Swamy</i>	182
Development of Noise Prediction Model and Traffic Management Measures-A Case Study. <i>Sheetal Agarwal and B. L. Swami</i>	192
A ZnFe ₂ O ₄ -Loaded TiO ₂ Nanotube Arrays Electrode with Enhanced Visible-Light Photoelectrocatalytic Activity. <i>YangHou, Xinyong Li, Guohua Chen</i>	197

Bioaugmentation Treatment for Coking Wastewater Containing Pyridine and Quinoline. <i>Yaohui Bai, Qinghua Sun, Cui Zhao, Donghui Wen & Xiaoyan Tang</i>	197
Performance of Aerobic Granulation and Phenol Removal in a Sludgy Blanket Reaction Process. <i>Ngoc-Thuan Le, Dul-Sun Kim, Tae-Han Kim, Young-Kyung Lee, Su-Eon Jeong, Mi-Jung Cho and Dong-Keun Lee</i>	198
Bio-Treatability of Wastewater Generated during Machinery Washing in Wood-Floor Industries. <i>Fabio Kaczala, Marcia Marques and William Hogland</i>	198
Decolourization and Degradation of Dyes By Mixed and Methanogenic Cultures under Batch Conditions. <i>Kapil Kumar, M.G. Dastidar and T.R.Sreekrishnan</i>	199

Adsorption/Desorption for Wastewater Treatment

Removal of Dye from Aqueous Solution by Wet Peroxide Oxidation. <i>Pradeep Kumar, Tjoon Tow Teng, Arun Kumar Kondru, Shri Chand</i>	200
Hydrophobic Zeolites for Removal of Organic Groundwater Contaminants - Adsorption Properties and Regeneration. <i>Rafael Gonzalez Olmos, Frank-Dieter Kopinke and Anett Georgi</i>	214
Biosorption of Cadmium (II) Ions by Citrus Peels in a Packed Bed Column. <i>Abhijit Chatterjee and Silke Schiewer</i>	221
Sargassum Biomass Mediated Recovery of Gold Through Biosorption, Bio-Crystallization and Pyro-Crystallization. <i>M. Sathishkumar, A. Mahadevan, K. Vijayaraghavan, S. Pavagadhi and R. Balasubramanian</i>	227
Ammonia Adsorption on Fixed Beds of Different Inorganic Materials. <i>Cong Duc Phan and Jae Young Kim</i>	234
Purification of Oily Wastewater Using Composite of Polysilicate Ferro Aluminum Sulfate – Rectorite. <i>Shi-qian Li, Pei-jiang Zhou</i>	240
Pre-concentration of Uranium from Natural Water Using Itaconic Acid Based Sorbent. <i>Gurijala Ramakrishna Naidu, Yakkala Kalyan, Sadananda Das and Ashok Kumar Pandey</i>	249
The Effect of Fe ₂ O ₃ Nanoparticles on the Removal of TCE by GAC. <i>Hafiz Salih, George A. Sorial, Rajib Sinha, E. Radha Krishnan, Craig L. Patterson</i>	249
Treatment of Refinery Wastewater Compounds (BTEX) by Chitin and Chitosan. <i>M. A. Mohamed and S. K. Ouki</i>	250
Removal of Cyanide from Aqueous Solution using Fly Ash. <i>Richa Sharan, Sunil K Gupta, Gurdeep Singh</i>	251
Ni Adsorption and Ni-Al LDH Precipitation in a Sandy Aquifer. <i>Erwin J.M. Temminghoff and Inge C. Regelink</i>	251
Removal of Methylene Blue from Dilute Aqueous Solutions through Biosorption. <i>Ramesh D. Dod, G.Banerjee, D.R. Saini, R.D. Dod, Y.B. Sontakke</i>	252
Studies on the Competitive Adsorption of Cu ²⁺ , Pb ²⁺ , Cd ²⁺ From Composites Adsorbent. <i>Shi-qian Li, Pei-jiang Zhou, Ming Zhang, A Yiguli</i>	252

Physico-chemical Wastewater Treatment

Improving Wastewater Oxygenation and Mixing Efficiency through Solar-Powered Circulation. <i>Kenneth Hudnell, Ron Vien, Scott Butler, Greg Rahe, David Green, Jerry Myers, Bruce A Richards</i>	254
The Study of Decomposition of BTEX in Groundwater by Persulfate - Analysis of Chloro-Alkyl Derivatives. <i>Sunlong Lin, Te-Kun Huang, Ta-Lin Chen, and Wen-Chieh Lo</i>	259
Interaction of 2-Chloronaphthalene with High Carbon Iron Filings (HCIF) in Semi-Batch and Continuous Systems. <i>Alok Sinha, Purnendu Bose</i>	268
Membrane with Photocatalytic Capability and Its Potential in Water Treatment. <i>Ning MA, Hongtao YU, Xie QUAN, Huimin ZHAO</i>	280

Reduction of Chromium (VI) by Zero Valent Iron (ZVI): Impact of Chlorides. <i>Rajneesh Kumar Srivastava, Gurdeep Singh, Alok Sinha</i>	287
Ligninase-Mediated Removal of 4,4'-Dibromodiphenyl Ether from Water. <i>Yijun Chen, Liang Mao, Jiuli Ruan, Yuan Gao, Shixiang Gao</i>	295

Reactions and Degradation of Wastewater Contaminants

Ozonation of Papermill Wastewater: Enhancing Biodegradability and Process Efficiency. <i>Analiza Palenzuela Rollon, Mercy Grace Dionisio and Marjorie L. Baynosa</i>	296
Oxidation of Triclosan by Ferrate(VI): Reaction Kinetics, Products Identification and Toxicity Evaluation. <i>Bin Yang, Guang-Guo Ying, Jian-Liang Zhao, Li-Juan Zhang, Yi-Xiang Fang</i>	303

Nanotechnology Applications

Effect of Ni (II) Doping On the CuFe ₂ O ₄ /Composite /Pistachio Composite. <i>Saeedeh Hashemian, Mohammad Hassan Dad</i>	304
New Strategy to Fabricate High-Performance Microfiltration Membrane with Trimodal Porous Structure. <i>Yinan Wu, and Fengting Li, Guangtao Li</i>	308
Transport, Dispersion and Deposition of nano-Particles in Porous Media: Experimental and Mathematical Modeling Study. <i>Zhen Li, E. Sahle-Demessie, Ashraf Aly Hassan, George A. Sorial</i>	308
Partition Of Hydrophobic Pollutants In Aquatic Systems And The Influence Of Nano-Scale Particles. <i>Quiming (Amy) Zhao, E. Sahle-Demessie, George Sorial</i>	309
Green Synthesis of Nanocomposite of Silver Modified Titania to Eliminate Biological Impurity from Water. <i>Xubin Pan and Jingbo Liu</i>	310
Determination and Quantification of Mercury (II) Using Silver Nanoparticles Embedded Nafion Membrane. <i>Yakkala Kalyan, Ashok Kumar Pandey and Gurijala Ramakrishna Naidu</i>	310
Development and Evaluation of Ordered Mesoporous Carbon Materials for TOC Removal. <i>Lu Lin and Daniel D. Gang</i>	311
Fabrication of a Novel Nanotube Anode and Characteristics in Organic Wastewater Treatment. <i>Chao Tan, and Yijiu Li</i>	312
A Novel Functionalized Mesoporous Nanofiber Membrane and its Application for the Adsorption of Heavy Metal ions from an Aqueous Solution. <i>Shengju Wu, Shihui We, Yinan Wu, Bingru Zhang and Fengting Li</i>	312
SiC/p-Si Nanowire Arrays Cathode for Photoelectrocatalytic Degradation of Organic Pollutants. <i>Huan Chen, Hongtao Yu and Xie Quan</i>	313
Environmental Remediation of Chlorinated Hydrocarbons using Multifunctional Nanoparticles. <i>Vijay T. John, Jingjing Zhan, Bhanu Sunkara</i>	313

AIR POLLUTION AND AIR QUALITY CONTROL

Aerosol

Healthy Environment – Indoor Air Quality of Some Brazilian Elementary Schools nearby Industries. <i>Ricardo Henrique Moreton Godoi</i>	315
--	-----

Air Quality Assessment

Characterization of Road Dust in Nanjing and Its Impact on Cleaning Efficiency. <i>Chuantong LI, JIA Hehua, LI Fayang</i>	316
---	-----

Effect of Road Development on Air Quality in Niger Delta, Nigeria. <i>Akpabio, John Udo Henry, John U.H. Akpabio, Anthony W. Akpan</i>	323
Evaluation of Particulate Pollution, Local Meteorology and Urban Public Health. <i>Dawn Roberts-Semple, and Yuan Gao</i>	337
Gamma Emitter Radioactive Isotopes in the Atmosphere of Madrid (Spain). <i>Saul García Dos Santos, Castro Catalina Jesús, Aragón Santamaría Pilar, Veiga Ochoa Elena, Alonso Herreros Jesús, Barros Corcuera Diego, and Fernández Patier Rosalía</i>	346
Industrial Carbon Polluters and Control Strategies To Meet New Compliance Standards. <i>Lawrence Goldenhersh</i>	347
Quantification of N ₂ O Fluxes from Irish Grasslands. <i>Rashad Rafique, and Gergard Kiely</i>	348

Transport of Pollutants

Ambient Air Concentrations of 210pb, 7be and 137cs in Gaborone (24.6°S, 025.9°E): Preliminary Results. <i>Alfred Sello Likuku, Jerzy Wojceich Mietelski, Renata Kierepko, Sylwia Blażej, Gilbert Gaboutloeloe</i>	355
Synthesis, Characterization and Catalytic Performance of Calcined Nialfe Hydrotalcite-Like Material for SO ₂ Removal. <i>Xinyong Li, Ling Zhao, Qidong Zhao, Yong Shi and Guohua Chen</i>	362
A Study on the Effect of Hydraulic-Conductivity JW Pavement on Diluting Air Pollutants Emitted from Vehicles. <i>Chung-Ming Liu, Jui-Wen Chen, Wei-Shian Lin and M.-T. Yen</i>	362

Waste Gas Control Techniques

Application of CFD Modeling to the Design of Droplet Separation Systems. <i>Curtis Rhodes, Harry Wechsler and Norman Mansson</i>	364
Structured Packing Performance – Experimental Evaluation Of Sulphur Dioxide Absorption in Water. <i>R. Hilda Chavez and Nicolas Flores-Alamo, Javier de J. Guadarrama</i>	370
Evaluation of the Operating Suitability of an Amine Based Process for CO ₂ Removal of Flue Gases. <i>H. Fahlenkamp and V. Kubacz</i>	377
Photocatalytic Degradation of TCE and PCE in Air. <i>Ngoc-Thuan Le, Dul-Sun Kim, Tae-Han Kim, Young-Kyung Lee, Su-Eon Jeong, Mi-Jung Cho and Dong-Keun Lee</i>	378

Air Pollutant Monitoring

The Relationship between Particulate Matters (Pm ₁₀) Emitted from a Cement Plant and Different Climatic Factors. <i>Jarrah Al- Zu'bi, Yasin Al-Zu'bi and Indira Al-Dahabi</i>	379
Characterizing the Emissions of Persistent Organic Pollutants (PCDD/FS, PBDD/FS and PBDES) From a Municipal Solid Waste Incinerator. <i>Yi-Chieh Lai, Lin-Chi Wang, Ying-Liang Chen, Guo-Ping Chang-Chien</i>	384
PM _{2.5} Emission Factors and Chemical Profile from Light-Duty Vehicles in Monterrey, Mexico: Tunnel Study. <i>Yasmany Mancilla, Alejandro E. Araizaga and Alberto Mendoza</i>	391
VOC Emission Factors and Profiles from Light-Duty Vehicles in Monterrey, Mexico: Tunnel Study. <i>Alejandro E. Araizaga, Yasmany Mancilla and Alberto Mendoza</i>	398
Atmospheric Mercury Monitoring at the Almadén Mining District (Spain). <i>José-María Esbrí, Pablo Higuera, Willians Llanos, Miguel-Ángel López-Berdonces, Eva-María García-Noguero and Alba Martínez-Coronado</i>	405

Hazardous Gas Biofiltration

Narrowing Loading Fluctuations of Hydrophobic Gaseous Mixture Prior to Biofiltration. <i>Ashraf Aly Hassan and George A. Sorial</i>	406
---	-----

Fuel Gas DeSOx, DeNOx, and Metal Removal

Environmental and Economic Impacts of Increased Efficiency in Coal Power Plants. <i>Roger H. Bezdek</i>	407
---	-----

Air Pollution Prevention and Management

New Approach to Improve Insulation in Gher Housing and Its' Environmental Effects. <i>Bilguun Byambajav, Takeuchi Tsuneo, Wakuda Yukihiko, Sugiyama Noriko</i>	415
--	-----

ECOSYSTEM ASSESSMENT AND RESTORATION

Ecosystem Assessment

Ecological Evaluation and Management of Lake Arpi and its Watershed Basin. <i>Ghazaryan Aramais</i>	417
The Self-Sufficient City. <i>Karen Berberyan</i>	423
A Preliminary Study of Ecological Risk Assessment of PAHs in Hoping Harbor, Taiwan. <i>Nien-Hsin Kao, Ming-Chien Su, and Shih-Ying Li</i>	429
Remediation of Eutrophic Water Body by Combining Typical Submerged Macrophyte and Bioenergizer. <i>Ma Limin, Meng Delei and Gong Bentao</i>	434
A Transactional “Glocal” Approach to Biodiversity Conservation through Sustainable Use. <i>Stratos Arampatzis, Robert Kenward, Basil Manos, Jason Papathanasiou</i>	441
Assessment of Habitat Scale of Zacco Platypus by Using Microsatellite DNA Markers. <i>Naofumi Kosaka, and Yutaka Sakakibara, Noriyuki Koizumi</i>	448
Research on Exploration of Main Factors Affecting the Aquatic Ecosystem Health of the Following Rivers of Dianchi Lake. <i>Yi HUANG, Hang WEN, Yu SU, Mingji LI, Jialiang CAI</i>	448

Restoration of Ecosystems

Morphological Adaptation of Aquatic Macrophytes in Response to Different Flow Velocities. <i>Shiang-Yuarn Chen, and Jen-Yang Lin</i>	450
--	-----

ENVIRONMENTAL ANALYSIS AND MEASUREMENTS

Environmental Analysis and Field Technologies

Formulation of New Hydrology –Finding of the Indication of Climate Change . <i>Masato Okabe and Tadashi Yamada</i>	456
Fundamental Research on Open Channel Flow with Hump and Narrow Path . <i>Akinori Katsuki, Kazutomo Yamashita, Quimpo Maritess Sescar and Tadashi Yamada</i>	463

Determination of Residual Pesticides in Drinking and Surface Water by Liquid Chromatography/Tandem Mass Spectrometry. <i>Xiaoming Zhao, Chunyan Hao, Bick Nguyen and Paul Yang</i>	463
Verification of Qualitative Spot Test Kits for Lead in Paint. <i>Julius M. Enriquez, Deepak K.C., Yukio KOIBUCHI, G W HUANG, Masahiko ISOBE</i>	463
Hydraulic Experiments on River Bed Formation in Rivermouth. <i>Makoto Aikawa, Shintaro Ichiki, Masato Okabe and Tadashi Yamada</i>	464
 <i>New Method Applications</i>	
Development of Analytical Method to Extract and Detect Pharmaceuticals in Plant Matrices. <i>Reza Kazemi, Tammy L Jones-Lepp</i>	465
 <i>Environmental Monitoring</i>	
A Study on Quantitative Evaluation of Mitigation Effects of Thermal Environment in the Vicinity of Rivers in Urban Area. <i>Shuheih Shuheih Ohno, Takuma KATO, Tadashi YAMADA</i>	466

INTRODUCTION

The Fifth International Conference on Environmental Science and Technology 2010 was held in Houston, Texas, USA, July 12-16, 2010. The Program included 16 sections, containing 60 sessions with approximately 600 platform and poster presentations. This conference series strives to provide a platform for an extremely diverse group of environmental topics for engineers and scientists from around the world.

Authors of the presentations accepted for the program were invited to submit their papers to the Conference Organizing Committee. More than 130 papers were received and then reviewed by the editors, session chairs, and the members of the Scientific/Technical Committee of the conference. Those papers and abstracts accepted for publication were assembled into two volumes.

Sections are arranged basically according to their order listed in the original program except the sessions entitled Bio-Assessment and Toxicology and Modeling. This exception was made to balance the length of the two volumes.

The conference also consisted of having a plenary session with four speakers from different universities at the United States and US Environmental Protection Agency. The abstracts of their talks are contained in this proceeding together with a link to their full presentation.

Environmental Science and Technology 2010 (I) contains the following sections:

- Plenary Session
- Water Pollution and Water Quality Control
- Air Pollution and Air Quality Control
- Ecosystem Assessment and Restoration
- Environmental Analysis and Measurements

Sections included in Environmental Science and Technology 2010 (II) are as follows:

- Land (Soil, Waste Solid) Pollution and Remediation
- Bio-Assessment and Toxicology
- Wetlands and Sediments
- Global Warming
- Metals (Distribution, Removal, Remediation, Speciation, and Phytoremediation)
- Characterization and Degradation of Organic Pollutants
- GIS for Environmental Assessment, Database, and Remote Sensing Applications
- Society and the Environment
- Environmental Planning and Management
- Renewable Energy Development

We would like to especially thank the session chairs who were instrumental in the success of the conference. The Conference was sponsored and organized by the American Academy of Sciences, with financial contributions from the co-sponsors and supporting organizations.

The papers in these proceedings represent the authors' results and opinions. No sponsors, cosponsors, participating organizations or editors should be construed as endorsing any specific contents or conclusions in the proceedings.

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STATUS OF ARSENIC CONTAMINATION IN GROUNDWATER OF SOUTHERN BANGLADESH: A POPULATION-BASED SURVEY

Nepal C Dey (BRAC, Dhaka, Bangladesh)

ABSTRACT-This study explores the status of arsenic contamination in tubewell water in southern Bangladesh. Through a survey of 6,593 households, a total of 3,812 tubewells were sampled at baseline (2006/07) and 3,591 at midline (2009). Households were selected through multi-stage sampling procedure where each sub-district was considered as a cluster. Findings reveal that proportion of unmarked (to identify presence of arsenic) tubewells increased from 80% at baseline to 90% at midline ($p < 0.001$). Proportion of tested tubewells was significantly decreased from 75% at baseline to 69% at midline ($p < 0.001$). Of the tested tubewells, 60% was reported to be free from arsenic contamination. This study underlines that information, education and communication campaigns should be strengthened to raise awareness regarding negative effect of arsenic on health.

Key words: Arsenic, Bangladesh, Groundwater, Ultra poor

INTRODUCTION

The arsenic contamination of groundwater in Bangladesh is the biggest natural calamity in the world in terms of the affected population. When rural people had developed the habit of drinking tubewell water, arsenic was found in tubewell water in many parts of Bangladesh too high concentration which has drastically reduced the coverage of safe water (GED & UNDP, 2009). It was reported that the people in 62 out of 65 districts of Bangladesh were suffering from various diseases because of drinking arsenic-contaminated tubewell water. More than 70% of the country's 150 million people are at risk and 32-52 million are potentially exposed to arsenic contamination above the Bangladesh drinking water standard ($>5\mu\text{gL}^{-1}$) where about 90% people live in rural areas (Roy *et al.*, 2008). It was reported that some proportion of tubewells are also contaminated with bacteria which are mainly due to poor maintenance. The Department of Public Health Engineering (DPHE) is responsible for marking arsenic-contaminated and arsenic-free tubewells as red and green respectively and warned the villagers against drinking water from the red tubewells.

Arsenic contamination impacts on poor population of Bangladesh. It has been well documented that the first victims of such pollution are the people with low nutrition (often people with low body weight) (IMF, 2006). Women suffer from arsenic not only in terms of physical illness but also social consequences as they cannot get married and are seen as a burden to their families and their communities (SOS, 2010). In a recent survey conducted in all districts of Bangladesh, nearly 19,000 arsenic patients have so far been identified from 104.9 million arsenic-affected population. This may cause many health effects including cancer of the liver, lung, bladder and skin (Smith *et al.* 1992). The United States Environmental Protection Agency (EPA) said that in Bangladesh with regard to protected future cases of arsenic-related health burden, skin cancer would affect 375,000 people (Roy *et al.*, 2008). The estimate also suggested that in Bangladesh approximately 6,500 people may die from cancer every year and 326,000 people in 50 years, while 2.5 million people will develop some kind of arsenicosis during that period. Availability of arsenic mitigation technologies and improving habit for using these technologies are the basic options for safe drinking in the rural areas. Recently, a report on water and sanitation explained necessity of the immediate measures against the menac of arsenic contamination in Bangladesh (World Bank, 2006). Acceptance of alternative arsenic mitigation technologies depends not only on the level of awareness but also physiocultural and socioeconomic variations among communities (BRAC, 2003). Currently 16% population is covered by arsenic mitigation technology and it is expected that the coverage will be increased to about 22% by 2015 (GED & UNDP, 2009).

The government of Bangladesh, incorporating stakeholders, has initiated different schemes to scale up access to safe water in rural areas and small towns. Still many rural people drink tubewell without knowing arsenic contamination level and some people drink even knowing as there is no alternate source

of water available to them. Lack of access to safe water and sanitary latrine, and poor hygiene behavior are responsible for death of thousands of people of Bangladesh in every year. Water, Sanitation and Hygiene (WASH) programme of BRAC has been working with the government of Bangladesh since 2006 in 150 sub-districts for providing safe and sustainable drinking water, improving sanitation and hygiene practices to achieve Millennium Development Goals (MDG 7, target 10) by 2015 (BRAC, 2008). Although there are several reports published on the impact of WASH intervention. However, no study has yet been conducted on the impact of WASH intervention for safe water in the arsenic-affected areas of southern Bangladesh. Therefore, the aim of the study was to explore the changes in status of arsenic test and exposures to arsenic-contaminated tubewell water in arsenic prone southern Bangladesh.

MATERIALS AND METHODS

This study was done in 11 sub-districts under BRAC WASH programme where arsenic contamination was found common (TABLE 1). Arsenic-related information was collected by using a structured questionnaire developed during the baseline followed by midline survey. Respondent was adult female member of a household who used tubewell water for drinking.

TABLE 1 STUDY SITES

Name of district	Name of sub-district
Jessore	Monirampur
	Keshobpur
	Jhikorgachha
	Sharsha
Khulna	Dumira
	Digalia
	Fultala
	Rupsha
	Botiaghata
Noakhali	Sonaimuri
	Senbug

Sampling procedure for the household survey. Through survey of 6,593 households, the study sampled 3,812 tubewells in the baseline (2006/07) followed-up 3,591 in the midline (2009) in 11 sub-districts of the southern Bangladesh. Households were selected through multi-stage sampling where each sub-district was considered as a cluster. A total of 600 respondents were selected from each cluster. The economic status of the respondents was classified as ultra poor, poor and non-poor households according to WASH baseline findings (BRAC, 2008). The ultra poor people who were landless or homeless and had no fixed source of income were selected. The household who had up to 100 decimal of land (agricultural and homestead) and used to sell manual labour for living was considered as poor. On the otherhand, the household that do not fall in any of the above category called non-poor.

Data collection and quality control. Data were collected by the trained enumerators who had previous experience and completed at least fourteen years of education. Information on water and other demographic and socioeconomic variables for each sampling unit was collected using structured questionnaires and spot observations. After entry, 20% of the data were rechecked to identify any inconsistencies.

Statistical Analysis. The statistical analysis was performed with SPSS 16.0 software. The groups were compared for all variables using the chi-square test to compare categorical value. The differences were considered statistically significant at the $p < 0.05$ (two-tailed test) level with admissible error of 5%.

Ethical consideration. Before the interview verbal informed consent was taken from the participants. The verbal informed consent form was read out to the participants in native language (*Bengali*) by the interviewer. Participants were informed about the objective of the study. They were also informed that their participation was entirely voluntary and they had the right to withdraw from the study at any time.

Furthermore, it was informed that they had right to refuse answers to any questions if they feel uncomfortable. Confidentiality was maintained; survey questionnaire was kept secure with the researcher and was not shared with anybody other than for research purpose. Permission to conduct this study was obtained early from IRPC (Internal Review and Publication Committee) of the Research and Evaluation Division of BRAC.

RESULTS AND DISCUSSION

Profile of the respondents. The economic status, education, main occupation, marital status, responsibility to household water collection and age of the participants are presented in TABLE 2. Around 53% respondents were non-poor and 30% were poor and remaining were ultra poor. The main occupation of most of the respondents was household works. Around 36% respondents were illiterate and 30% passed primary education, around 32% secondary, 1.2% higher secondary and remaining passed bachelor degree. More than 90% respondents were married. Among the respondents, 43% were in age limit 10-30 years, 49% in 31-50 years and remaining were in higher ages.

TABLE 2 PROFILE OF THE RESPONDENTS

Indicators	Percent	Indicators	Percent
Economic status		Marital condition	
Ultra poor	17.7	Married	90.8
Poor	29.5	Unmarried	2.7
Non-poor	52.8	Others (widow, separated & divorced)	7.5
Education		Responsible for household water collection	
Illiterate	35.6	Women	95
Primary	30.2	Other members	5
Secondary	31.7		
Higher secondary	1.2		
Bachelor	1.3		
Main occupation		Age (Year)	
Household works	93.2	11-30	43
Day laborer	1.9	31-50	49
Student	1.2	51-60	6
Employee	0.8	61-above	2
Business	0.2		
Others (Agriculture, rickshaw pulling, work in bus, etc.)	2.7		
n = 6,593			

Status of tubewell marking. Red-marked tubewells indicate arsenic contamination of water while green-marked tubewells indicate arsenic free. The percentages of unmarked tubewells increased significantly ($p < 0.001$) in the midline (TABLE 3) though it was high risk area for drinking tubewell water. This might be because of lack of awareness among the households or lack of monitoring and improper management.

TABLE 3 STATUS OF TUBEWELL MARKING

Status	Baseline	Midline	P value
Red marked (%)	8.9	3.8	
Green marked (%)	8.7	5.9	
Unmarked (%)	82.4	90.3	<0.001
n	3812	3591	

TABLE 4 shows the marking status of tubewells in different districts. Marking of tubewells was less in Khulna district both at baseline and midline where more than 90% of the tubewells were unmarked (TABLE 4). Whereas, most of the tubewells (96%) were unmarked in the Noakhali district, the highest arsenic concentration ($4730 \mu\text{gL}^{-1}$) area which was a new experience in 20 years in arsenic research [10].

TABLE 4 STATUS OF MARKING OF TUBEWELL IN DIFFERENT DISTRICTS

Marking status	Arsenic contaminated tubewells					
	Jessore		Khulna		Noakhali	
	Baseline	Midline	Baseline	Midline	Baseline	Midline
Red marked	13.9	6.9	1.2	0.9	9.7	1.8
Green marked	12.8	7.7	7.5	5.9	3.0	2.2
Unmarked	73.4	85.4	91.4	93.2	87.3	95.9
n	1685	1584	1191	1246	936	761

TABLE 5 presents the status of marking of tubewells based on economic category of the participants. The proportion of unmarked tubewells increased in the midline among all categories (ultra poor, poor and non-poor) of households. The proportion of unmarked tubewells increased significantly from 81% at baseline to 93% at midline for ultra poor households which were found highest among all categories of households.

TABLE 5 STATUS OF MARKING OF TUBEWELL BY ECONOMIC CATEGORY

Marking status	Household statuses					
	Ultra poor		Poor		Non-poor	
	Baseline	Midline	Baseline	Midline	Baseline	Midline
Red marked (%)	11.5	2.6	8.2	3.7	8.6	4.0
Green marked (%)	7.5	4.0	9.1	6.7	8.8	6.0
Unmarked (%)	81.0	93.4	82.7	89.6	82.6	89.9
n	521	454	1061	998	2230	2128

Status of response on arsenic testing and results of testing tubewell water. The status of responses on arsenic testing and the results of testing in tubewell water among the study households are presented in TABLE 6 and 7. Proportion of tested tubewells significantly decreased from 75% at baseline to 69% at midline. However, around 24% of the tubewells were not tested at baseline and 29% at midline (Table 6). It indicates that though it was a high risk area for drinking tubewell water but people were not much aware of arsenic contamination in tubewell water and its affect on public health.

TABLE 6 STATUS OF RESPONSES ON ARSENIC TESTING OF TUBEWELL WATER

Status of knowledge	Baseline	Midline	P value
Tubewells tested for arsenic identification (%)	74.9	69.3	<0.001
Tubewells not tested for arsenic identification (%)	23.5	28.6	
Don't know whether tubewells water tested/not tested (%)	1.6	2.1	
	2212	2281	

Of the tested tubewells, around 60% were reported to be arsenic-free and 40% had arsenic contamination (TABLE 7) which could be compared with the findings of other research where 43% of

tubewells were found to be arsenic-contaminated (Chakraborti *et al.*, 2008) Some changes occurred where a small proportion likely to be increased at midline who did not know about testing of tubewell water for arsenic identification and the test results. This might be because of lack of awareness raising activities and lack of facilities for arsenic testing in the study area or both. Knowledge on the affect of arsenic in public health is important for raising awareness for safe water. It would be more effective for the people of that area if awareness raising activities could be increased on arsenic free safe water and mitigation options.

TABLE 7 STATUS OF RESPONSES ON THE RESULTS OF TESTING OF TUBEWELL WATER FOR ARSENIC CONTAMINATION

Status	Baseline	Midline	P value
Arsenic free tubewells (%)	58.0	59.8	<0.001
Arsenic contaminated tubewells (%)	41.8	39.7	
Don't know about the results of testing (%)	0.2	0.6	
n	1656	1581	

CONCLUSION

This study reveals that the household members still drink water from arsenic-contaminated tubewells. Proportion of respondents who did not know about arsenic test and test results of tubewell water increased in the midline. This might be because of lack of awareness or lack of facilities for arsenic testing in the study area where more than 95% of women were responsible for collecting water from tubewells. As proportion of unmarked tubewells was high both at baseline and midline though study area was a highly risk for drinking tubewell water, it is necessary to motivate people for marking their tubewells based on results of arsenic testing. Information, education and communication campaigns should be strengthened to raise awareness and thereby testing and marking of tubewells will be enhanced. Besides, availability of arsenic-free safe water needs to be urgently ensured to prevent health hazard.

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