CSIR WATER RESEARCH INSTITUTE

(CSIR WRI)






Annual Report 2012

CSIR
WATER RESEARCH INSTITUTE

Annual Report

2012

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QUALITY RESEARCH

SUSTAINABLE WATER USE FOR DEVELOPMENT

CSIR WATER RESEARCH INSTITUTE

ACCRA, GHANA

ACRONYMS

ARDEC	-	Aquaculture Research and Development Centre
ANFTS	-	African Network for Fish Technology and Safety
BOD	-	Biochemical Oxygen Demand
CCAA	-	Climate Change Adaptation in Africa
COD	-	Chemical Oxygen Demand
CPWF	-	Challenge Programme on Water and Food
CSIR	-	Council for Scientific and Industrial Research
CWSA	-	Community Water and Sanitation Agency
DFID	-	Department for International Development
DO	-	Dissolved Oxygen
DWL	-	Dynamic Water Level
ECD	-	Environmental Control Dam
EIA	-	Environmental Impact Assessment
EPA	-	Environmental Protection Agency
FC	-	Fisheries Commission
FCR	-	Food Conversion Ratio
FDC	-	Frequency Distribution Curve
FoE	-	Friends of the Earth
GAMA	-	Greater Accra Metropolitan Area
GIS	-	Geographic Information System
GWCL	-	Ghana Water Company Limited
GWSSA	-	Groundwater in Sub-Saharan Africa
GMET	-	Ghana Meteorological Agency
HSD	-	Hydrological Services Department
IAB	-	Institute of Aquatic Biology
IAEA	-	International Atomic Energy Agency
IDRC	-	International Development Research Centre
IGF	-	Internally Generated Funds
ILGS	-	Institute of Local Government Studies
IMC	-	Internal Management Committee
INI	-	Intelligence Nature International
ISSER	-	Institute of Statistical, Social and Economic Research
IWMI	-	International Water Management Institute
IWRM	-	Integrated Water Resources Management
KNUST	-	Kwame Nkrumah University of Science and Technology
NGGL	-	Newmont Ghana Gold Limited
NGO	-	Non-Governmental Organizations
OPCW	-	Organization for the Prohibition of Chemical Weapons
PBBs	-	Polybrominated Biphenyls
PCR	-	Polymerase Chain Reaction
PFC	-	Pioneer Food Cannery
PURC	-	Public Utilities Regulatory Commission
RCM	-	Regional Climate Model
RGU	-	Robert Gordon University
RLWRDS	-	Research Library and Water Resources Documentation System
SP-PAGIRE	-	Secrétariat Permanent au Plan d'Action et de Gestion Intégrée des Ressources en Eau

SSA	-	Sub-Saharan Africa
STMIE	-	Science, Technology and Mathematics Innovations Education
SWAT	-	Soil and Water Assessment Tool
SWL	-	Static Water Level
TDS	-	Total Dissolved Solids
TNA	-	Technology Needs Assessment
TSS	-	Total Suspended Solids
UDS	-	University for Development Studies
WAQUA	-	West African Quaternary Research Association
WATSAN	-	Water and Sanitation
WHO	-	World Health Organisation
WRC	-	Water Resources Commission
WRI	-	Water Research Institute
WRRI	-	Water Resources Research Institute
WSF	-	Water Storage Facility
WSSD	-	World Summit on Sustainable Development
WTP	-	Water Treatment Plant
WVI	-	World Vision International

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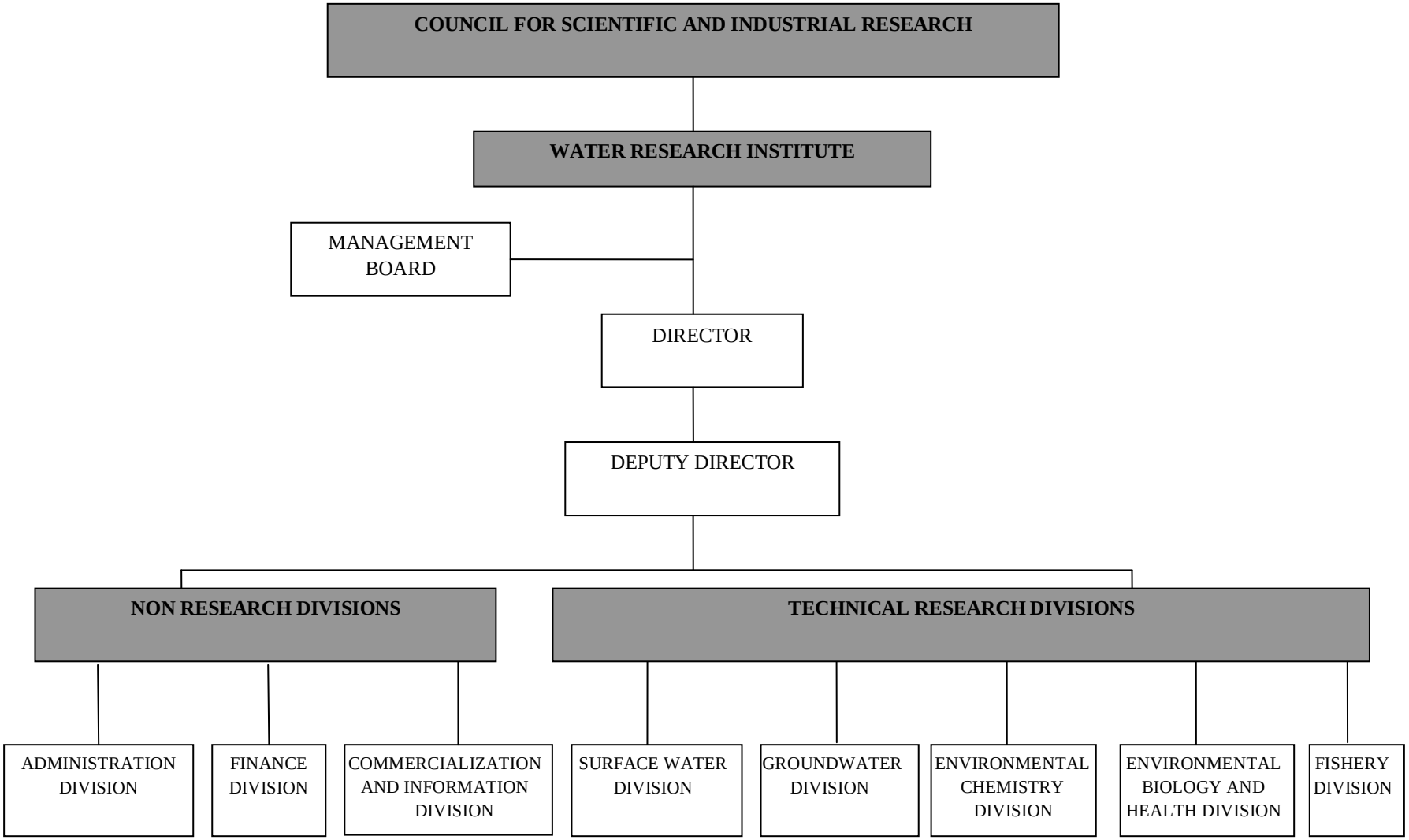
Organizational Chart



EXECUTIVE SUMMARY

This report contains an overview of research and commercialization activities undertaken by the Water Research Institute of the Council for Scientific and Industrial Research in 2012. The Water Research Institute (WRI) is one of the 13 institutes of the Council for Scientific and Industrial Research (CSIR). The overall goal of the CSIR WRI is to conduct research into all aspects of water resources (both living and non-living) in order to provide scientific and technical information and services as well as strategies for the sustainable development, utilization and management of such resources for the socio-economic advancement of the country.

The 2012 Annual Report consists of four (4) chapters namely Introduction, Administration, Research and Development Activities and Finance. The report has been compiled based on the research and development activities, commercialization of research and development activities through consultancy and advisory services, and administrative matters such as staff strength, appointments, promotions, national service recruitment, as well as financial and accounting matters during the year 2012.

The Institute undertook a total of 31 research projects during the year. These included: assessment of human health risk from exposure to toxic chemicals via recycling of e-waste at Agbogbloshie market – Accra, Ghana; cyanobacteria and cyanotoxins in drinking water reservoirs and water supply; sustainable management of Lake Bosomtwe in the Ashanti Region of Ghana – hydrology, anthropology and water quality; quality of the Nima and Dzorwulu creeks and their suitability for urban agriculture; groundwater in Sub-Saharan Africa: implications for food security and livelihood (GWSSA); eco-health approach to the control of Onchocercaisis in the Volta Basin of Ghana; and non-destructive genetic sampling in fish: an improved method for DNA extraction from fish fins.

A total of 16 technical reports, 8 conference papers, 23 consultancy reports and 28 Journal papers were authored by scientists of the Institute in collaboration with scholars worldwide.

1.0 INTRODUCTION

1.1 Establishment

The Water Research Institute (WRI) is one of the 13 research institutes of the Council for Scientific and Industrial Research (CSIR). It is a public institution established in 1996 by the CSIR Act 521. It was created by the merger of the Institute of Aquatic Biology (IAB) and the Water Resources Research Institute (WRRI), both of the CSIR, which were created in 1965 and 1982, respectively.

1.2 Vision

To become a centre of excellence in the provision of scientific research into water and related resources for sustainable socio-economic growth

1.3 Mission

To conduct research into all aspects of water resources (both living and non-living) in order to provide scientific and technical information and services as well as strategies for the sustainable development, utilization and management of such resources for the socio-economic advancement of the country

1.4 Values

Our core values include dedication to duty, commitment, loyalty to quality assurance and customer satisfaction

1.5 Key Objectives

The key objectives of the Institute are:

- To generate, develop and transfer appropriate technologies, information and services for sustainable development, utilization and management of surface water resources;
- To generate, process and disseminate information on the availability of groundwater, rate and volumes to be abstracted for various uses as well as the reliability and sustainability of its recharge;
- To generate, process and disseminate water and waste water quality information to end users;
- To enhance public health status through sound environmental management and water pollution control strategies;
- To increase local fish production through participatory research and technology transfer in aquaculture and sustainable management strategies in inland and coastal waters of Ghana; and
- To undertake commercialisation of research and development activities through consultancy and advisory services and the provision of water resources information, documentation and technical support services.

1.6 Divisions

The mandate of the Institute is realized through the research and development activities of five (5) Technical Divisions and three (3) Non-technical Divisions. The Technical Divisions are:

- Environmental Biology and Health
- Environmental Chemistry
- Fishery

- Groundwater
- Surface Water

The Non-technical Divisions are:

- Administration
- Commercialization and Information
- Finance

1.7 Branches

- Main office in Accra
- Branch office at Tamale in the Northern Region
- Aquaculture Research and Development Centre (ARDEC) at Akosombo in the Eastern Region (Figure 1)

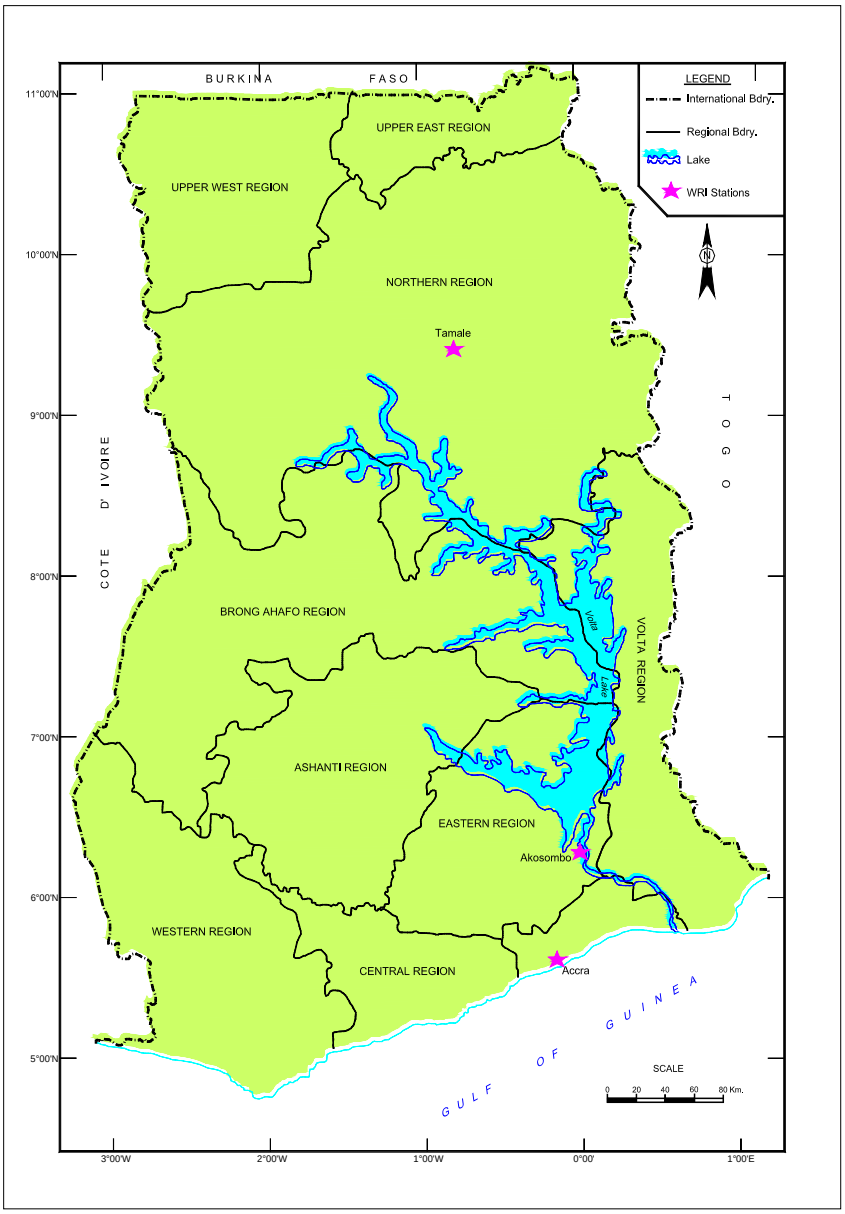


Figure 1: Location map showing branches of CSIR Water Research Institute

An overview of the major activities of the Institute during the year 2012 is herein presented. We shall be grateful to receive any comments and suggestions you may wish to make on any aspects of our activities or report. Kindly send them to the following address:

The Director,
CSIR Water Research Institute,
P. O. Box AH 38,
Achimota-Ghana

or

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CSIR Water Research Institute,
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E-mail : ***info@csir-water.com; wricidss@yahoo.com***
Website : ***www.csir-water.com***

2.0 ADMINISTRATION

2.1 Management

The Institute was managed by an eight-member (8) Management Board and a sixteen-member (16) Internal Management Committee (IMC). The Board is made up of representatives from the University, Corpoorate CSIR, cognate institutes, private and public institutions, and Non Governmental Organisation (NGO). The Board was chaired by Prof. C. Dorm-Adzobu, Dean, Faculty of Arts and Social Sciences, Central University College. The IMC is made up of the Directorate of the Institute, all Heads of Division, officers in charge of the Institute's outstations, and representatives from the Research Staff Association, Senior Staff Association and the Trade Union Congress (Local Union). Membership of the Board and IMC are given in Appendices I and II, respectively.

2.2 Staff Strength

Staff strength at the end of the year 2012 stood at 249. This was made up of 60 *Senior Members,* 91 *Senior Staff and* 98 *Junior Staff*. Staff distribution and the list of senior members and senior staff are presented in Appendix III.

2.3 Statistics on Human Resource Activities

The number of appointments, promotions/upgrading, resignations, retirements and deaths in 2012 is shown in Appendix IV.

2.4 Human Resources Development

To enable staff acquire the necessary skills and knowledge for enhancement of their performance in the Institute, and in conformity with the policy of CSIR to provide training opportunities for its staff, as at the end of 2012, eleven (11) members of staff were offered variety of training and development opportunities at various levels both locally and abroad. Two (2) other members of staff who successfully completed their respective programmes during the year returned to post. The details are given in Appendix V.

Short-term training programmes attended by some staff of the Institute were:

- Training course on dam safety inspection, International Centre for Hydropower, Trondheim, Norway 11 – 15 June 2012
- Training on strategic planning for Senior Members, Management Development and Productivity Institute (MDPI), Accra, 17 – 21 September 2012
- Analytical chemistry training on the use of GC, GC-MS, Organization for the Prohibition of Chemical Weapons (OPCW), Pretoria, South-Africa, 30 April – 11 May 2012
- Training on geographical information systems (GIS), Accra, 17 – 21 September 2012
- Sub- regional training course for customs authorities of state parties in North, West and Central Africa on technical aspect of transfer regime of the Chemical Weapon Convention, Accra, 8 – 11 October 2012

2.5 Participation in Scientific Meetings

Some research and technical staff participated in a number of workshops, seminars and conferences held at the national, regional and international levels during the year. Among them were:

- 2nd GEF African regional workshop on technology needs assessment (TNA) for climate change adaptation in Navaisha, Zambia, 28 – 30 February, 2012
- Write workshop (URADAPT project) in Addis Ababa, Ethiopia, 23 – 30 June, 2012
- Climate change and population conference on Africa, Accra, July 2012
- Annual general meeting and conference, African Technology Studies Network (ATPS), Addis Ababa, Ethiopia, 18 – 24 November 2012
- 23rd annual general meeting and conference, CSIR Research Staff Association (RSA), Ejisu, 6 – 8 November 2012
- 43rd engineering week celebration and annual conference, Accra, 28 – 30 March 2012
- Workshop on environmental, health and safety auditing skills, Accra, 23 – 25 April 2012
- Workshop on horizontal model assessment scenarios for Ghana, Accra, 23 – 27 July 2012
- Workshop on the use of personal geographic assistant, Accra, 17 – 21 September 2012
- Workshop on 'using of sense-maker: beyond the statistics', Accra, 26 January 2012
- Workshop on data validation and sustainable model design, Accra, 27 – 28 February, 2012 and 3 – 5 April 2012
- WASHTech and WASHCost sustainability model, Accra, 26 March 2012
- Forum on impact of biotechnology on food production, Accra, 1 August 2012
- Workshop on strategic action programme for the Volta Basin, Accra, 19 – 20 September 2012
- Workshop on costing sustainable rural water, sanitation and hygiene (WAHS) services in Ghana, Accra, 30 November 2012
- Workshop on draft Ghana Building Code, Accra, 26 – 27 September 2012
- Workshop on Challenge Programme for Water and Food (CPWF), Ouagadougou, Burkina Faso, 3 – 5 July 2012
- 2nd Climate Change Colloquim, Accra, 9 February 2012
- Workshop on weather index insurance/early warning systems, Accra, 13 February 2012
- World Water Day Forum, Akuse, 22 March 2012
- 33rd meeting of the CSIR WRI IMC, Accra, 21 November 2012
- Workshop on integrated and sustainable agricultural production systems for improved food security and livelihoods in dry areas, Ouagadougou, Burkina Faso, 28 – 30 May 2012
- Joint 4th IHP Africa National Committees Regional Meeting and Africa Water Science, Policy and Management Conference: Water sciences for sound Africa water policies and governance in a changing environment, Dar-es-Salaam, Tanzania, 23 – 27 April 2012
- 6th meeting of the research into strategic action platform (Re-SAP), Accra, 28 February 2012
- 7th meeting of the research into strategic action platform (Re-SAP), Accra, 22 May 2012
- Workshop on the impact of climate change and desertification on agriculture and food security, Ouagadougou, Burkina Faso, 14 – 26 May 2012
- Workshop on research ethics: strengthening of institutional review boards and capacity building of scientist on research ethics, Accra, 16 October 2012
- Corporate Women's Conference, Accra, 28 – 29 November 2012

- 3rd Ghana environmental management project (GEMP) gender stakeholder committee meeting, Accra, 30 October 2012
- 1st National schistosomiasis control forum in Ghana (SCIG), Akosombo, 15 March 2012
- Workshop on re-optimisation and re-operation study of Akosombo and Kpong dams, Accra, 22 – 23 August 2012
- Invasive species compendium workshop on IAS management and reporting in West Africa, Accra, 13 – 15 November 2012
- Gender orientation and monitoring and evaluation workshop, Accra, 6 September 2012
- GHAGIS training methods and tools in the application of advance GIS technology using personal geographic assistant software, Accra, 17 – 21 September 2012
- Workshop on assessing current issues affecting the livelihoods of Lagoon communities in Ghana, Accra, 14 May 2012
- 43rd world standard day celebration – 'open day', Accra, 11 – 12 October 2012
- Climate change and urban and peri-urban agriculture with special reference to urbanizing Tamale, Tamale, 27 April 2012
- Round-table/regional learning meeting on Ghana environmental management programme, northern sector, Tamale, 13 – 17 November 2012
- Biennial 3rd West African Quaternary Research Association (WAQUA) International Workshop, Accra, 8 – 12 October 2012
- Localizing Ghana national climate change adaptation strategy, Tamale, 21 – 22 November 2012
- Workshop on African network for fish technology and safety (ANFTS) in Ghana, Accra, 30 May 2012
- Training workshop in quality management systems – ISO 2001; 2008 model, Accra, 25 – 26 June 2012
- Regional assessment workshop on climate change vulnerability of West African mammals and freshwater fish, Lome, 24 – 27 July 2012
- Workshop on research infrastructure for Africa-Europe Cooperation, Accra, 3 – 4 December 2012
- Annual African Technology Policy Conference and Workshop, Addis Ababa, 19 – 22 November, 2012
- International Atomic Energy Agency (IAEA) regional training workshop in the application of isotope technique in water resources case studies, Cairo-Egypt, 8-12 April 2012
- Applied science and quality systems on quality management for sustained success, Accra, 24 – 26 June 2012
- Workshop on finalisation of the Draft National Environmental Policy, Accra, 9 – 12 November 2012

2.6 Membership of Committees and Boards

Staff served on various committees and boards such as:

- CSIR WRI Editorial Committee
- CSIR-WRI Estate Committee
- CSIR-WRI Internal Management committee
- CSIR-WRI Procurement/Tender Committee
- CSIR-WRI Seminar Workshop Committee

- Darwin Initiative – Ghana
- Editorial Board, Journal of Water Resources and Ocean Science
- Editorial Committee for the Journal of the Ghana Institution of Engineers (GhIE)
- Ghana Atlas Team
- Ghana Chemical Society
- Ghana Coordinating Committee (GCC) of the Ghana Dams Dialogue and Development in Ghana
- Ghana Institution of Engineers (GhIE) Subcommittee on Education and Training
- Ghana-Iran Joint Commission for Co-operation and Development, Ministry of Education and Sports/Ministry of Foreign Affairs
- Ghana National Commission for UNESCO, (Ministry of Education and Sports)
- Ghana Science Association
- Ghana Technology Needs Assessment (TNA) Team
- Governing Board, Ghana Meteorological Agency
- Governing Board, Ghana Irrigation Development Authority
- Governing Commissioners, Water Resources Commission
- Irrigation Working Group, Agriculture Programme, DAI/CMC/ Millennium Development Authority
- National Filariasis Task force
- National Malaria Task force
- Northern Regional Environmental Management Committee
- Pra Basin Board, Water Resources Commission
- Project Steering Committee, Flood Hazard Assessment for the White Volta Basin
- Research Staff Association
- Resources Centre Network (RCN) Ghana for WASH/Water resources issues through networking
- Review Editor, West African Journal of Applied Ecology
- Steering Committee, Technical Co-operation Africa Project
- Technical Review Committee, CSIR WRI
- World Water Day National Committee

2.7 National Service and Industrial Attachment

The Institute supported tertiary institutions towards training of students as part of its capacity building activities. The duration of the training programmes was between four (4) and twelve (12) weeks. The details are presented in Appendix VI.

2.8 Staff Publications

Several technical and non-technical reports, conference and journal papers were produced by staff during the reporting year. Most of the technical papers and theses have been shelved at the Institute's library as reference material. The details are given in Appendix VII.

3.0 RESEARCH AND DEVELOPMENT ACTIVITIES

3.1 ENVIRONMENTAL BIOLOGY AND HEALTH DIVISION

The objective of the Environmental Biology and Health Division is to enhance public health status through sound environmental management and water pollution control strategies. The Division has expertise in areas of microbiology, parasitology, entomology, aquatic invertebrates, molecular biology and public health. Its approach to research, consultancy, advisory services, technology transfer, water-related public health and environmental issues is multidisciplinary. Activities of the Division include:

- enhancement of public health status through sound environmental and water pollution control strategies;
- microbiological quality analyses of water and other samples;
- research into water-related/borne parasitic diseases of public health importance;
- research into water-related vectors of diseases of public health importance to develop innovations in control and prevention;
- environmental impact assessment and watershed management;
- identification and management of invasive plants in Ghana;
- molecular epidemiology, understanding the mechanism and genetics of drug resistance and the development of molecular biology diagnostic tools;
- production of health education and supply of biological specimens as teaching materials;
- consultancy in the establishment of science and medical laboratories; and
- training of scientists, technologists, technicians and students.

3.1.1 Sustainable Land and Water Management Project (SLWMP)/Macro-invertebrate Monitoring

(Project Staff: Mr. E. D. O. Ansa – Research Scientist and Mr. G. B. Amegbe)

This project was carried out in collaboration with the Environmental Protection Agency. It started in 2012 to establish baseline data on the distribution of macro-invertebrates of some rivers and streams in Northern Ghana. It is expected to end in 2014.

In the year under review, baseline survey of macro-invertebrate fauna existing in some rivers and streams in the Upper East, Upper West and Northern regions were conducted. Pre-selected sampling sites of the study area were sampled with a hand net over a defined area and samples preserved in formalin for further processing in the laboratory. Individual macro-invertebrates were identified as far as possible with the aid of available taxonomic keys and water quality values assigned to sensitive species. Rivers and streams in the study area were classified as clean, slightly polluted and polluted based on available literature on identified taxonomic species from the study area. A summary of some results of the study is shown in Table 1.

Table 1: Macro-invertebrates in River Kongua at Kpaglahe in the Wa East District, Upper West Region

Taxon	Hand Net 01	Hand Net 02	Hand Net 03	Total	Relative Abundance
ANNELIDA					
Nais sp.	8		2	10	6.80
Aediinae					
Aedes sp.	1			1	0.68
COPEPODA					
Cyclops		1	8	9	6.12
COLEOPTERA					
Gyrinidae					
Orectogyrus vagus sp. C3	4			4	2.72
DIPTERA					
Ceratopogonidae					
Ceratopogonidae sp.	1	1		2	1.36
Chironomidae					
Nanocladius sp. CO1	12	8	14	34	23.13
Polypedilum sp. CC8			21	21	14.29
Stenochironomus sp CC16	14	9		23	15.65
Stictochironomus puripennis sp CC49	5		13	18	12.24
EPHEMEROPTERA					
Centroptilum sp. E31		1		1	0.68
ODONATA					
Gomphidae					
Gomphidae sp. O. sp. 24			1	1	0.68
OSTRACODA					
Ostracoda sp.	18	1	3	22	14.97
PISCIDAE					
Pisces unident		1		1	0.68
TOTAL				147	100.00

It was concluded from the study that River Kulpani at Jeyiri, River Kongua at Kpaglahe, River Nakong at Navrawei and Sissili, all in the Upper West Region, were classified as clean due to the presence of sensitive indicator taxa such as *Centroptilum* sp, Dytiscidae, Coenagriidae and Gomphidae. River Nasia in the Northern Region was slightly polluted while Gbani stream was polluted.

3.1.2 The Shell of *Cocos nucifera* and the Seed of *Moringa oleifera* as Biosorbents for the Removal of Lead (II) in Industrial Wastewater

(Project Staff: Mr. E. D. O. Ansa – Research Scientist, Mr. M. A. Acheampong and Mr. O. Yeboah)

In collaboration with the Department of Chemical Engineering, Kumasi Polytechnic, Kumasi, this study was initiated in 2011 to assess the removal of lead (Pb) from industrial wastewater using the eco-technology of biosorption. It is expected to end in 2013.

During the reporting period, *Cocos nucifera* shell and *Moringa oleifera* seeds were washed, dried, grounded and sieved into fractions with particle size ranges of 0.25 – 0.5 mm, 0.5 – 0.8 mm, 0.8 – 1.0 mm, 1.0 – 1.4 mm and 1.4 – 1.6 mm. The effect of sorbent concentration was investigated by varying the amount of sorbents. Batch sorption experiment with 2.0 g coconut

shell and *Moringa oleifera* seeds and 10 mg/l Pb (II) solution was conducted to determine the effect of the particle size, by comparing the 0.25 – 0.5 mm to 1.4 – 1.6 mm ranges. The effect of pH was also investigated. The characteristics of the two biosorbents used in the study are shown in Table 2.

Table 2: Characteristics of the sorbents used in the study

Sorbent	Total volume ($cm^3 g^{-1}$)	Porosity (%)	ρ ($g\ cm^{-3}$)	Surface area (S_{BET}) ($m^2 g^{-1}$)
C. nucifera	0.90	55	1.35	0.4
M. oleifera seeds	0.46	34	1.14	0.1

The removal of lead (Pb) from industrial wastewater in relation to the particle size ranges of *Cocos nucifera* shell and *Moringa oleifera* seeds is shown in Figure 2.

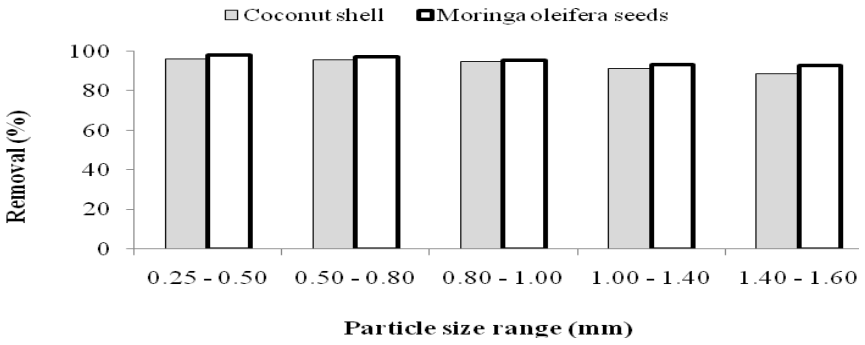


Figure 2: Removal of lead (Pb) in relation to particle size ranges of *Cocos nucifera* shell and *Moringa oleifera* seeds

It was concluded that the two sorbents had very rough and corrugated surfaces and showed good promise for the removal of lead. *Moringa oleifera* seeds showed better removal efficiency as its equilibrium uptake of Pb (II) was 2.3 mg g^{-1}, compared with 1.6 mg g^{-1} for *Cocos nucifera* shell. The different particle sizes of sorbents however did not significantly influence the removal of Pb (II). In addition, a pH range of 3 – 5 was optimal for the removal of Pb (II) concentration of 10 mg/l.

3.1.3 Cyanobacteria and Cyanotoxins in Drinking Water Reservoirs and Water Supply

(Project Staff: Dr. Gloria Addico – Research Scientist and Mrs. Ruth Amole)

This collaborative study with the Robert Gordon University, Aberdeen, Scotland, UK, was completed in the reporting year. Its objectives included:

- characterization of cyanotoxins (microcystin) associated with drinking water reservoirs in Ghana;
- documentation of cyanobacteria species and biomass in the reservoirs; and
- assessing the risk of exposure to cyanotoxins on human health.

During the reporting year, a total of 40 water samples were collected from the Brimsu and Kwanyarko reservoirs which supply some communities in the Central Region of Ghana with potable water. The water samples were collected from the various treatment stages (intake, flocculation, sedimentation, filtration, and chlorination) of each reservoir and analysed for microcystin.

The results showed four different microcystin which included MC-LR, MC-YR, MC-LA and MC-RR. MC-LA was a variant identified for the first time in Ghana. All these four microcystin variants were present at the intake of the Brimsu Reservoir. Only microcystin-LR was identified at the intake of the Kwanyarko Reservoir. All four microcystins identified in this study were very toxic with MC-LR and MC-YR being implicated in the death of 76 dialysis patients in Caruara, Brazil. These toxins were found to be present in the patients' livers and blood samples (Pouria et al., 1998). Phytoplankton species composition and biomass obtained at the five treatment stages of the Brimsu and Kwanyarko reservoirs are shown in Tables 3 and 4.

Table 3: Phytoplankton species composition and biomass obtained at the five treatment stages of the Brimsu water treatment plant in the Central Region of Ghana (Counts/ml)

Species	Intake	Flocculation	Sedimentation	Filtration	Chlorination
Green Algae					
Ankistrodesmus falculatus	-	77	46	12	-
Staurastrum gracile	3	-	6	2	-
Scenedesmus *dimorphus*	12	20	24	-	-
Ulothrix tenuissima	44	-	-	-	-
Blue-green Algae					
Anabaena flos-aquae	546	208	191	50	32
Merismopedia punctata	91	84	70	9	-
Microcystis aeruginosa	300	171	86	53	40
Planktothrix agardhii	693	253	153	68	31
Pseudanabaena recta	553	79	-	-	-
Diatoms					
Synura sp	89	18	39	5	-

Table 4: Phytoplankton species composition and biomass obtained at the five treatment stages of the Kwanyarko water treatment plant in the Central Region of Ghana (Counts/ml)

Species	Intake	Flocculation	Sedimentation	Filtration	Chlorination
Green Algae					
Ankistrodesmus falculatus	-	51	-		9
Chlorella vulgaris	12	-	2		14
Staurastrum gracile	-	8	11		4
Scenedesmus *dimorphus*	-	-	-		-
Ulothrix tenuissima	185	-	-		-
Blue-green Algae					
Anabaena flos-aquae	123	112	95		38
Chlorococcus cronbergae	8	-	-		-
Merismopedia punctata	175	218	-		-
Microcystis aeruginosa	603	202	75		23
Planktothrix agardhii	244	90	78		24
Pseudanabaena recta	133	54	32		-
Diatoms					
Gyrosigma sp	3	-	-		-
Navicula graciloides	12	-	9		-
Synura sp	3	-	-		-
Synedra acus	13	88	-		2

Quantification of microcystin detected yielded a total intracellular microcystin concentration of 0.79 µg/l at the intake of the Brimsu Reservoir. The results also showed a decreasing concentration of intracellular microcystin from the intake stage through to the chlorination stage, with the Brimsu and the Kwanyarko reservoirs having concentration of 0.10 µg/l after the final treatment stage (Figure 3).

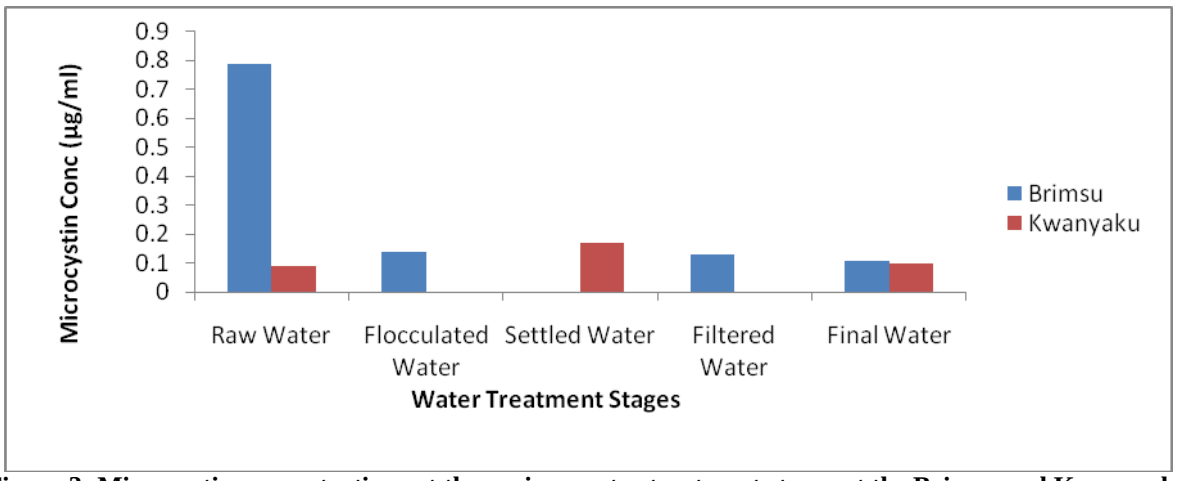


Figure 3: Microcystin concentrations at the various water treatment stages at the Brimsu and Kwanyarko reservoirs

It was concluded from the study that although microcystin levels recorded were lower than the WHO acceptable limit of 1 µg/l for drinking water and do not present any immediate risk to consumers, people using the raw water as their source of drinking water may be at risk due to the tumour promoting activity of microcystin. It was recommended that drinking water should be regularly monitored for cyanobacteria and levels of microcystin to protect human health.

3.1.4 Ecological Study of the Water Storage Facility and Its Impacts on the Awonsu Stream and the Tano River

(Project Staff: Dr. Felix J. Akpabey – Research Scientist)

In collaboration with the Fisheries Commission, this study was initiated in 2011 to undertake an ecological study of the Water Storage Facility (WSF) to determine the impacts of regular and long term discharges of water from the reservoir on natural water bodies located within the concessional area of Newmont Gold Ghana Limited. The specific objectives were to assess the:

- ecological state of the WSF in relation to water and sediment quality;
- the types, diversity and quality of fauna and flora;
- presence of water related disease vectors, and how these vary seasonally.

It is expected to end in 2015.

During the reporting period, water samples were collected from selected locations in the WSF, the River Tano, Awonsu and Subri streams and analyzed.

A total of 29 algal taxa were encountered in the study. These include 18 green algae (chlorophyta) constituting 62.07 %; 7 blue-green algae (cyanophyta) constituting 24.14 % and 4 diatoms (bacillariophyta) constituting 13.79 %. The presence of green algal species such as *Euglena, Phacus* and *Scenedesmus* was an indication of faecal pollution and this

could be attributed to some human settlements within and bordering the large drainage basin that encompassed the water bodies.

3.1.5 Water Quality Studies in Relation to Cage Fish Culture in Busa and Sing Reservoirs in Upper West Region

(Project Staff: Dr. K. Kwarfo-Apegyah – Senior Research Scientist, Mr. Mark Osa Akrong – Research Scientist, Mr. Gerard Quarcoo – Research Scientist, Mr. Etornyo Agbeko – Research Scientist, Mr. Michael Kumi – Research Scientist, Ms. Millicent Ewurama Adu-Boakye – Principal Technical Officer and Salifu Abdul Latif – Principal Technical Officer)

This project started in 2011 to monitor bacteriological water quality parameters that influence fish production; identify the source of pollutants that are hazardous to fish production in the reservoirs; and make recommendation to control the pollution of the reservoirs to ensure sustainable and profitable cage and wild fish production. It is expected to end in 2013.

Activities carried out in the reporting year included collection of water samples from the Busa and Sing Reservoirs at the up-, mid- and down-streams. Water quality parameters monitored were Physico-chemical, microbial and Phytoplankton concentrations.

The study showed that there was variation in the levels of coliform bacteria in the two reservoirs and these could be attributed to human and animal activities such as cattle dropping directly into the reservoirs. The elevation in bacterial counts could also be attributed to run-off carrying sediments containing faecal matter from the surroundings. However, faecal coliform levels were below the WHO recommended levels of 10^3 FC/100ml for wastewater pond (WHO, 1989). Comparatively, it was generally observed from the study that total and faecal coliform levels were higher in the Busa reservoir than the Sing Reservoir (Figures 4 – 6).

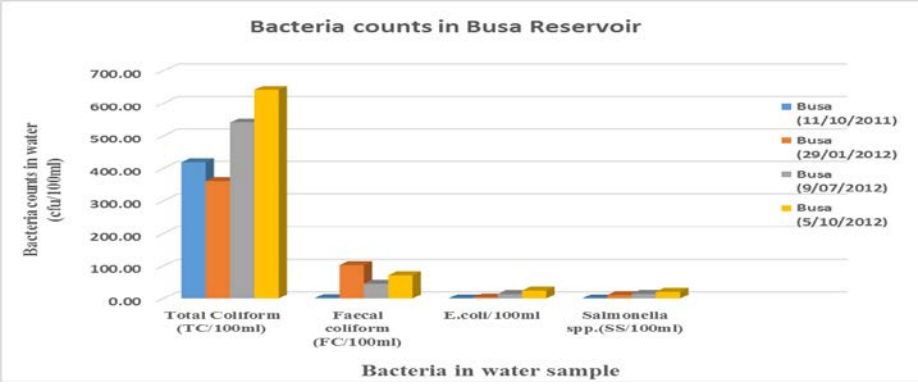


Figure 4: Levels of bacteria count in Busa reservoir

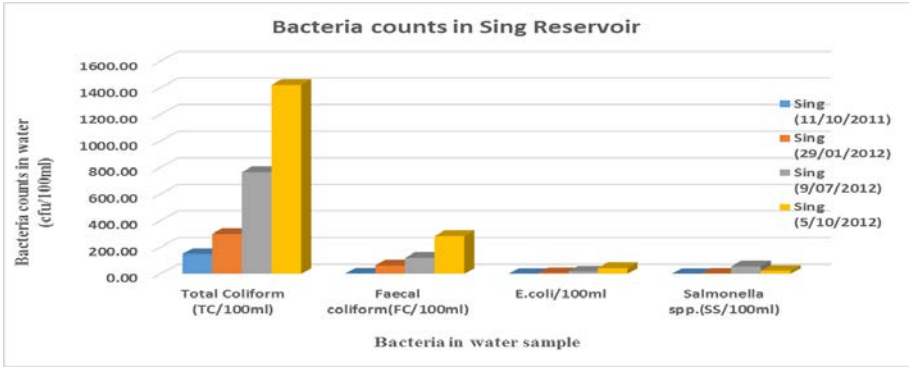


Figure 5: Levels of bacteria count in Sing reservoir

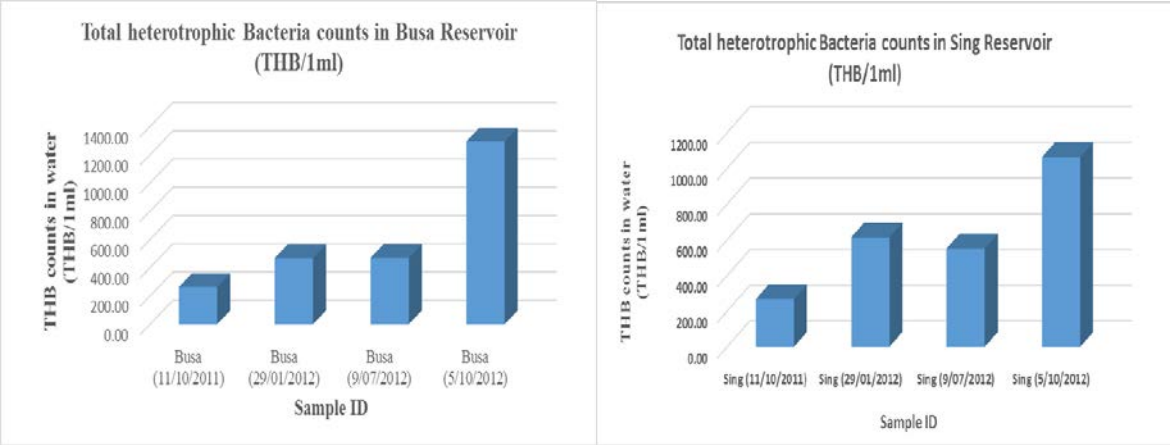


Figure 6: Levels of Total Heterotrophic bacteria counts in Busa and Sing reservoirs

The Busa reservoir showed an overall ionic dominance pattern of $HCO_3^{-1} > Ca^{+2} > Cl^{-1} > Mg^{+2} > SO_4^{-2}$ and $Na^{+1} > K^{+1}$ while the Sing reservoir showed an overall ionic dominance pattern of $HCO_3^{-1} > Ca^{+2} > Cl^{-1} > Na^{+1} > SO_4^{-2}$ and $Mg^{+2} > K^{+1}$. The dominance of Cl^{-1} over SO_4^{-2} in the Busa Reservoir could be attributed to inflow of water from the domestic wastes being discharged into it. The dominance of Ca^{+2} over Na^{+1} and Mg^{+2} in the two reservoirs could be due to the fish feed and geology of the surrounding land of the reservoirs. The detailed result is shown in Figures 7 and 8. The Water Quality Index (WQI) revealed that both Busa and Sing reservoirs were in Class III, the poor quality state. It was concluded from the study that though bacteria levels in the Busa and Sing reservoirs were high, the levels were below the WHO and EPA recommended levels of 10^3 fc/100ml and 10000 cfu/100ml respectively, for aquaculture in wastewater pond, indicating that the water qualities of the two reservoirs were suitable for fish production.

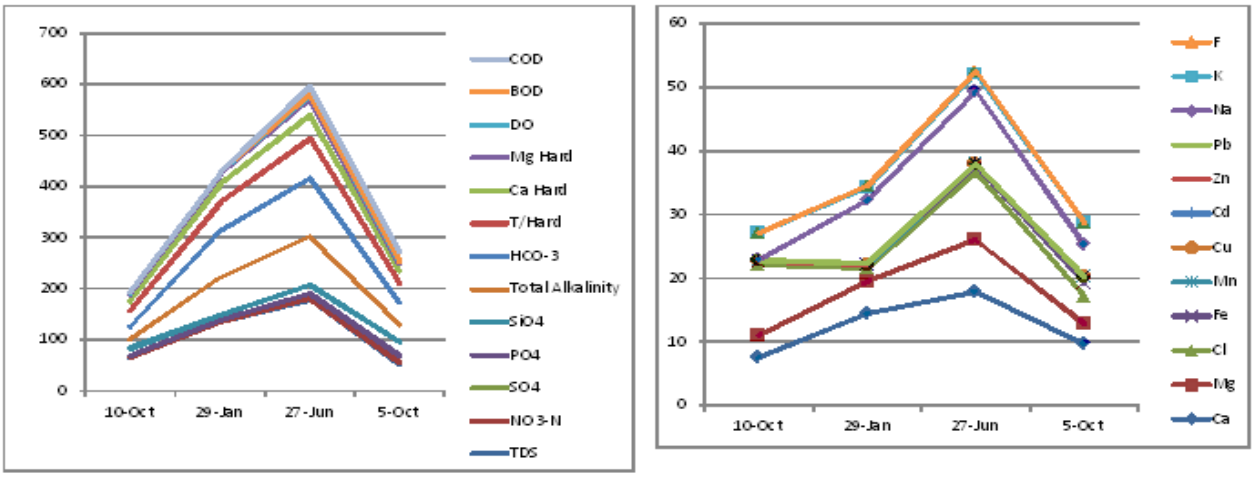


Figure 7: Nutrients, trace metals and major ions results for Sing reservoir in mg/l

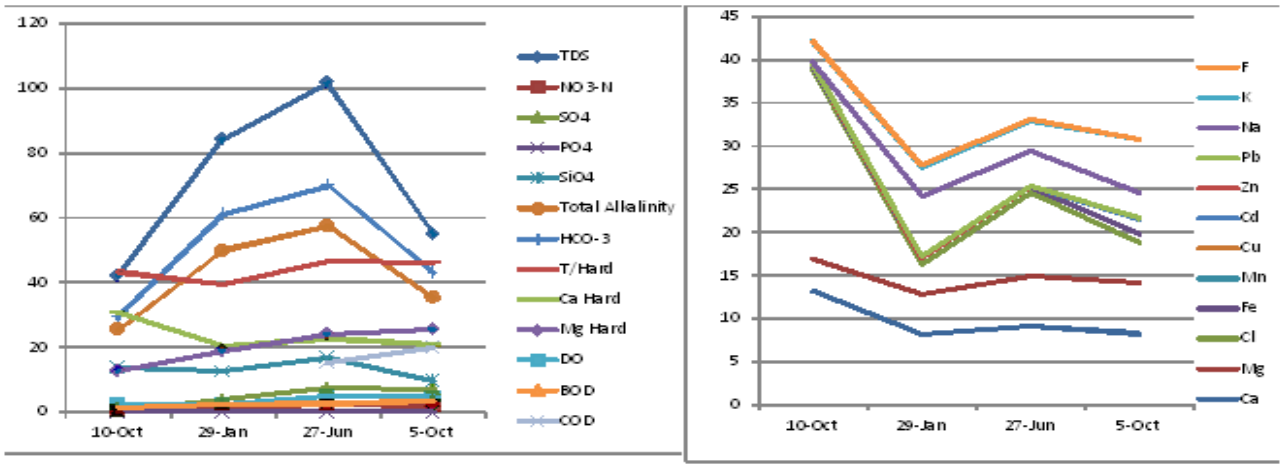


Figure 8: Nutrients, trace metals and major ions results for Busa reservoir in mg/l

3.2 ENVIRONMENTAL CHEMISTRY DIVISION

The long-term general objective of the Environmental Chemistry Division is to generate, process and disseminate water and wastewater quality information to end-users. Specific objectives are to:

- perform quality and quantity assessments of industrial, agricultural and domestic discharges in both urban and rural areas and identify their impact on aquatic ecosystems;
- collect, process and disseminate comprehensive high quality and reliable environmental data on surface and groundwater with regard to their chemical constituents; and
- monitor pollution in coastal waters and lagoons of Ghana.

Currently, the major research programmes of the Division are:

- Water quality monitoring;
- Industrial wastewater studies;
- Environmental impact studies; and
- Development of strategies for water pollution control.

3.2.1 Quality of the Nima and Dzorwulu Creeks and their Suitability for Urban Agriculture

(Project Staff: Miss. Mohammed Saada – Research Scientist, Dr. Isaac Hodgson – Principal Research Scientist, Serapis Aseidu Appiah and Lawrence Yawson)

Many urban dwellers eat exotic vegetables daily in Accra. However, the water sources used for irrigation are of concern as these sources may contain heavy metals and pesticides which accumulate in the soil over a period of time and enter into the food chain. It was against this background that this on-going study was initiated in the reporting year to assess the quality of the waste water in the Nima and Dzorwulu Creeks and determine their suitability for Urban Agriculture. The specific objectives were to determine the:

- physico-chemical parameters of the waste waters;
- heavy metal levels in both the water and soil; and
- pesticide residue levels in the water, soil and the vegetables.

Activities undertaken during the year under review included monthly sampling of water from the Nima Creek from six selected sites (NC1-NC6) for heavy metal analysis and physico-chemical analysis.

The study showed that pH ranged from 7.21 – 7.37 units. These values were within the recommended guideline range of 6.5 – 8.4 units for irrigation. The electrical conductivity range of 1176 – 1409 µS/cm and that of total dissolved solid (420 – 590 mg/l) were also within recommended guideline values. Sodium and chloride levels ranged from 195 – 218 mg/l and 203 – 278 mg/l, respectively. The chloride values were within the recommended range of 140 – 350 mg/l while the sodium values were above the recommended value of <70. Thus, care must be taken when these sources are used for surface and sprinkler irrigation. The Sodium Adsorption Ratio (SAR) of the water ranged from 5.52 – 6.55 units as compared to the recommended value of 3 – 6 units. Hence, there could be slight infiltration problems when the water is used for irrigation. The detailed result obtained from the study is shown in Table 5.

Table 5: Mean concentrations of physico-chemical and heavy metal parameters of water sampled from the Nima Creek

Parameters	NC 1	NC 2	NC 3	NC 4	NC 5	NC 6
pH	7.37	7.21	7.29	7.31	7.3	7.3
Conductivity (µS/cm)	1409	1337	1303	1329	1249	1176
Turbidity (NTU)	87.3	96	102	219	183	71.9
Total Suspended solids (mg/l)	180	175	620	245	220	95
Total Dissolved Solids (mg/l)	590	525	420	455	560	535
Biochemical Oxygen Demand (mg/l)	66.6	59.6	36.6	44.7	32.4	18.6
Chemical Oxygen Demand (mg/l)	395	160	189	249	323	115
Oil / Grease (mg/l)	16	20	17	10	16	11
Ammonia (mg/l)	4.79	2.32	3.8	2.7	7.09	3.3
Nitrate (mg/l)	0.76	0.97	0.59	0.219	0.82	0.645
Phosphate (mg/l)	0.85	0.7	0.55	0.43	0.6	0.52
Iron (mg/l)	0.17	0.214	0.1515	0.168	0.429	0.082
Lead (mg/l)	0.009	0.002	N/A	0.026	0.012	0.023
Zinc (mg/l)	0.022	0.01	0.0645	0.011	0.019	0.047
Cadmium (mg/l)	0.002	0.002	0.00465	0.005	0.003	0.012
Calcium (mg/l)	37.1	48	49.1	49.2	46.4	44
Magnesium (mg/l)	16.8	22.3	20.4	26	24.9	26.8
Sodium (mg/l)	197.5	195	213	218	203	215
Bicarbonate (mg/l)	268	244	366	329	305	317
Alkalinity (mg/l)	220	200	300	270	250	260
Fluoride (mg/l)	0.465	0.072	0.5	0.079	N/A	0.167
Sulphate (mg/l)	550	420	460	650	780	650
Potassium (mg/l)	33	23.5	24.5	27	25	24.5
Chloride (mg/l)	278	242	209	212	208	203
Copper (mg/l)	0.024	0.014	0.021	0.013	0.030	0.017
Chromium (mg/l)	0.012	0.003	0.015	0.0225	0.008	0.01
Cobalt (mg/l)	0.01	0.011	0.0145	0.012	0.015	0.017
Aluminium (mg/l)	1.5	1.99	2.68	2.8	3	4.42
Manganese (mg/l)	0.01	0.049	0.076	0.047	0.031	0.027
Sodium Adsorption Ration (SAR)	5.52	5.6	6.43	6.08	5.76	6.55
Adjusted SAR	6.22	6.27	7.34	6.84	6.45	7.28

NOTE: The assessment was based on the recommended guidelines by Tchobanoglous et al. (1991)

3.2.2 Three-Districts Water Supply Project

(Project Staff: Mr. Humphrey F. Darko – Research Scientist, Dr. O. D. Ansa-Asare – Principal Research Scientist, Dr. J. A. Ampofo – Principal Research Scientist and Mr. Mohammed Bello)

The aim of this study was to ensure that the quality of treated water supplied to communities within Dangme East, Dangme West and North Tongu districts meets the required standards. Its specific objective was to assess the quality and suitability of the treated water for potable use.

In the year under review, water samples were collected from the Raw Water Tank, Slow Sand Filtration Tank and the Clear Water (Chlorinated) Tank at Aveyime where the Treatment Plant is located. Additional water samples were collected from a booster station reservoir at Dawa and along the distribution lines from standpipes in different communities within the three districts. A total of 36 water samples were collected, 24 from standpipes, 3 from the booster reservoir and the rest from the Raw Water Tank, Slow Sand Filtration Tank and the Clear Water Tank. These water samples were analyzed physico-chemically and bacteriologically.

The results of the study showed that all physico-chemical properties of the water samples collected were satisfactory compared to the WHO guideline limits for drinking water. For example, pH of the water samples collected ranged from 7.05 – 8.05 units which was within the WHO (2006) drinking water guideline range of 6.5 – 8.5 units. However, the bacteriological qualities of some water samples rendered them unsafe for potable use. For instance, in April 2012, all water samples from the standpipes conformed to the WHO guidelines and Ghana Standards GS 175-1 (2009) of zero total coliform, faecal coliform and *E. coli* counts per 100 ml of sample tested, except Sege, Nakomkope and Tsopoli standpipes. In June 2012, Dawa Booster Reservoir water samples had total coliform while Tsopoli had *E. coli.* In September 2012, all the water samples conformed to the WHO guidelines and Ghana Standards GS 175-1 (2009) of zero total coliform, faecal coliform and *E. coli* counts per 100 ml of sample tested except Koluedor standpipe which had counts of bacteria. Dawa Booster Reservoir also had high number of total heterotrophic bacteria, hence was not suitable as a source for drinking. Thus, out of the 27 water samples collected from standpipes and the booster reservoir in the reporting year, 26 % were found not suitable for potable use. The detailed results of the bacteriological analysis are shown in Tables 6, 7 and 8.

Table 6:Bacteriological quality of water sampled in April 2012

Sample Identification	**Total coliform (cfu/100)**	**Faecal coliform (cfu/100)**	***E. coli* (cfu/100)**	**Total heterotrophic bacteria (cfu/100)**
Raw Water (Intake) Tank	0	0	0	18
Slow Sand Filtration Tank	0	0	0	17
Clear Water Tank (Chlorinated Tank)	0	0	0	<1
Agbetikpo Standpipe	0	0	0	<1
Blavi (Standpipe)	0	0	0	9
Battor(Standpipe)	0	0	0	85
Koluedor (Standpipe)	0	0	0	60
Nakomkorpe (Standpipe)	8	1	0	972
Sege (Township Standpipe)	0	0	0	648
Dawa (Booster Station Reservoir)	0	0	0	<1
Dawa (Standpipe)	0	0	0	<1
Tsopoli (Standpipe)	1	0	0	4860
Ghana Standards	**0**	**0**	0	**500**
WHO Guidelines	**0**	**0**	0	**-**

Table 7: Bacteriological quality of water sampled in June 2012

Sample Identification	Total coliform (cfu/100)	Faecal coliform (cfu/100)	*E. coli* (cfu/100)	Total heterotrophic bacteria (cfu/100)
Raw Water (Intake) Tank	465	5	1	82
Slow Sand Filtration Tank	0	0	0	11
Clear Water Tank (Chlorinated Tank)	0	0	0	<1
Battor Standpipe	0	0	0	<1
Bla (Standpipe)	0	0	0	<1
Dedukope (Standpipe)	0	0	0	3
Koluedor (Standpipe)	0	0	0	12
Nakomkorpe (Standpipe)	0	0	0	<1
Sege (Township Standpipe)	0	0	0	<1
Dawa (Booster Station Reservoir)	62	0	0	0
Dawa (Standpipe)	0	0	0	0
Tsopoli (Standpipe)	0	0	0	0
Ghana Standards	**0**	**0**	**0**	**500**
WHO Guidelines	**0**	**0**	**0**	**-**

Table 8: Bacteriological quality of water sampled in September 2012

Sample Identification	Total coliform (cfu/100)	Faecal coliform (cfu/100)	*E. coli* (cfu/100)	Total heterotrophic bacteria (cfu/100)
Raw Water (Intake) Tank	9	0	0	28
Slow Sand Filtration Tank	89	32	11	5
Clear Water Tank (Chlorinated Tank)	0	0	0	<1
Battor Standpipe	0	0	0	1
Bla (Standpipe)	0	0	0	<1
Dedukope (Standpipe)	0	0	0	<1
Koluedor (Standpipe)	8	0	0	11
Nakomkorpe (Standpipe)	0	0	0	<1
Sege (Township Standpipe)	0	0	0	415
Dawa (Booster Station Reservoir)	0	0	0	1612
Dawa (Standpipe)	0	0	0	2
Tsopoli (Standpipe)	0	0	0	1
Ghana Standards	**0**	**0**	**0**	**500**
WHO Guidelines	**0**	**0**	**0**	**-**

3.2.3 Potable Water Quality Studies for PFC

(Project Staff: Mr. Humphrey F. Darko – Research Scientist, Dr. O. D. Ansa-Asare – Principal Research Scientist and Mr. Michael Afram Dankwah)

The objective of the study was to assess the quality of water used for factory operations at the Pioneer Food Cannery (PFC) Limited, Tema. During the reporting year, a total of 24 water samples were collected at various sections within and outside the Pioneer Food Cannery (PFC) Limited, Tema, and analyzed physico-chemically. The study showed that all physico-

chemical parameters of water samples collected were within acceptable limits of the WHO, hence suitable for use in the factory operations.

3.2.4 Final Effluent Quality Studies for PFC and Phyto-Riker

(Project Staff: Mr. Humphrey F. Darko – Research Scientist, Dr. O. D. Ansa-Asare – Principal Reserarch Scientist and Mr. Daniel Amoah)

The objective of the study was to assess the quality of the final effluent of the Pioneer Food Cannery (PFC) Limited and Phyto-Riker (GIHOC) Pharmaceutical Company in relation to EPA's environmental standards for discharging into the environment.

The scope of work included collection of water samples, laboratory analysis, data interpretation, preparation and submission of reports. During the reporting year, samples from PFC were collected in the months of January, March, May and July 2012 for analysis. During each sampling period, 2 influent samples and 2 effluent samples, including the final effluent were collected, making a total of 4 samples for analysis. At Phyto-Riker, final effluent samples were collected quarterly in the months of March, June, September and December 2012. Only one (1) sample of the final effluent was collected at a time. Parameters such as Alkalinity, pH, Conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Nitrate-Nitrogen, Phosphate-Phosphorus (Total Phosphorus for Phyto-Riker), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Oil/Grease, total and faecal coliforms were considered during the analysis.

At PFC, the study showed that all parameters were above their respective EPA guideline values in all the months except Nitrate-Nitrogen levels in the final effluents. The pH of the final effluent was, however, within the EPA guideline in March 2012. Meanwhile, at Phyto-Riker (GIHOC) Pharmaceutical Company, concentrations of all parameters measured, except Ammonia-Nitrogen and Total Phosphorous, in the final effluents were satisfactory as they fell within the EPA guideline values. Ammonia-Nitrogen concentrations in the final effluents were above the EPA guideline values in all the months except in September 2012 while Total Phosphorous levels were above the EPA guideline value only in March 2012.

3.2.5 PURC Water Analysis

(Project Staff: Mr. Humphrey F. Darko – Research Scientist, Dr. O. D. Ansa-Asare – Principal Research Scientist, Mr. Mark O. Akrong – Research Scientist and Mr. Jude Quansah)

This study was undertaken to investigate the quality of drinking water supplied by GWCL to consumers in selected communities to determine whether it meets the required standards for potable use.

During the reporting year, water samples were collected from selected sampling points in different localities designated by the PURC, from standpipes and booster stations in the Sekondi-Takoradi Metropolis in May and August 2012. A total of forty-four (44) and forty-two (42) samples were collected in May and August, respectively in 2012. The samples were then analyzed physico-chemically and bacteriologically.

Generally, the results of the physico-chemical examination of water samples from the Sekondi-Takoradi Metropolis indicated that all were suitable for potable use as concentrations of the various parameters were within their respective WHO guideline values. The bacteriological quality of the water samples, however, rendered 72.7 % of sampled water

in May 2012 as potable and safe for drinking, while only 50.0 % of sampled water in August 2012 was safe for drinking.

3.2.6 Assessment of Human Health Risk from Exposure to Toxic Chemicals via Recycling of E-Waste at Agbogbloshie Market – Accra, Ghana

(Project Staff: Mr. Samuel Obiri Research Scientist, Miss. Mohammed Saada – Research Scientist, Dr. Osmund Ansa-Asare – Principal Research Scientist, Mr. Daniel Amoah and Mr. Michael Dolerku)

Industrialization activities in the developed countries have led to the production of more electronic products. The breakdown of these electronic products by users both in developed or developing countries have given rise to electronic waste (e-waste). Driven by profit, the recycling of e-waste using crude processes is being carried out in some locations such as Agblogbloshie, Koforidua and Tema in Ghana. It has become a new source of environmental pollution in the country as the operation has led to the release of large quantities of toxic metals and organic pollutants into the surrounding environment. The air, surface water, ground water, soil and river sediment of e-waste processing sites have been contaminated by heavy metals, such as cadmium, copper and lead, as well as organic contaminants, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and polybrominated diphenyls ethers (PBDEs). It was within this context that the study was initiated in the reporting year to assess the human health risk associated with the consumption of contaminated food stuffs such as vegetables sold in e-waste processing regions. The specific objectives were to:

- determine levels of heavy metals such as antimony (Sb), arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), silver (Ag), tin (Sn) and zinc (Zn) in vegetables and other food items sold at the Agblogbloshie e-waste market;
- determine levels of organic contaminants such as polybrominated biphenyls (PBBs), PBDEs and PCBs in vegetables and other food items sold at the Agblogbloshie e-waste market;
- evaluate cancer and non-cancer health risks from exposure to the aforementioned toxic chemicals; and
- recommend to government and other relevant stakeholders to put in appropriate policies to safeguard the environment and human beings.

It is expected to end in 2013.

In the year under review, vegetables and other agricultural products sold at the Agblogbloshie and Kaajarno markets were sampled randomly and analysed for heavy metals such emitted from open burning of e-wastes and deposited on the vegetables. Vegetables sampled from these two markets included tomatoes, carrots, cabbage and kontomire. A similar research was conducted at the Madina market and used as control for the study.

The preliminary results showed that toxic heavy metals such as manganese, copper, zinc, lead, iron and cobalt from the burning of e-waste at the Agbogbloshie e-waste/scrap market (Figure 9) had been deposited on vegetables such as tomatoes, carrots, cabbages and kontomire and other items being sold at the market (Table 9). It was observed that the toxic chemicals in the fumes were carried away by wind to other places in the metropolis where e-waste were not dismantled or burned.

The study when completed would establish the cancer and non-cancer human health risk associated with the exposure to the toxic chemicals via ingestion of vegetables contaminated with the deposition of toxic fumes from the burning of the e-waste.

Figure 9: Open burning of e – waste during the day, mainly by children, at Agbogbloshie e – waste market

Table 9: Mean concentration of heavy metals in vegetables sold at Agbogbloshie, Kaajarnor and madina markets

Market	Type of vegetables	Parameters											
		Co		Mn		Cu		Zn		Pb		Fe	
		Conc. mg/kg	Std	Conc. mg/kg	Std	Conc. mg/kg	Std	Conc. mg/kg	Std	Conc. mg/kg	Std	Conc. mg/kg	Std
Kaajarnor	Tomatoes	0.667	0.31	0.534	0.20	0.006	0.05	1.062	0.58	0.943	0.45	1.484	2.16
	Cabbage	0.476	0.32	2.673	3.73	0.170	0.87	1.388	2.40	3.671	4.63	2.998	3.24
	Carrot	0.531	0.24	2.820	3.64	1.429	3.39	4.352	4.85	0.807	0.65	1.307	1.47
	Garden Eggs	0.531	0.72	1.188	1.33	1.528	0.52	3.531	4.01	0.807	0.69	2.804	3.85
	Kontomire	0.263	0.26	2.202	0.49	1.656	1.61	0.205	0.14	1.021	1.47	0.643	0.63
Madina	Tomatoes	0.035	0.04	0.046	0.04	0.004	0.00	0.006	0.00	0.011	0.01	0.004	0.07
	Cabbage	0.002	0.01	0.002	0.00	0.004	0.00	0.002	0.00	0.019	0.03	0.429	0.85
	Carrot	0.005	0.01	0.006	0.02	0.006	0.01	0.003	0.01	0.004	0.02	0.006	0.01
	Garden Eggs	0.011	0.02	0.018	0.01	0.067	0.08	0.050	0.09	0.005	0.01	0.004	0.01
	Kontomire	0.039	0.03	0.048	0.03	0.047	0.03	0.001	0.00	0.094	0.11	0.002	0.00
Agbogbloshie	Tomatoes	0.476	0.26	0.023	0.02	0.017	0.00	0.047	0.03	0.608	0.30	0.368	0.32
	Cabbage	0.408	0.03	0.024	0.00	0.004	0.00	0.003	0.00	0.549	0.44	0.036	0.04
	Carrot	0.606	0.28	0.114	0.10	0.621	1.09	0.589	1.12	1.043	1.29	0.272	0.26
	Garden Eggs	0.061	0.03	0.047	0.04	0.017	0.02	0.010	0.01	0.004	0.00	0.004	0.00
	Kontomire	1.186	0.39	0.004	0.00	3.267	6.48	0.001	0.00	0.399	0.78	0.077	0.14

3.3 FISHERY DIVISION

The Fishery Division has a mandate to engage in research to generate scientific information whose application would enhance sustainable management and development of Ghana's fish, fisheries and aquaculture resources. The Division's goal is to increase local fish production to support livelihoods through increasing yield from existing fisheries and development of sustainable aquaculture and culture based fisheries practices.

Currently, the Division's major research and development programmes are aquaculture development, environmental impact assessment and monitoring of fish population in relation to socio-economic development activities, fisheries enhancement and culture-based fisheries.

3.3.1 Enhancement of Fish Production and Water Conservation in Dugouts for Climate Change Adaptation in South-western Part of Yendi Municipal Area

(Project Staff: Etornyo Agbeko – Research Scientist, Dr. Kwadwo Kwarfo-Apegyah – Senior Research Scientist and Daniel Nsoh Akongyuure – Research Scientist)

The impact of climate change such as variability in rainfall pattern causing floods and long dry spells or drought with resultant effects on fish stock is evident in all agro-ecological zones in Ghana. The vulnerability of most dugouts could probably be exacerbated by climate change. The availability of high quality protein foods like fish presents uncertainties triggered in extreme ways by climate change. Adaptation to climate change, especially in relation to fisheries and the aquatic ecosystems, is needed as a response strategy to adjust to actual or expected climate and its effects in order to moderate harm or harness potential opportunities. It was against this background that this study was conducted to:

- promote fish culture and culture-based fisheries practices for livelihood and food security improvement within rural communities in Yendi district; and
- conserve water in dugouts and soil moisture in their surroundings for climate change adaptation.

It was completed in the reporting year.

In the year under review, fisheries baseline survey was conducted in communities with dugouts in the South-Western part of Yendi Municipality. Six communities with suitable dugouts were identified. Mawulea and Zialuwa dugouts were selected and re-stocked with 6,500 fingerlings of *Oreochromis niloticus* (Akosombo strain). Two fish farmer groups of 60 members including 20 women were trained in fish culture techniques and fish management. Fish catch assessment of selected dugouts was also carried out. Advocacy on good fisheries management practices such as sustainable harvesting of dugouts was demonstrated with some hands-on training in fishing

Low fingerling mortality was recorded after re-stocking. The survival rate of the stocked fish was 99.6 %. Fish availability increased after stock enhancement with *Oreochromis niloticus.* Fish catch assessment indicated a rich biodiversity of fish species in both dugouts (Figure 10). After stock enhancement, fish revenue increased from GH¢150.00 in 2011 under the outright sale of dugout to migrant fishermen to GH¢308.00 in 2012 under sustainable (selective) harvesting strategy adopted. The strategy ensured juvenile fish growth, prevented recruitment, over-fishing and depletion of fish stock.

It was concluded from the study that fish stock enhancement with *Oreochromis niloticus* and management interventions could revamp dwindling fish stock in dugouts. *Sarotherodon galilaeus* encountered in the two dugouts had comparatively good growth performance with an average weight of 190 g as against 161 g for *O. niloticus*. Thus, *S. galilaeus* could be considered as one of the new candidate species for further aquaculture research in view of climate change. The study also revealed that selected dugouts were becoming more resilient to minimize climate change impacts while adaptation is increasing to harness fisheries potentials of the dugouts. The need for fish hatchery to meet the increasing demand for fingerlings in Northern Ghana was recommended at the end of the study.

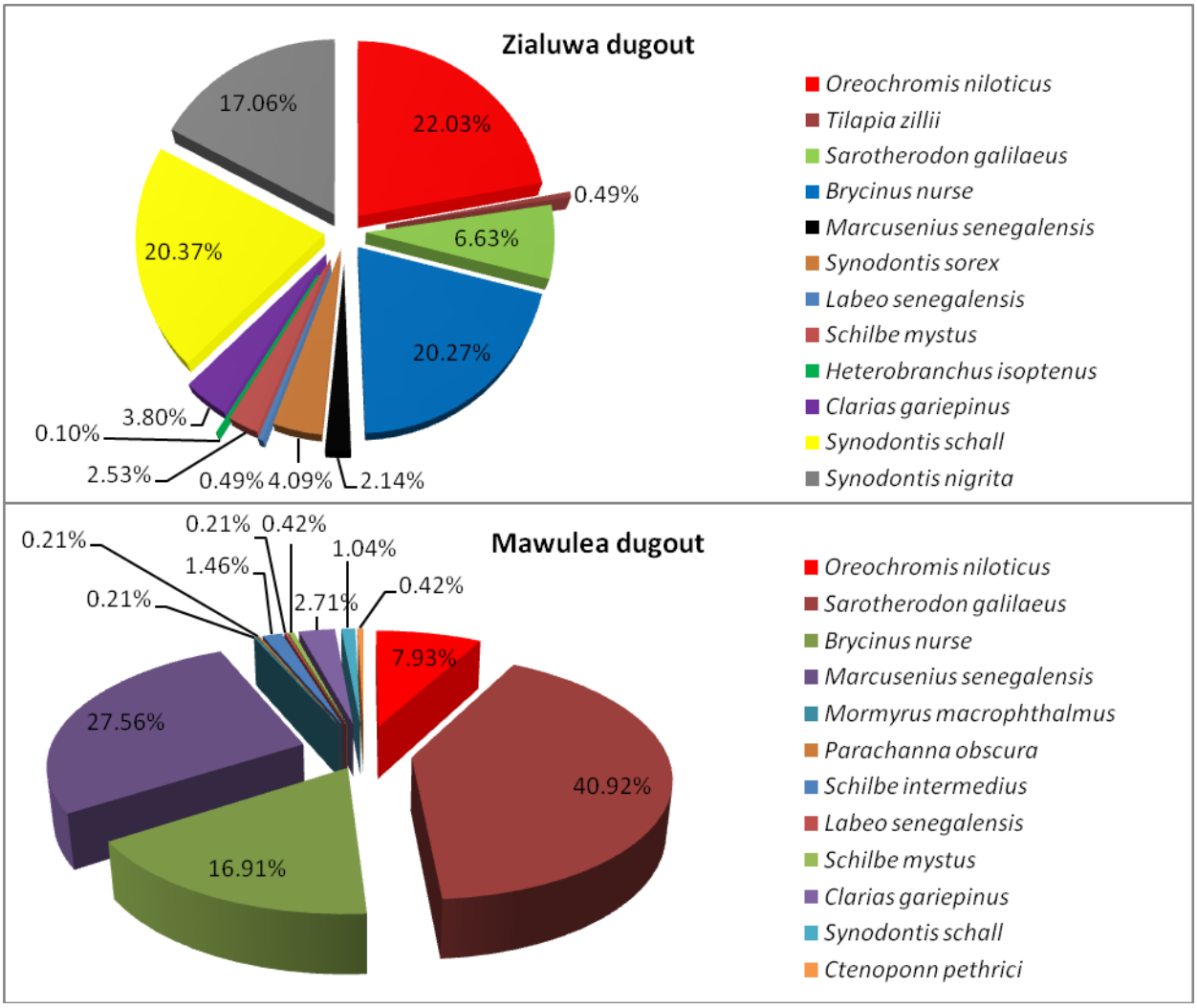


Figure 10: Percentage composition of fish species after stock enhancement in selected dugouts

3.3.2 Report on the condition of *Oreochromis niloticus* in the Water Storage Facility (WSF) at Newmont Ghana Gold Limited

(Project Staff: Dr. H. R. Dankwa – Principal Research Scientist, Mr. Solomon Amoah Owiredu – Research Scientist, Edem Amedorme and Bright Awunor)

This study was initiated in the reporting year to assess the length-weight relationship, condition factor and sex ratio of *O. niloticus* in the WSF at Newmont Ghana Gold Limited. It is expected to end in 2013.

During the reporting year, samples of *O. niloticus* were obtained from the northern, middle and southern sections of the Water Storage Facility (WSF) using purse seine gear and analysed. The length of fish was measured using the measuring board and the weight was measured using the electronic balance. The sex ratio of population of *O. niloticus* in the WSF was also established.

A total of 718 individuals of *O. niloticus* were sampled. Values of 46.69±22.46 g and 13.36±2.18 cm for average weight and length, respectively were recorded at the southern section. The length-weight relationship showed that the fishes were undergoing negative allometric growth with *b*-value less than 3 (Table 10). The sex ratio skewed towards the female *O. niloticus* and variance analysis (ANOVA) for the 'K' values revealed a P-value less than 0.05 which indicated significant differences in the 'K' values, hence differences in growth conditions of *O. niloticus*. To keep the population of *O. niloticus* in check, it was recommended that carnivorous species such as *Clarias gariepinus* should be introduced in the WSF.

Table 10: Descriptive statistics and W-L relationship parameters for *O. niloticus*

Species/ Sampling site	**Northern section**	**Middle section**	**Southern section**
Number (N)	250	300	168
W,mean ± S.D (W_{min} - W_{max})	30.08 ± 25.75 (5.30 - 111.30)	40.52 ± 28.47 (5.00 - 127.30)	46.69 ± 22.46 (12.40 - 110.80)
L,mean ± S.D (L_{min} - L_{max})	10.83 ± 3.00 (6.50 - 19.00)	12.4 ± 3.14 (6.50 - 20.00)	13.36 ± 2.18 (9.00 - 18.80)
W-L equation	$W = 46.11L^{2.95}$	$W = 53.70L^{2.99}$	$W = 44.61L^{2.92}$
Correlation coefficient	0.9916	0.9842	0.9643
Growth type	Allometric (-)	Allometric (-)	Allometric (-)
Condition factor (K)	1.93	1.80	1.82
Sex Ratio	1: 1.4	1: 1.3	1: 2.4

Note: N: sample size; W: weight (g); min: minimum; max: maximum; L: length (cm); S.D: standard deviation; *b*: slope

3.3.3 Non-destructive Genetic Sampling in Fish: An Improved Method for DNA Extraction from Fish Fins

(Research Staff: Rhoda Lims Osae-Sakyi – Research Scientist and Dr. Mike Osei-Atweneboana – Senior Research Scientist)

Morphological characteristics have over the years been an important tool in defining biological populations. However, genetic differences, particularly at the subspecies level, are not identifiable with morphological analyses. Also in recent years, a great number of vertebrate species have been designated at risk, either threatened or endangered and DNA-based studies have been one of the major interests in gathering information on the diversity, conservation biology and population analyses. It was against this background that the study was initiated in the reporting year to non-destructively sample fish fins for molecular analysis. The specific objectives were to:

- ascertain the best extraction protocol that yields high quantity and quality DNA;
- determine the integrity of DNA extracted from fish fins by Polymerase Chain Reaction (PCR) and gel electrophoresis analysis; and
- identify the best preservative method of fish fins.

It is expected to end in 2015.

During the reporting year, fin clips of Tilapia, *Sarotherodon galilaeus* were obtained from Akatsi and Dzemeni. Approximately 100 – 300 mg of fins (1 to 2 cm^2) were initially stored in 70 % ethanol. Some of the ethanol-fixed tissues were then dried on a filter paper. Fins were cut into small pieces and placed in Lysis buffer (150ml 1M Tris-HCl pH 8.0; 10ml 5M NaCl; 50ml 0.5M EDTA pH 8.0; 100ml 0.5 %SDS; 290ml ddH_2O) inside a 15 ml tube. Thirty (30) µl Proteinase K (10 mg/ml) was added and the tissues incubated at 65°C overnight. The DNA was then isolated by applying three different methods: phenol chloroform extraction by adding 250 ml of phenol:chloroform:isoamyl alcohol (25:24:1) to the samples, Chelex extraction by adding 200 µl of a 5 % Chelex-100 solution and by Kit extraction using GF-1 Tissue Extraction Kit.

After completion of the extraction processes, the DNA was amplified using Polymerase Chain Reaction (PCR). DNA samples were used as templates in PCR with specific primers, (ONMICSAT F1, ONMICSAT R1, UNH 154 and UNH 222). PCR was performed in 50 µl total reaction volume containing 2 µl of DNA, 1× PCR buffer, 1.5 mM $MgCl_2$, 0.2 mM of each dNTP, 0.5 µM of each primer and 0.5 µl of Taq DNA polymerase. PCR was carried out in a peQlab thermal cycler under the following conditions: heating of head lid to 110 °C followed by 30 cycles of 45s at 95°C, 1 min at 50°C ± 5 gradient annealing temperature, with extension of 1 min at 72°C. All amplified DNA products were visualized by 0.8 % agarose gel electrophoresis and compared with a standard marker.

It was observed from the study that fin samples that were preserved in ethanol and air dried prior to extraction gave relatively sharper bands (Figure 11 Well 6) as compared to those that were not air dried. Kit extraction appeared to be the best extraction protocol as all the samples extracted by this method gave relatively sharp bands (Figure 11 Wells 6-10) as compared to phenol-chloroform and chelex extraction. Gel electrophoresis indicated successful amplification of DNA in the PCR.

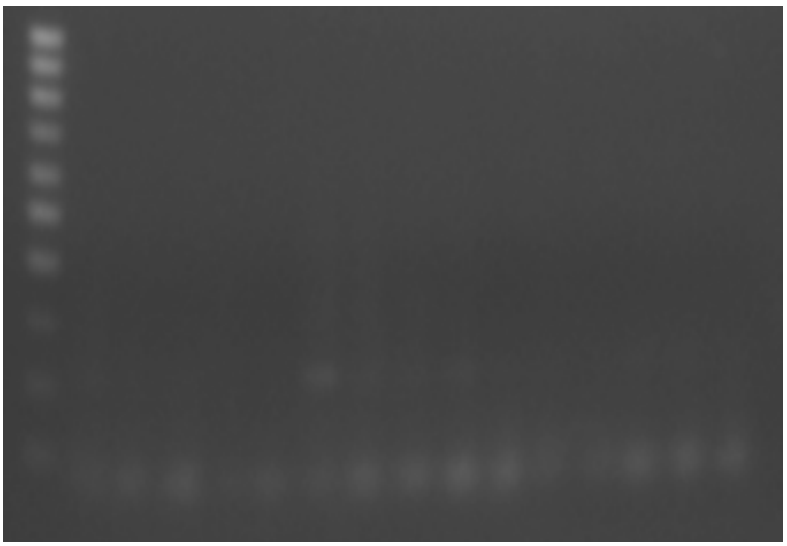


Figure 11: Agarose gel (0.8 %) of DNA samples obtained from fish fins
Lane 1: Molecular Weight Marker (100bp). Lanes 2–5: total DNA isolated from fish fin clips using phenol chloroform. Lane 7-10: total DNA isolatedfrom fins using kit extraction protocol. Lanes 12–14: samples extracted by chelex solution. Lanes 6, 11, 16: the control sample for the respective protocols.

It was concluded from the study that fin clips was a better alternate source of fish sampling as it provided adequate DNA required for any molecular analysis without causing any harm to the species.

The study when completed will help generate DNA markers that will be used to examine patterns of genetic variation and distance among different fish populations of high commercial value particularly the Nile Tilapia, *Oreochromis niloticus* in fish farms and along the ecological zones of the Volta Lake. The analyses will allow an estimate of genetic diversity within a population; and a comparison of genetic types (haplotypes) between populations. This will further give the potential to identify more productive strains of *O. niloticus* that can increase tilapia production and help determine which strain of *O. niloticus* tilapia should be used as part of a national aquaculture extension effort as far as traits like reproductive efficiency, temperature tolerance, growth rate, survival rate, fecundity rate and disease resistance are concerned.

3.3.4 Effect of Stocking Densities on Growth, Survival and Economics of *Oreochromis niloticus* Fry Treatment in Hapa-in-pond System

(Project Staff: Emmanuel Tetteh-Doku Mensah – Research Scientist, Dr. Felix K. Attipoe – Research Scientist and Mercy Johnson-Ashun – Technical Staff)

Stocking density and survival are important indicators that determine the economic viability of a production system. Knowing the best densities for a species is a critical factor for good husbandry practices and creation of efficient culture systems. Hormonal treatment of tilapia fry is the most simple and reliable way to produce all male tilapia stocks, which consistently grow to a larger, more uniform size than mixed sex or all-female tilapia. It was against this background that this project was initiated and completed in the reporting year to study the effect of growth and survival of *O. niloticus* fry treatment by varying the stocking densities in hapa-in-pond system and estimating its profitability.

During the year under review, improved Akosombo strain of 'generation 7' broodstock were manually selected, sex determined and transferred into 10 m^3 hapas in a 0.2 hectre pond. A total of 30 females and 10 males were counted, batch weighed and stocked in each hapa. Broodstock were fed twice daily with diet containing 36 % crude protein at a feeding rate of 1.5 % of biomass in each hapa. Fry of *O. niloticus* in hapas were harvested after ten days in the mornings (6:30 am) into a 10 m^2 hapa in a freshly prepared 0.2 hectre pond. Treatment replicates (of varying stocking densities of fry: 20,000, 15,000 and 10,000) were distributed to the mounted hapas and stocked with harvested fry of *O. niloticus*. Each treatment stocked was in triplicate. The initial weight and number of fry were taken prior to the stocking. Stocked fry were acclimatized for a day before commencing hormonal treatment using 17α-methyltestosterone. Feeding was done five times daily at two hour interval starting from 8:00 am to 4:00 pm. Fry was fed at an initial biomass of 20 % for the first two weeks, then 15 % from week 3 to 4. Fry in each hapa were sampled weekly. Their weights were determined using a weight balance, measured to the nearest ± 0.1 g. Water quality parameters such as temperature, pH and dissolved oxygen levels were monitored daily throughout the trial period.

All physico-chemical parameters were within acceptable optimal range for fry culture. The highest average weight of 0.226 g was attained in Treatment 'A' with the least in Treatment 'C' (Figure 12). As shown in Table 11, the highest survival was achieved in Treatment 'B' while the least survival was in Treatment 'C', though there were no significant differences (at

p > 0.05). Feed applied was high in Treatment 'C', with a high Food Conversion Ratio (FCR) of 3.69. The lowest biomass of 848.40 g was recorded in Treatment 'C' while the highest was in Treatment 'A'. The highest profit index of 23.24 was recorded in Treatment 'B' (Table 12).

It was concluded from the study that varying the stocking densities of the *O. niloticus* fries significantly affected growth, feed conversion and yield but did not significantly affect survival and profit index. However, good growth performance and economic benefit would be high in tilapia fry treatment if stocking rate does not exceed 1500 fries per square metre.

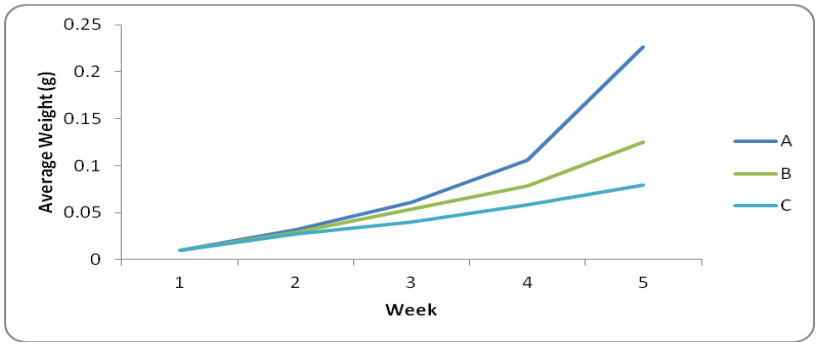


Figure 12: Average weight of different stocking densities of *O. niloticus* fry cultured for 5 weeks

Table 11: Some production parameters generated from trial

Treatment	Recovery	Survival (%)	Feed Applied (kg)	Biomass (g)	FCR
A	6229	62.29	2.34	1407.75	1.66
B	10188	67.92	2.90	1270.15	2.28
C	10649	53.25	3.13	848.40	3.69

Table 12: Economic variables among the various treatment groups

Treatment	Cost of Hormone Feed (GH¢)	Value of Fry (GH¢)	Profit Index
A	21.22	373.74	17.61
B	26.30	611.30	23.24
C	28.39	638.96	22.51

3.3.5 Comparative Growth Study of *Oreochromis niloticus* and *Sarotherodon galilaeus* Under Two Different Culture Regimes (Hapa-in-pond and Cage Systems)

(Project Staff: Emmanuel T. D. Mensah – Research Scientist, Dr. Felix Attipoe – Research Scientist and Ken Atsakpo – Technologist)

This study was undertaken to compare some production performance traits in the culture of *O. niloticus* and *S. galilaeus* under cages and hapa-in-pond systems. It was completed in the reporting year.

During the reporting year, a 24 week trial was conducted to study the growth of *Oreochromis niloticus* and *Sarotherodon galilaeus* under cages and hapa-in-pond culture regimes. Mixed

sex fingerlings of average weight 26.90 ± 0.21 g were stocked in cages and hapas at a rate of 32 fish/m³ and 5 fish/m³ respectively. Fingerlings were fed with 36 % crude protein commercial fish diet.

O. niloticus showed superior growth over *S. galilaeus* in cage culture with an appreciable FCR value (Table 13). There were significant differences in final mean weight, mean daily weight gain, specific growth rate and mean relative weight gain between the cage and hapa-in-pond culture regimes except for the culture between *S. galilaeus* in cage and *O. niloticus* in hapa. Net yield was high in *O. niloticus* but survival was relatively high among *S. galilaeus* (Table 14). Although high value of fish crop was realized in *O. niloticus* under the two culture regimes, profit indices did not vary significantly (Table 15).

It was concluded from the study that the improved strain of *O. niloticus* grew about two times faster than *S. galilaeus* especially when cultured in cages, hence more economical to farmers. The male to female ratio of *O. niloticus* in terms of size showed a distinct difference in growth, hence the need for sex reversal. It was however recommended that though the hapa-in-pond system is also suitable for the culture of the two species, it should be practiced on a semi-intensive system to decrease the cost of production. Research geared towards gene improvement of *S. galilaeus* strain for improved growth performance to ensure profitability should also be considered.

Table 13: Growth parameters of *O. niloticus* and *S. galilaeus* cultured under the two regimes

Growth Parameter	*O. niloticus*		*S. galilaeus*	
	Cage	**Hapa**	**Cage**	**Hapa**
Initial mean weight (g)	27.02 ± 0.42^{a}	27.12 ± 0.34^{a}	26.72 ± 0.63^{a}	26.72 ± 1.04^{a}
Final mean weight (g)	299.67 ± 16.40^{b}	128.39 ± 9.04^{c}	137.51 ± 6.22^{b}	71.09 ± 18.47^{c}
Final av. Condition factor, K	3.83 ± 0.09^{a}	3.80 ± 0.05^{a}	3.73 ± 0.09^{a}	3.77 ± 0.06^{a}
Mean daily weight gain (g)	1.38 ± 0.08^{b}	0.52 ± 0.05^{ab}	0.56 ± 0.03^{ab}	0.23 ± 0.09^{b}
Specific growth rate (g)	1.22 ± 0.03^{b}	0.80 ± 0.04^{ab}	0.83 ± 0.04^{ab}	0.49 ± 0.13^{b}
Mean relative weight gain (%)	90.88 ± 0.50^{b}	80.33 ± 1.20^{b}	79.12 ± 1.44^{b}	61.10 ± 5.11^{b}
Feed conversion ration	1.58 ± 0.16^{b}	3.57 ± 0.49^{b}	1.83 ± 0.08^{b}	4.19 ± 0.23^{b}

*mean ± standard deviation, [a] = no significant difference, [b, c] = significant difference

Table 14: Yield estimate of *O. niloticus* and *S. galilaeus* cultured under the two regimes

Yield estimate	*O. niloticus*		*S. galilaeus*	
	Cage	**Hapa**	**Cage**	**Hapa**
Stocking density	450	50	450	50
Stocking rate (fish/m³)	32	5	32	5
Recovery	295 ± 13.44^{a}	33 ± 3.54^{c}	361 ± 15.76^{a}	36 ± 4.95^{c}
Gross yield (kg)	88.04 ± 9.32^{b}	4.34 ± 0.48^{a}	46.58 ± 11.70^{b}	2.49 ± 0.88^{a}
Net yield (kg)	75.75 ± 9.32^{b}	2.99 ± 0.50^{a}	34.41 ± 11.87^{b}	1.15 ± 0.88^{a}
Survival (%)	65.45 ± 2.99^{a}	65 ± 7.07^{a}	80.11 ± 14.61^{a}	71 ± 9.90^{a}

*mean ± standard deviation, [a] = no significant difference, [b] = significant difference, [c] = no significant difference.

Table 15: Economic parameters of the 2 species under the 2 culture regimes

Economic parameter	*O. niloticus*		*S. galilaeus*	
	Cage	**Hapa**	**Cage**	**Hapa**
Price of fingerling (GH¢)	0.5	0.5	0.3	0.3
Cost of fingerlings (GH¢)	225	25	135	15
Prize of feed/kg (GH¢)	2.04	2.04	2.04	2.04
Total feed fed (kg)	139.62	16	85.25	10.77
Total cost of feed (GH¢)	284.82	32.64	173.91	21.97
Value of fish crop (GH¢)	651.98	76.18	396.50	50.08
Profit (GH¢)	142.16	18.54	87.59	13.11
Profit index	2.29	2.33	2.28	2.28

3.3.6 Investigations into the Periodic Fish Kills in the Environmental Control Dams of the Newmont Ghana Gold Ltd at Ahafoano

(Project Staff: Dr. H. R. Dankwa – Principal Research Scientist, Mr. Edem Amerdome – Technologist, and Mr. Bright Awunor – Fisherman)

Periodic fish kills in the Water Storage Facility (WSF) and Environmental Control Dams (ECD) of Newmont Ghana Gold Ltd. at Ahafoano has been of serious concern for Management since such fish kills are readily linked, by the surrounding communities, to the possible effects of chemicals, especially cyanide from mining operations. Hence, this study was started in the reporting year to determine the possible causes of periodic fish kills in the WSF and ECDs at Newmont –Ahafoano. It is expected to end in 2013.

In the year under review, fish samples were taken quarterly from the WSF and ECDs with gill nets, drag nets and purse seine to identify fishes and their composition, condition as well as environmental conditions with respect to water quality.

Nine species including *Oreochromis niloticus, Sarotherodon galilaeus, Tilapia zillii, Clarias gariepinus, Heterobranchus bidorsalis, Parachana obscura, Astatotilapia guntheri, Hepsetus odoe* and *Barbus ablabes* were identified in the study. ECD 3 had the least number of species whiles ECD 4 had the highest number of species (Table 16).

Table 16: Fish species caught from the WSF and the ECDs of Newmont Ghana Gold Ltd. at Ahafo

Species	WSF	ECD 2	ECD 3	ECD 4
Oreochromis niloticus	+	+	+	-
Sarotherodon glilaeus	-	-	-	+
Tilapia zillii	-	-	-	+
Clarias gariepinus	+	+	+	+
Heterobranchus bidorsalis	+	+	-	-
Parachana obscura	+	+	-	-
Astatotilapia guntheri	-	-	-	+
Hepsetus odoe	-	-	-	+
Barbus ablabes	+	-	-	-

Note: + Present, - Absent

The condition factor for the species in the various sites was quite comparable (Table 17). Temperature at all the sites ranged between 25.3 – 26.5 °C whereas dissolved oxygen levels ranged from 2.76 mg/l in the WSF to 6.2 mg/l in ECD 4. On the average, much bigger

individuals of *O. niloticus* were caught in the WSF compared to the ECDs in spite of the low oxygen level recorded in the former. The size distribution of *S. galilaeus* which was the dominant species in ECD 4 had a modal class of 70 – 80 mm. All the fish kills recorded in the WSF and ECD 2 involved only *O. niloticus* even though there were other species such as *H. bidorsalis, C. gariepinus* and *P. obscura* which could withstand very low dissolved oxygen levels and other harsh environmental conditions because they possess accessory breathing organs which enable them to take oxygen from the atmosphere.

The preliminary result is however not conclusive yet on whether low dissolve oxygen levels were the cause of the fish kills.

Table 17: Condition Factor of species from the WSF and the ECDs

Species	WSF	ECD 2	ECD 3	ECD 4
Oreochromis niloticus	3.44	3.53	3.51	-
Sarotherodon glilaeus	-	-	-	4.30
Tilapia zillii	-	-	-	3.86
Clarias gariepinus	1.22	1.07	1.33	1.03
Heterobranchus bidorsalis	1.43	1.42	-	-
Parachana obscura	1.82	1.54	-	-
Astatotilapia guntheri	-	-	-	+
Hepsetus odoe	-	-	-	1.38
Barbus ablabes	2.65	-	-	-

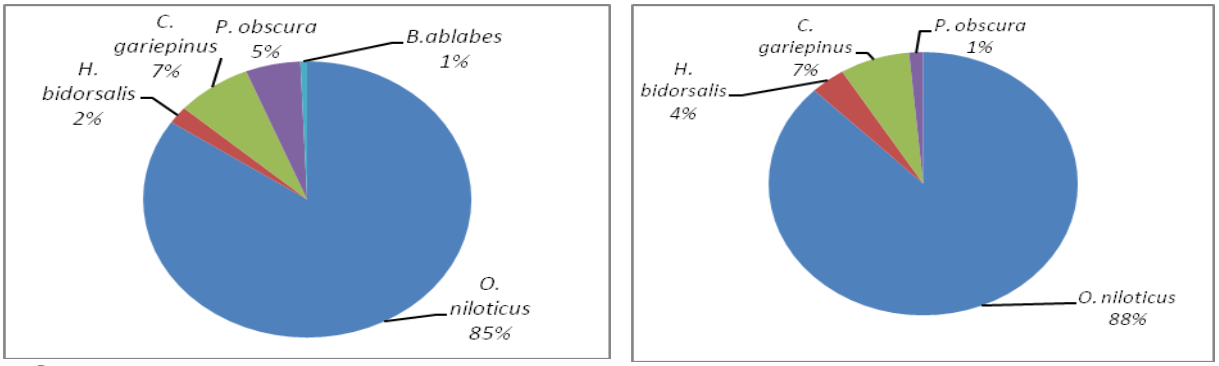
3.3.7 Water Storage Facility (WSF) – Ecological Study and its Ecological Impacts on the Awonsu Stream and the Tano River

(Project Staff: Dr. H. R. Dankwa – Principal Research Scientist and Mr. Edem Amerdome – Technologist)

This study began in the reporting year to assess the ecological status of the Water Storage Facility and to determine how releases from the facility may impact on the ecology of the Awonsu stream and the Tano River. It is expected to end in 2013.

Activities carried out during the reporting period included quarterly fish sampling in the WSF and ECD2 with gill nets, drag nets and purse seine to identify fishes and their composition, their condition as well as environmental conditions with respect to water quality.

Fish species sampled were *Oreochromis niloticus, Clarias gariepinus, Heterobranchus bidorsalis, Parachana obscura* and *Barbus ablabes.* With the exception of *Barbus ablabes* which was caught only in the WSF, all the other species occurred in both the WSF and the ECD2. Thus, in case of any spillage from the WSF, these species are likely to be introduced into the Awonsu stream and the Tano River. Since *Oreochromis niloticus* constituted about 84 % of the catch (Figure 13), their impact on the fish fauna in the Awonsu and the Tano, in terms of changes in fish composition and ecological balance, could be higher than the other species.



WSF ECD2

Figure 13: Fish species composition in the WSF and ECD 2

The size frequency distribution of *O. niloticus* in the WSF was between 60 mm and 190 mm with a modal class of 120 – 130 mm and an average weight of 37 g while the size frequency in ECD 2 ranged from 70 – 210 mm with a modal class of 70 – 80 mm and an average weight of 20 g. Thus, on the average, *O. niloticus* in the WSF were much bigger than those in the ECD 2. The temperature and dissolve oxygen levels were 26.5 and 2.76 mg l^{-1} in the WSF and 26.4 and 3.65 mg l^{-1} in the ECD 2, respectively. The condition factor (Table 18) was specific for each fish species and could vary slightly within a year due to various factors such as stress as a result of poor water quality, reproductive activities and food availability. The Shannon diversity index (H') was calculated to be 0.26 and 0.21 for the WSF and ECD 2, respectively, reflecting the poor fish diversity of both water bodies. The evenness index (Es) was 0.34 for the WSF and 0.30 for ECD 2, thus both the WSF and ECD 2 were ecologically unstable.

Table 18: Condition Factor (K) of fish species in the WSF and ECD 2

Species	WSF	ECD 2
Oreochromis niloticus	3.44	3.53
Clarias gariepinus	1.22	1.07
Heterobranchus bidorsalis	1.43	1.42
Parachana obscura	1.82	1.54
Barbus ablabes	2.65	-

3.4 GROUNDWATER DIVISION

The long-term objective of the Groundwater Division is to generate, process and disseminate information on the availability of groundwater, quantity of water to be abstracted for various uses as well as the reliability and sustainability of its recharge.

3.4.1 Borehole Drilling and Pumping Test for Berekum and Surrounding Communities

(Project Staff: Dr. William A. Agyekum – Research Scientist and Mr. Collins Okrah – Research Scientist)

This collaborative study with GWCL and CWSA-Brong Ahafo Region ended in the reporting year. The objective was to drill additional boreholes to increase water production-base in order to meet the increasing population water demand at Berekum.

During the year under review, reconnaissance visit to the project communities to obtain first hand hydrogeological overview of the project area was accomplished. This was followed by geophysical investigation to select suitable and optimum drilling points within the 100-acre GWCL catchment area in Berekum. Drilling and development of successful boreholes were also carried out.

The combined modelled resistivity results and bedrock topography (Figure 14) were used to obtain optimum points where drilling was carried out. Four (4) successful boreholes were drilled to depths ranging from 85 to 100 m followed by pumping test to determine the aquifer characteristics and provide information about the production capacity of the boreholes and their safe discharge rates (Figures 15 and 16). The final yields of the four successful boreholes were between 120 and 600 lpm.

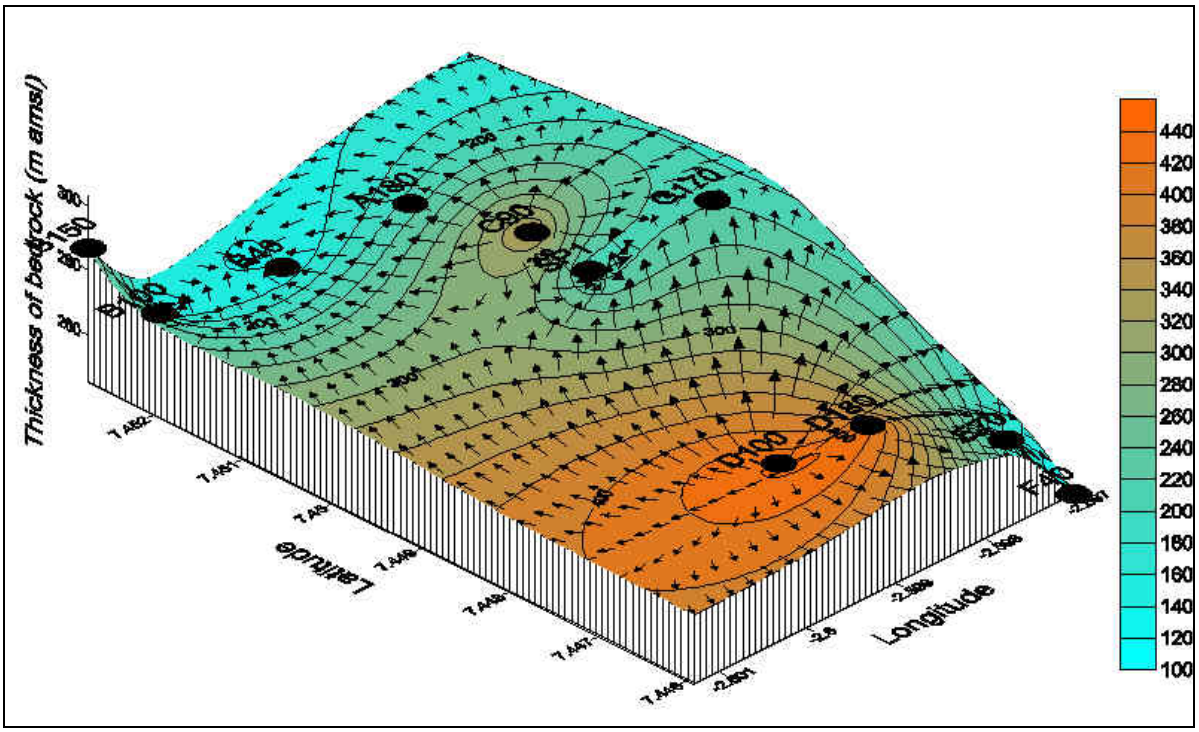


Figure 14: Modelled Geophysical Results to obtain bedrock topography of the project area

A

B

Figure 15: Drilling to obtain a successful borehole (A) and air lifting to clean successful borehole (B)

Figure 16: Conducting Pumping test

At the end of the study, the following recommendations were given:

- Though the yielding capacities of the boreholes were 200 lpm, 220 lpm, 180 lpm and 1,800 lpm for BH1, BH2, BH3 and BH4 respectively, BH1 – BH3 could be pumped safely at 150 lpm, whilst BH4 could withstand a safe pumping rate of 600 lpm.
- Each of the four (4) boreholes should be pumped continuously for a period of 20 hours, and allowed for 4 hour recovery intervals between pumping periods.
- The pump setting depths of the pumps must be at a mean depth of 75m below ground level.

3.4.2 Construction of 25No. Boreholes in Assin-North, Gomoa-West Municipal and Ajumako/Enyan/Essiam District (Lot 3)

(Project Staff: Mr. Collins Okrah – Research Scientist and Dr. William A. Agyekum – Research Scientist)

In collaboration with CWSA, this project was started and completed in the reporting year. The specific objectives were to conduct geophysical survey, supervise borehole drilling and carry out pumping test and water quality analysis.

During the reporting year, a total of 4,070 m traverse was profiled with electromagnetic method and 75 points were selected for vertical electrical sounding in order to obtain the best 25 points for drilling in each of the 25 beneficiary communities.

Analyses of the geophysical results indicated that three (3) sub-surface lithological layers of varying resistivity values underlay all communities whose basement rock was granite. In areas underlain by Tarkwaian rocks, four (4) different sub-surface resistivity layers were obtained. Apparent conductivity of the terrain ranged between 12 and 91 m mho/m with an average value of 36 m mho/m. The overburden thickness or the regolith was generally between 14 m and 56 m. The bedrock underlying the project communities was noted to be characterized by slightly-to-moderately developed fractures (Figure 17). The typical response curves for the apparent conductivity and the apparent resistivity measurement are shown in Figures 18 and 19 respectively.

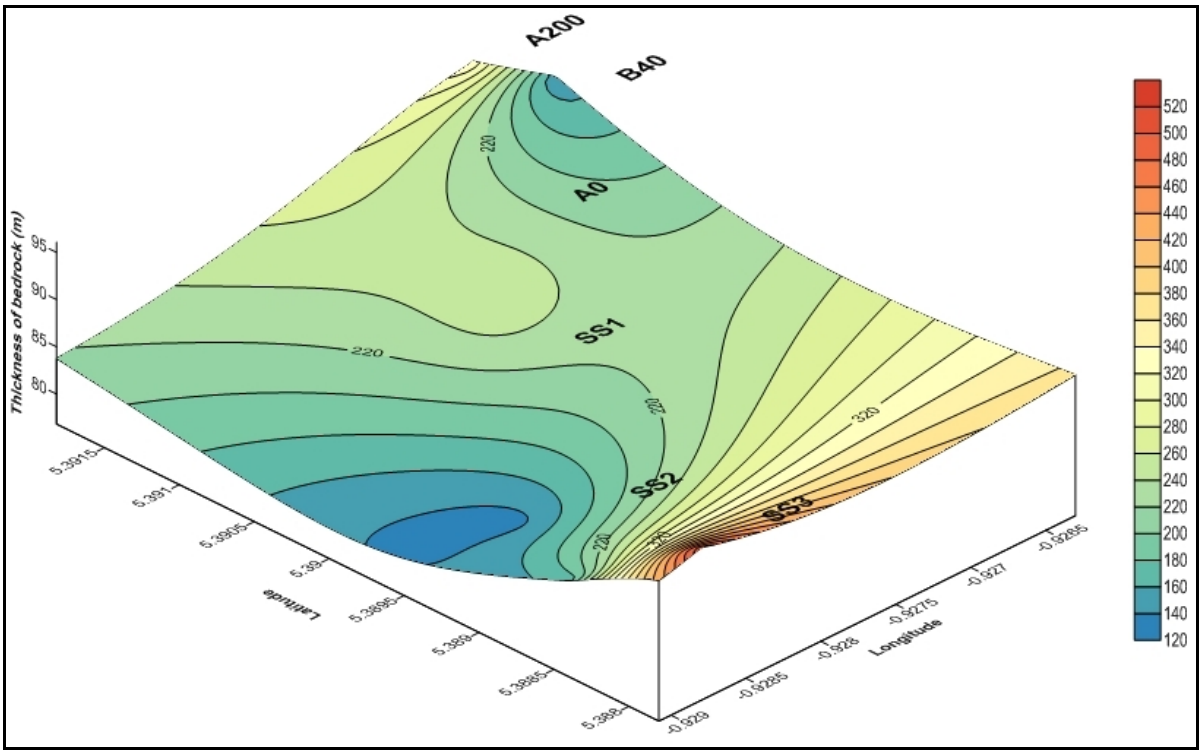


Figure 17: Resistivity of bedrock topography underlying Mando community

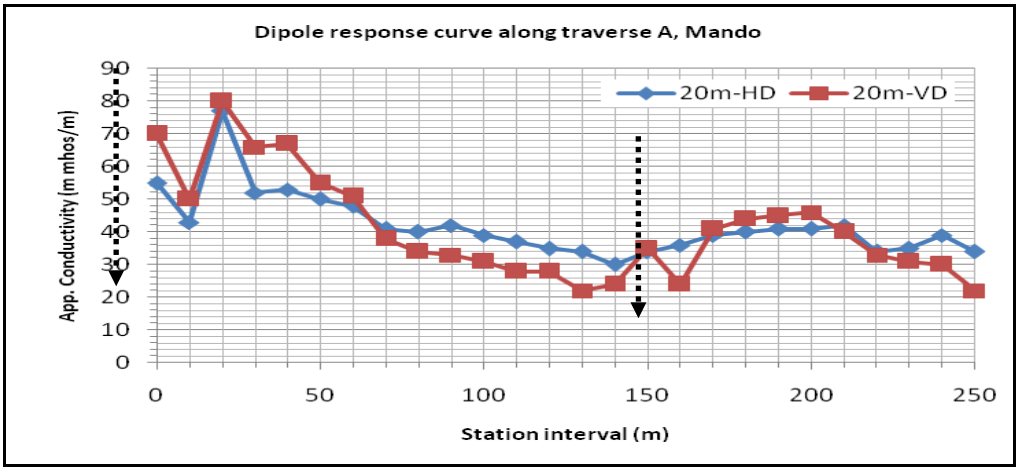


Figure 18: Typical EM-response curve in the study area

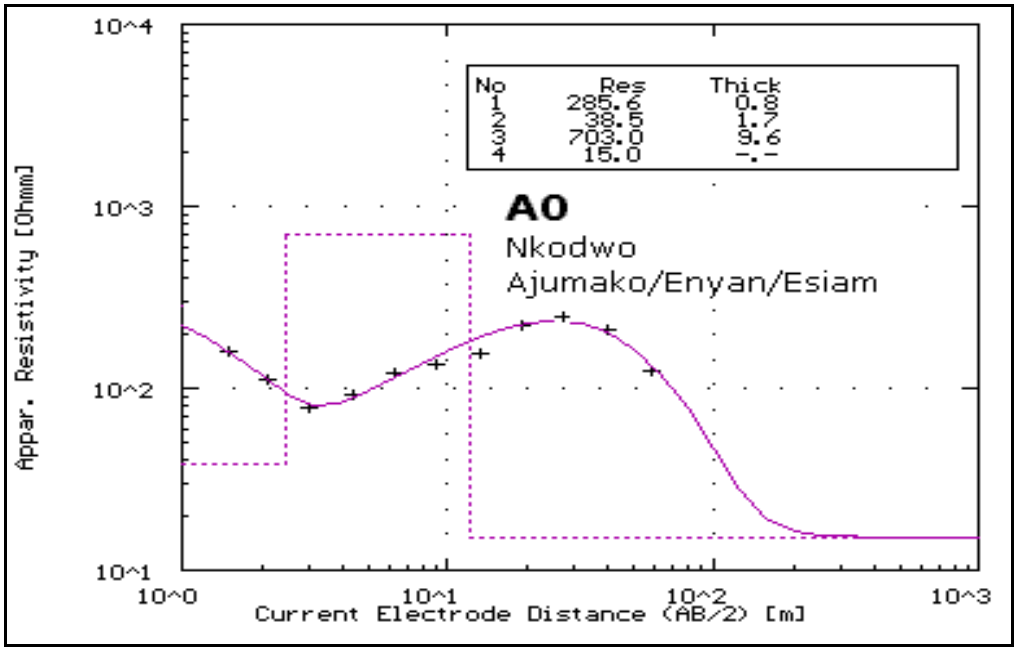


Figure 19: Typical VES Curve in the study area

Ten (10) boreholes drilled in the Ajumako/Enyan/Esiam District produced 70 % success rate, ten (10) other boreholes drilled in the Assin-North Municipality produced 90 % success rate while five (5) boreholes drilled in the Gomoa-West Municipality produced 100 % success rate. The depth of the boreholes drilled ranged from 30 to 75 m with the average depth of 52 m to intercept aquifer zones which ranged from 14 to 69 m deep. Drilling yields ranged between 4 and 168 lpm with an average yield of 38 lpm.

Pumping test conducted on the successful boreholes indicated that static water levels were in the range of 2.7 to 40.0 m below ground level (bgl) with an average value of 15 m bgl. The pumping test was used to determine the transmissivity of the basement aquifers, which ranged between 0.1 m^2/day and 31.0 m^2/day (average = 1.9 m^2/day), as well as the Specific Capacity values of the aquifers which ranged from 0.2 to 19.0 m^3/day/m (average = 2.8 m^3/day/m).

The water quality analysis conducted on the successful wells showed slightly high values of total coliform, high turbidity levels and high iron concentration in few samples from Assin-North and slightly high salinity level of some samples from Gomoa-West. Water quality of samples from Ajumako/Enyan/Esiam District were within WHO standards for drinking purposes.

3.4.3 Assessment of Groundwater Resources of the Northern Region

(Project Staff: Dr. Anthony A. Duah – Research Scientist and Mr. Carl Ofori-Agyeman – Research Scientist)

This on-going project was initiated in 2011 and is expected to end in 2013. Its specific objectives were to:

- assess the availability, quantity, quality, suitability and movement of groundwater resources in the Northern Region of Ghana through the analysis of data and on hydrogeological information compiled and collated on drilled boreholes in the region over the years;

- develop single -parameter groundwater-use maps to show the spatial distribution and variation of groundwater characteristics in the region;
- develop an updated composite hydrogeological map for the region comprising the integration of all the single-parameter groundwater and quality maps;
- produce a comprehensive groundwater assessment report for the region; and
- assess the future trends of groundwater resources sustainability, suitability, development and utilization in the region.

Activities carried out during the reporting year included compilation and analysis of borehole data to derive statistics on groundwater utilization in the region; computation of the statistics on single aquifer parameters for the various districts and municipalities in the region; and data analysis of single aquifer parameters such as yield, static water level (SWL), dynamic water level (DWL) and depth to aquifer. The number of boreholes assessed in the Northern Region is shown in Figure 20.

Preliminary results obtained were used to establish percentage borehole yield ranges in the Northern Region (Figure 21), borehole success rate on District basis and borehole status (wet and dry) for the entire Northern Region on District basis.

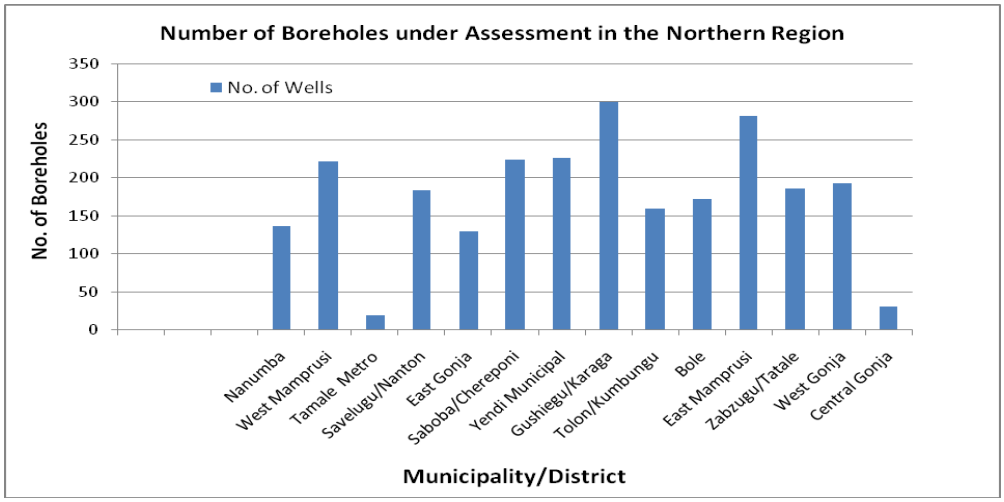


Figure 20: Number of boreholes under assessment in the Norhern Region of Ghana (Total = 2,463)

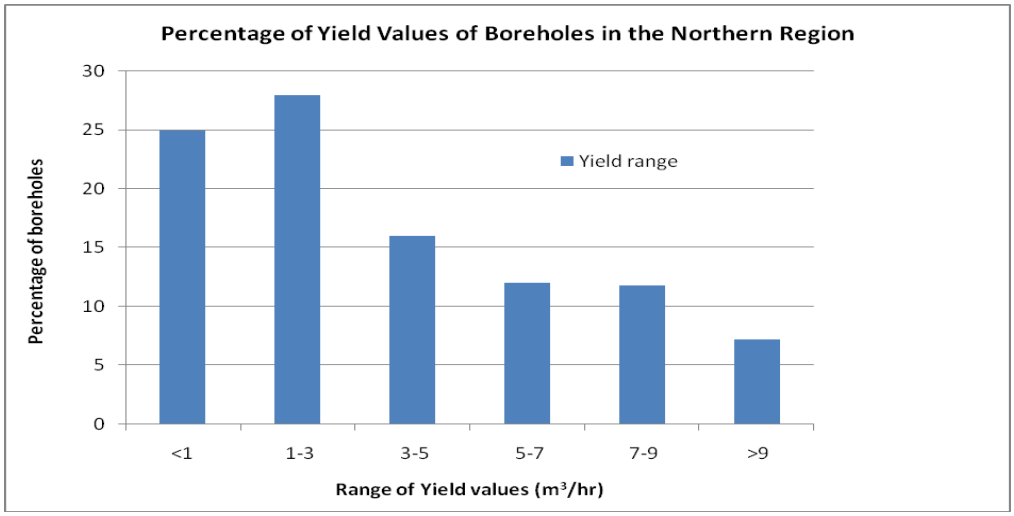


Figure 21: Percentage range of yields of boreholes in the Northern Region of Ghana

3.4.4 Provision of Consultancy services for Borehole Construction at the Ghana Standards Authority in Accra

(Project Staff: Mr. Manu Evans – Research Scientist, Mr. Collins Okrah – Research Scientist and Dr William A. Agyekum – Research Scientist)

The study was initiated in the reporting year to carry out geophysical survey to locate possible drilling points for borehole construction, drill selected points and conduct pumping test of the successful boreholes, and mechanize the boreholes to pipe the water into a reservoir.

Activities carried out in the year under review included geophysical survey, drilling, pumping test and water quality analysis.

The results of the geophysical investigations indicated that the area is generally underlain by four (4) lithological layers of varying resistivity values. The overburden thickness of the regolith is about 68 m. The bedrock underlying the project site is characterized by slightly-to-moderately developed fractures to facilitate groundwater development. The depth of drilled borehole was 141 m with estimated yield of 9 l/min (0.54 m^3/h). Analysis of water sampled from the boreholes indicated that with the exception of iron, manganese, sodium, chloride and turbidity, all physico-chemical parameters were within WHO permissible limits. The typical response curves for the apparent resistivity measurement and the VES analyzed results are shown in Figure 22 and Table 19

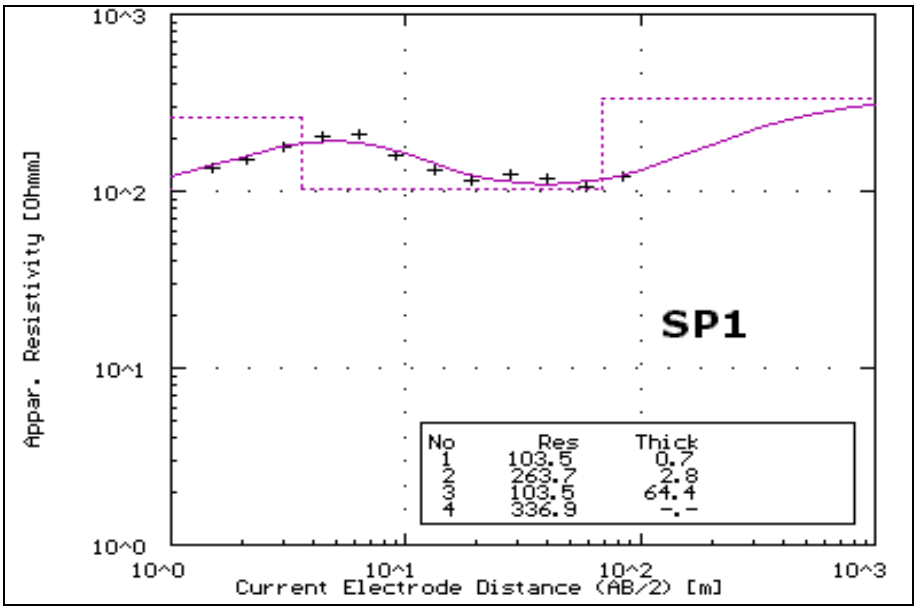


Figure 22: Typical VES Curve in the study area

Table 19: VES Model results

VES Point	Layer	Apparent Resistivity (Ω-m)	Thickness (m)	Depth (m)	Rank
SP1	1	103.5	0.7	0.7	**1st**
	2	263.7	2.8	3.5	
	3	103.5	64.4	67.9	
	4	336.9	-	-	
SP3	1	178.8	1.1	1.1	**2nd**
	2	189.2	1.6	2.7	
	3	542.5	37.4	40.1	
	4	292.4	-		
SP2	1	126.7	1.0	1.0	**3rd**
	2	131.4	1.8	2.8	
	3	101.9	7.9	10.7	
	4	488.9	-	-	
SP4	1	68	1.0	1.0	**4th**
	2	42	1.6	1.6	
	3	47.4	2.2	4.8	
	4	662.1	-	-	

3.4.5 Hydrogeological Consultancy Services in the Northern Region of Ghana under the Northern Region Small Towns Water and Sanitation Project (NORST)

(Project Staff: Mr. Patrick Amankwah Mainoo – Research Scientist, Dr. William Atuobi Agyekum – Research Scientist)

This collaborative study with the Northern Region Small Towns Water and Sanitation Project (NORST) CWSA – Northern Region, ended in the reporting year. The overall goal was to provide an increased access to potable water and sanitation facilities to small towns in the eastern corridor of Northern Region. The specific objective was to undertake hydrogeological and drilling supervision services for Wapuli and Wonjuga – Kudani small towns in the Saboba and Chereponi districts, respectively.

The scope of work included desk study, data scouting and analysis, field reconnaissance survey, geophysical survey to delineate zones where high yielding boreholes (yield > 100.0 l/min) could be drilled to serve as sources of potable water supply to the beneficiary project towns, and borehole drilling and construction supervision.

The main geological setting of the selected towns was the Pendjari-Oti of the Voltaian Supergroup with Bimbilla formation at Wapuli and Afram Sandstone formation at Wanjaga-Kudani. At Wapuli, three traverses were investigated and the resulting pseudo-sections presented in Figures 23 to 25. Test drilling was conducted at sites A400 m, C240 m and C660 m. The first attempt at site A400 m resulted in a marginal borehole yield of 31 l/min. The second test drill at site C240 m resulted in a high-yielding borehole that yielded 300 l/min. The third test drill conducted at point C660 m resulted in a marginal borehole yield of 25 l/min. It was noted that boreholes drilled into the relatively low resistivity Pendjari and Kodjari formations tend to be relatively high yielding as compared to those of moderate to high resistivity layers. At Kudani, three (3) traverses were investigated and the pseudo-sections presented in Figures 26 to 28. The first test drill at site A400 m resulted in borehole with yield of 160 l/min. Test drill conducted at point B380 m resulted in borehole of marginal

yield of 31 l/min. The third attempt at site C140 m, however, resulted in a relatively high yielding borehole of 360 l/min. Similar to the scenario observed at Wapuli, drilling through the low resistivity band of the Pendjari and Kodjari formations along the traverses produced relatively high-yielding boreholes.

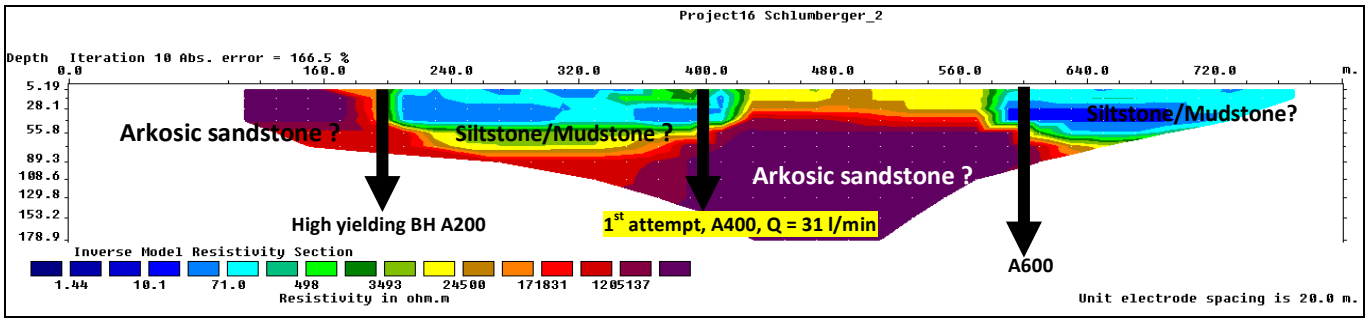


Figure 23: Apparent Resistivity pseudo section along traverse A, Wapuli using Schlumberger electrode configuration

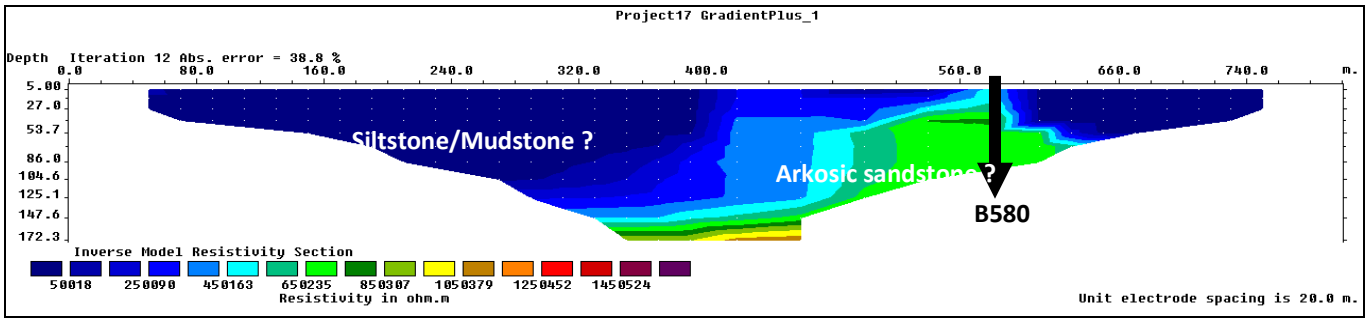


Figure 24: Apparent Resistivity pseudo section along traverse B, Wapuli using Gradient Plus electrode configuration

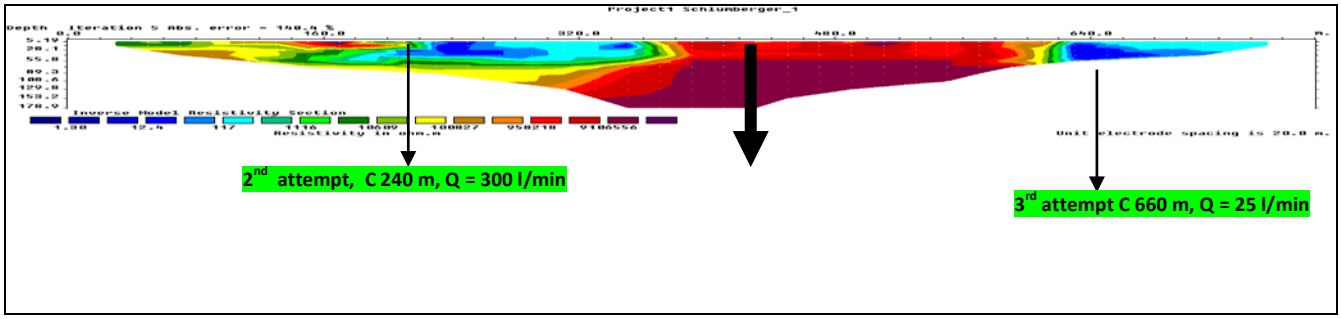


Figure 25: Pseudo-section obtained along traverse C using Wenner Reciprocal array, Wapuli

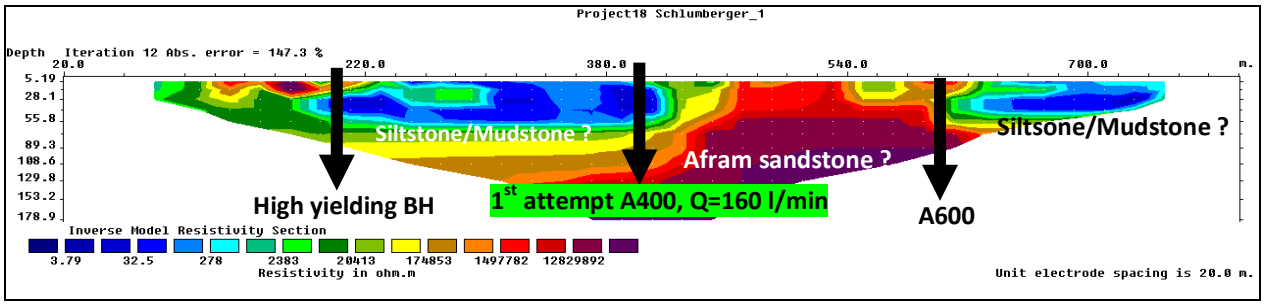


Figure 26: Resistivity pseudo section along traverse A, Kudani using Schlumberger electrode configuration

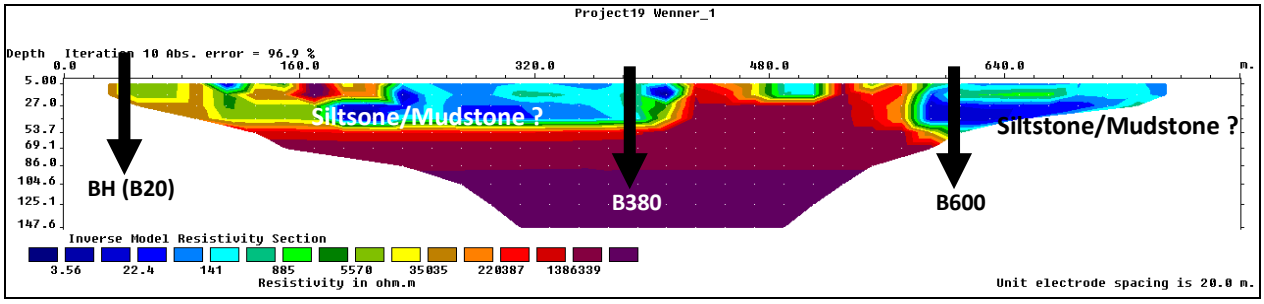


Figure 27: Resistivity pseudo section along traverse B, Kudani using Wenner electrode configuration

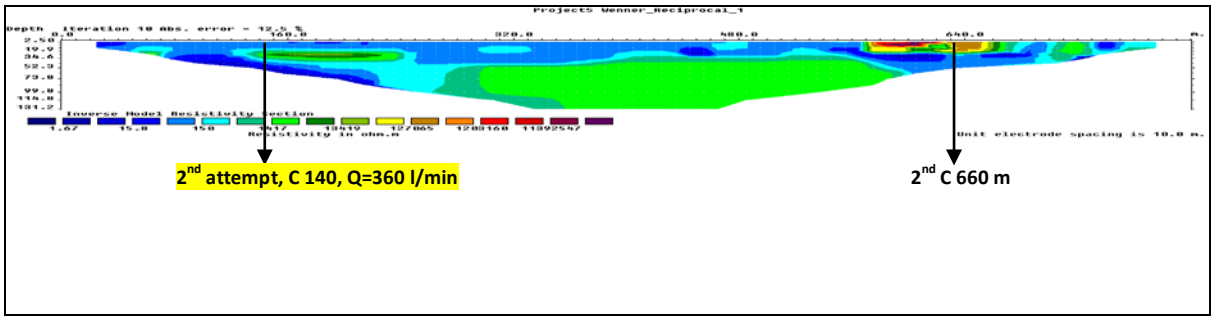


Figure 28: Pseudo-section obtained along traverse C using Wenner Reciprocal array at Kudani

The transmissivity coefficient values ranged from 20.04 to 31.89 m^2/d. The highest transmissivity coefficient value of 31.89 m^2/d was recorded on borehole at site C140, Kudani and the least at site A190, Wapuli. The Specific capacity values varied from 11.12 to 31.91 m^3/d/m. The drawdown during constant pumping tests ranged from 18.05 to 25.9 m. A summary of the aquifer characteristics underlying the boreholes is presented in Table 20.

Table 20: Aquifer characteristics on boreholes in Wapuli and Kudani

Town	**Wapuli**	**Wapuli**	**Kudani**
Temp. ID	A190	C240	C140
Constant Pumping rate (l/min)	230	400	200
Constant Pumping rate (m^3/h)	13.8	24	12
Pumping Duration (min)	1440	1440	1440
Drawdown (m)	23.21	18.05	25.9
Specific Capacity (m^3/d/m)	14.27	31.91	11.12
Transmisitivity (m^2/d)	20.04	26.76	31.89

The water quality assessment indicated that the two boreholes A190 and C240 drilled in Wapuli in the Saboba District were of excellent quality as the levels of parameters measured were all within the WHO Guideline values. On the other hand, the two (2) boreholes A200 and C140 at Kudani community had high levels of Flouride. The levels of Sodium at Kudani varied between 340 and 648 mg/l and exceeded the recommended WHO guideline value of 200 mg/l. Similarly, Chloride concentration in Kudani boreholes exceeded the WHO guideline value of 250 mg/l and ranged between 638 and 817 mg/l.

It was concluded that geophysical investigations to establish suitable drilling sites for drilling high yielding boreholes in Wapuli and Wonjuga – Kudani small towns in the Saboba and Chereponi districts were successful. In addition, the 2D-Apparent Resistivity survey was

suitable for the hydrogeologically difficult terrain like the Voltaian Sedimentary rocks on the Eastern corridor of Ghana. It was noted that interpretation of the results was highly subjective and must be tied to the prevailing geological setting and field experience in similar settings. Also, to ensure effective decision-making, 2-D resistivity surveys should be conducted on parallel profiles to validate the occurrence of detected anomalies. Other tools such as remote sensing techniques should be incorporated in the reconnaissance survey to enhance the selection of highly prospective sites for geophysical investigations.

3.5 SURFACE WATER DIVISION

The long-term objective of the Surface Water Division is to generate, develop and transfer appropriate technologies, information and services for sustainable development, utilization and management of surface water resources for socio-economic development.
The specific objectives include:

- Assessment of surface water resources of the country for socio-economic development
- Assessment of sediment transport by streams/rivers and discharges into reservoirs for planning and management of water resources
- Development and adaptation of appropriate technologies and water conservation techniques for water supply to households, communities, farms and industries
- Assessment of climate change effects and adaptation strategies

3.5.1 The Impacts of Proposed Water Treatment Plants on the Hydrological Situation of the Dayi and Volta Rivers in the Volta Region of Ghana

(Project Staff: Mr. F. Y. Logah – Research Scientist, Dr. K. Kankam-Yeboah – Principal Research Scientist and Ms. Debora Ofori – Research Scientist)

The Institute, in collaboration with the Hydrological Services Department, started and ended this study in the reporting year to investigate the impacts of proposed Water Treatment Plants (WTP) at Hohoe, Kpeve and Juapong in the Hohoe, South Dayi and Kadjebi districts, respectively on the hydrological situation of the Dayi and Volta rivers in the Volta Region of Ghana.

During the reporting period, river stations with good records of streamflow values from the Hohoe, South-Dayi and Kadjebi districts in the Volta Region were selected. Low streamflow requirements of the rivers and base-flow contribution to streamflow were estimated. The effects of the proposed WTP and the risk of river drying out were also assessed.

Streamflow value of 4,493 m^3/day was estimated from the Frequency Distribution Curve (FDC) at 90 % probability of exceedance as the minimum sustainable streamflow (low flow threshold) for the Dayi River. In the Volta River at Akosombo, an amount of 74.50×10^9 m^3 was equaled or exceeded 90 % of the time. The study showed that streamflow value of 0.03 m^3/s is expected in the basin at least once every year in the Dayi River. Similarly, low streamflows with magnitudes 0.014 m^3/s, 0.010 m^3/s and 0.009 m^3/s are expected to occur at least once in a 10, 50 and 100-year periods, respectively in the Dayi River. With water demand projection approximately 4,500 m^3/day for the year 2011, any attempt to increase abstraction due to future demand would affect flows in the Dayi River.

It was concluded from the study that there was high possibility of the Dayi River drying out in the basin especially during the dry periods if abstraction rate goes beyond 4,493 m^3/day. It was therefore recommended that dams should be constructed to harvest storm water generated from May to November each year to enable the Dayi produce sufficient water for the WTP during the dry periods of December to April each year for domestic water supply. However, construction of Water Treatment Plants at Kpeve and Juapong would have negligible effects on the Volta River which could be used for domestic water supply.

3.5.2 Hydro-meteorological Station at CSIR Water Research Institute's Head Office

(Project Staff: Dr. K. Kankam-Yeboah – Principal Research Scientist, Mr. Collins K. Asante- Sasu – Principal Technical Officer, Mr. G. Appiah –Technical Officer and Mr. F. T. Oblim – Technical Officer)

The weather station at the CSIR Water Research Institute's Head Office in Accra is located at 05° 35705N, 00° 11105W with an altitude of 45.72 m above mean sea level. During the reporting year, hydro-meteorological data on rainfall, temperature, evaporation, sunshine duration and wind-run were collected daily, digitally stored and analyzed to describe the environmental conditions at any particular time and determine the water balance of the area.

The total rainfall for the reporting year was 557.2 mm with major peak in June and minor peak in October. The total rainfall of 2012 fell below that of 2011 by 322.9 mm (Figure 29). Out of 365 days in the year 2012, there were only 59 rainy days. The total evaporation for the year was 1536.2 mm and this exceeded rainfall by 979 mm. Rainfall exceeded evaporation only in June with a difference of 34.4 mm (Figure 30). Therefore, crops could suffer from water deficit unless supplementary irrigation was undertaken in most parts of the year. Data on other hydro-meteorological parameters of the station in 2012 is shown in Table 21. However, the Stevenson's screens and thermometers for measuring maximum and minimum temperatures needed serious attention.

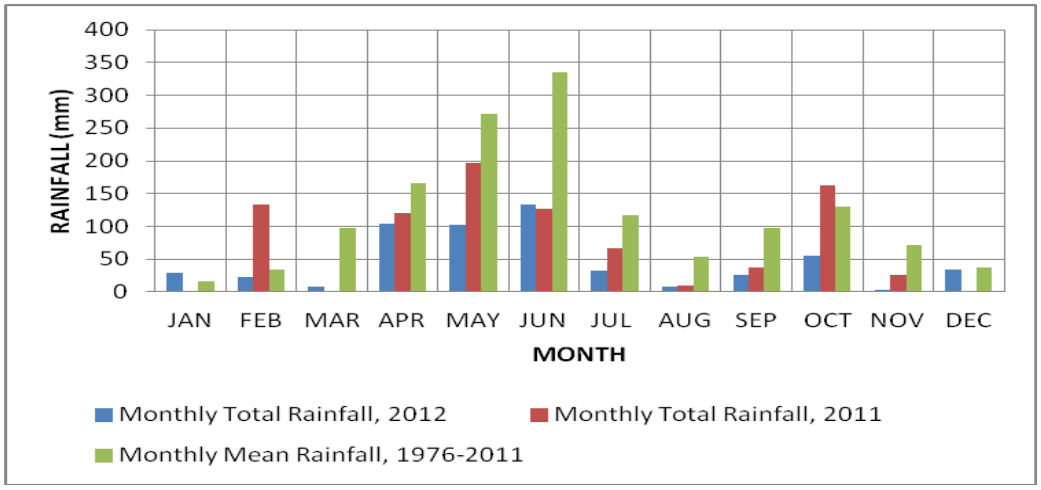


Figure 29: Rainfall regimes for the years 2012, 2011 and 1976 – 2011

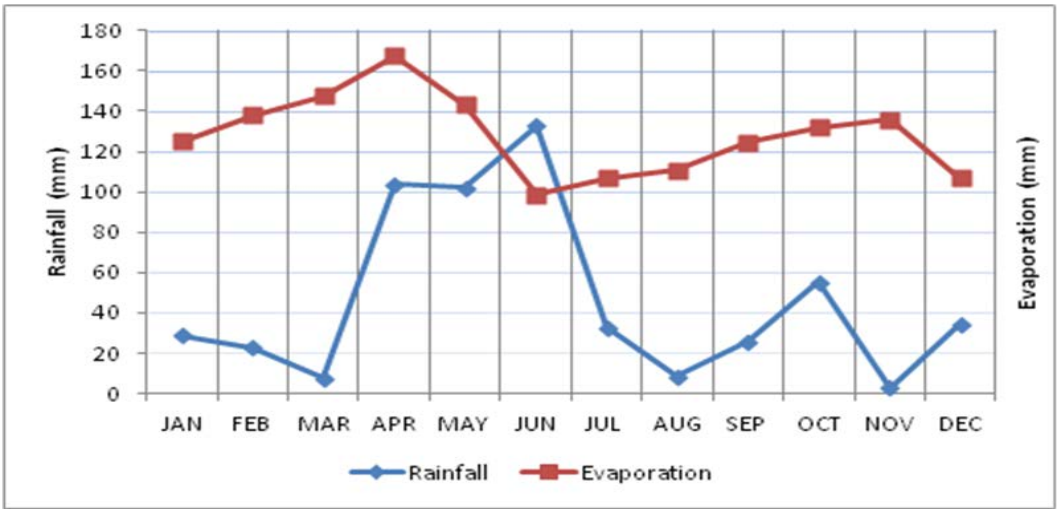


Figure 30: Comparison of rainfall and evaporation patterns in 2012

Table 21: Hydro-meteorological data at CSIR Water Research Institute Station, Accra in 2012

Parameter	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Rainfall (2012) mm	28.8	22.7	7.5	103.9	102.2	132.9	32.5	8.5	25.9	55.2	2.7	34.4	**557.2**
Rain day	2	4	3	7	8	10	4	4	6	7	1	3	**59**
Rainfall (2011) mm	0	132.6	0	120.6	196.4	126.1	67.2	10	37.7	163.3	26.2	0	**880.1**
Rainfall (Average 1976 – 2011) mm	15.7	33.9	97.3	166.4	271.9	334.5	117.1	53.0	98.2	130.4	70.9	37.6	**1426.9**
Evaporation (mm)	124.8	138.2	147.5	167.3	143.2	98.5	107.0	110.5	124.7	131.9	135.7	106.9	**1,536.2**
Temperature (°C)													
Mean Temperature	-	-	-	-	-	-	-	-	-	-	-	-	
Maximum Temperature	-	-	-	-	-	-	-	-	-	-	-	-	
Minimum Temperature	24	25	26	26	25	-	-	-	-	-	-	-	
Windrun (Knots)	1.47	2.46	2.50	2.65	2.15	2.43	3.47	3.67	3.47	4.35	1.96	1.73	**32.31**
Sunshine (Hours)	6.4	4.9	6.0	6.9	7.5	4.7	5.2	4.8	5.6	7.6	8.4	7.7	**75.8**
Relative Humidity (%)	75	76	75	79	81	86	85	83	81	81	79	78	

3.5.3 URAdapt - Managing Water at the Urban-Rural Interface: The Key to Climate Change Resilient Cities

(Project Staff: Dr. B. A. Amisigo – Senior Research Scientist, Mr. Fred Logah – Research Scientist, Dr. K. Kankam-Yeboah – Principal Research Scientist and Mr. Collins Kissi – Principal Technical Officer)

In collaboration with IWMI, Ghana Institute of Local Government Studies (ILGS), Addis Ababa University (AAU), Ethiopia, Climate Change Adaptation in Africa (CCAA), International Development Research Centre (IDRC) of Canada and the United Kingdom's Department for International Development (DFID), this project which started in 2009 ended in the reporting year. The objectives were to:

- develop a shared understanding amongst multiple stakeholders of climate change and its effects on water management at the urban-rural interface using simplified scenarios for greater comprehension of the consequences;
- generate new knowledge, using scenarios, on the upstream and downstream implications of urban water demand, and of resulting wastewater generation, as well as on water investments needs; and
- prepare, in participation with city stakeholders, and for the benefit of the most vulnerable groups, a strategic action plan for adapting to climate change based on improved water resource management.

In the reporting year, the water resources stress conditions in the Densu Basin were estimated from current total water abstractions from the basin. Other studies conducted on the impact of climate change on the future flows of the Lower Volta River were examined to support the programmed future water supply to Greater Accra Metropolitan Area (GAMA). Statistical downscaling of the output of the REGCM4 model performed on rainfall and temperature data for the Densu for IPCC SRES scenarios A1B and B1 was also considered. Future potential evapotranspiration data in the Densu Basin under climate change was estimated as part of the inputs to the HEC-HMS hydrologic model. The HEC_HMS modeling was completed for the Densu Basin and climate change impact analyses performed. Statistical downscaling of the output of the REGCM4 model for the Densu for IPCC SRES scenarios A1B and B1 was started using LARS-WG stochastic weather generator. Interactions with selected national stakeholders of the project continued at two Re-SAP meetings where results in climate change scenario and hydrological modelling in the Densu basin were presented and discussed. In addition, the finalised strategic agenda for climate change mediated interventions in the water resources management in the Densu Basin and for meeting the future water supply needs of GAMA were presented to policy makers in Accra. A draft paper and a report on the modelling activities and results obtained were also prepared and presented.

The study showed that the current level of water abstraction in the Densu Basin was 34 % of total annual inflow into the Weija Reservoir (Table 22). Abstractions from Weija for water supply to GAMA was 33 % while abstractions in the upper catchments was just 1 % of total annual inflow into the Weija Reservoir. The total annual abstraction was high enough for the basin's water resources to be considered as already under stress in hydrological terms. The upper catchments of the Densu Basin (upstream of Nsawam) generated most of the flows (more than 60 %) into the Weija Lake. The Lower Volta River would still have more than enough flows to support all of the programmed future water abstractions for GAMA water supply even under the dry climate change scenario of the climate change study in the Volta Basin (Table 23). However, drying conditions and declining streamflows were predicted for the Densu Basin in the current study (Figures 31 and 32). It was estimated that up to 10 % reduction in the Densu streamflows will occur from 2001 to 2050 as a result of the impacts of climate change.

Table 22: Surface water availability and use rate in the Densu Basin

Point of Water abstraction	Rate of abstraction (million m^3/year)	Estimated basin streamflow (WRC, 2007) (million m^3/year)	Percent abstraction
Weija water supply scheme	93.1		33.2
Weija Irrigation Project	0.0		0.0
Other points	3.6		1.3
Basin Total	**96.7**	**280.0**	**34.5**

Table 23: Lower Volta streamflows under the dry and wet climate change scenarios of de Condappa *et al* (2008) and current and programmed percentage levels of abstraction for GAMA water supply

Climate change scenario	Annual renewable water for the Lower Volta (Billion m^3)	Water withdrawals for GAMA			
		2011		2015*	
		Volume (Billion m^3)	Percent of Lower Volta Flows	Volume (Billion m^3)	Percent of Lower Volta Flows
Baseline	29.1	0.127	0.44	0.223	0.77
Dry scenario	**24.2**	**0.127**	**0.52**	**0.223**	**0.92**
Wet scenario	33.5	0.127	0.38	0.223	0.67

** There are plans to increase the water supply to GAMA from both the Densu and Lower Volta to nearly 223 million m^3 annually by 2015(GWCL sources)*

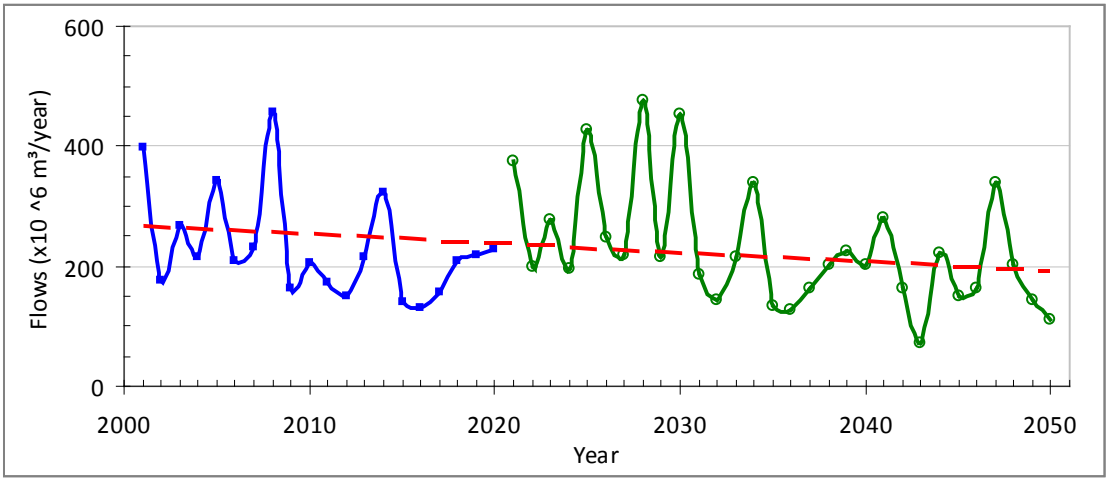


Figure 31: Predicted annual streamflows into the Weija Lake for A1B scenario for the period 2001-2020 and 2021-2050

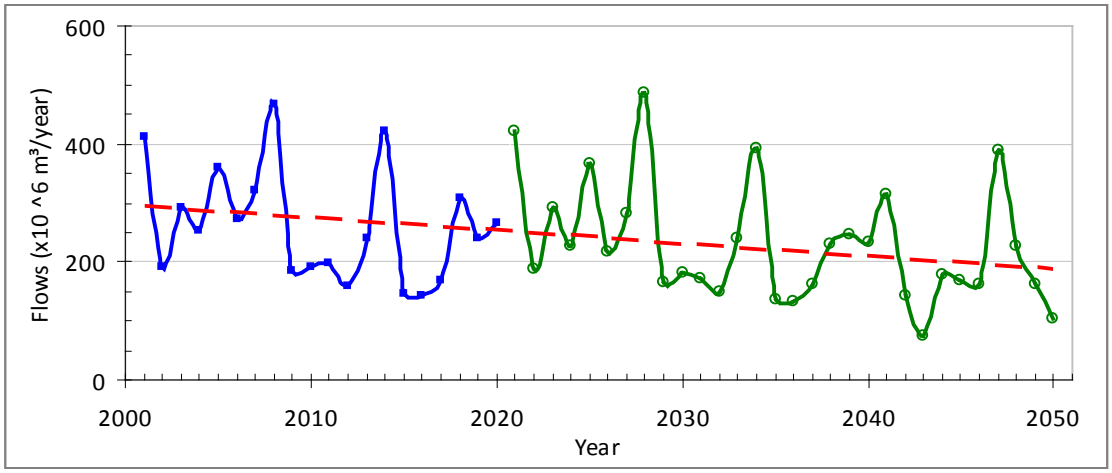


Figure 32: Predicted annual streamflows into the Weija Lake for B1 scenario for the period 2001-2020 and 2021-2050

It was concluded that if, as a result of the projected drying in the basin, the communities in the upstream part of the basin rely more on the streamflows for agriculture, for example, there would be significant reduction in water availability to the Weija dam and hence to GAMA since it is the upper catchments of the Densu Basin that generate most of the flows into the Weija Lake. Therefore, there is the potential for serious conflicts between GAMA and upper catchment communities in the use of the basin's water resources in the future. An integrated approach involving all stakeholders and balancing water abstractions from the Densu and the Lower Volta would be required to reduce conflicts in the use of the water resources of the Densu Basin and to properly manage and conserve these resources.

The following recommendations were given:

- GAMA should be concerned about the threat to meeting its water supply needs from the Densu Basin in the future due to the drying conditions and resultant reduced river flows predicted for the basin.
- Roof rainwater harvesting and groundwater could be explored as supplementary sources of water supply to GAMA.

3.5.4 Sustainable Management of Lake Bosomtwe in the Ashanti Region of Ghana – Hydrology, Anthropology and Water Quality

(Project Staff: Ing Dr Frederick K. Amu-Mensah – Senior Research Scientist, Mrs. Marian Amu-Mensah – Research Scientist, Mr. Humphrey Darko – Research Scientist, Mr. Mark O. Akrong – Research Scientist, Dr. Joseph A. Ampofo – Principal Research Scientist, Mrs. Regina Banu – Research Scientist, Mr. Gabriel Appiah, Mr. Collins Asante Sasu, Mr. Mohammed Bello, Mrs. Wilhelmina Tetteh and Ms Hawa Ahmed)

The study started in the reporting year in collaboration with Man and Biosphere (MAB) Ghana, CSIR Forestry Research Institute of Ghana (FORIG), Friends of the Earth (FoE), Intelligence Nature International (INI), and A Rocha Ghana. The specific objectives were to:

- identify and document sources of water into the lake and their seasonality with emphasis on catchment hydrology;
- investigate associated anthropological impacts on the hydrologic processes within the catchment;
- develop a comprehensive and long term water quality monitoring programme as a tool for water quality management;

- assess the microbiological water quality of Lake Bosomtwe; and
- identify collection points for water sampling from various communities.

It is expected to end in 2013.

Activities carried out during the reporting period included installation of two Automatic raingauges and five semi-automatic raingauges for rainfall data collection; collection of inflow records from flowing streams; sampling and analysis of in-flow channel bedload; and Lake water, stream flow and rainwater sampling, bacteriological analysis of the water samples, data analysis and report writing. Field anthropological observations and questionnaire administration were also undertaken in some communities around the lake.

The study showed significant variation in rainfall occurrence and amounts though the catchment was relatively small hydrologically. All water samples, except for rainwater, did not conform to Ghana Standards and WHO guidelines of zero (0) total coliform, faecal coliform, *E.coli*, *Salmonella spp*., *Aeromonas spp*., *Enterococcus spp*, as well as <500 cfu for Total Heterotrophic Bacteria, hence bacteriologically unsafe for drinking and recreational purposes. The mean total coliform counts in all the sampling points was 699 cfu/100ml. The highest value of 2232 cfu/100ml was recorded at the Apewu sampling point. The mean faecal coliform count in all the sampling points was 116 cfu/100ml. Apewu sampling point had the highest coliform count of 1116 cfu/100ml. Seven (7) sampling points representing 27 % of a total of twenty six (26) sampling points had no faecal coliform. Twelve (12) sampling points representing 46 % had zero (0) cfu/100ml *E.coli* count. The highest *E.coli* count was however recorded in Apewu (744 cfu/100ml). The *Aeromonas spp*. count in all the water samples ranged between 0 and 144 cfu/100ml and the highest count was recorded at the Krobo sampling site. The total Heterotrophic bacteria count ranged from 11 to 5184 cfu/100ml in all the sampling points. The highest Heterotrophic bacteria count was recorded at Ankaase. The detailed results of some parameters are shown in Figures 33 to 37.

The poor quality of the lake could be attributed to contamination from human faeces, domestic wastes as well as other human activities such as rearing of animals close to the lake. The preliminary results therefore showed that human activities along and in the lake impacted negatively on the water quality of the lake.

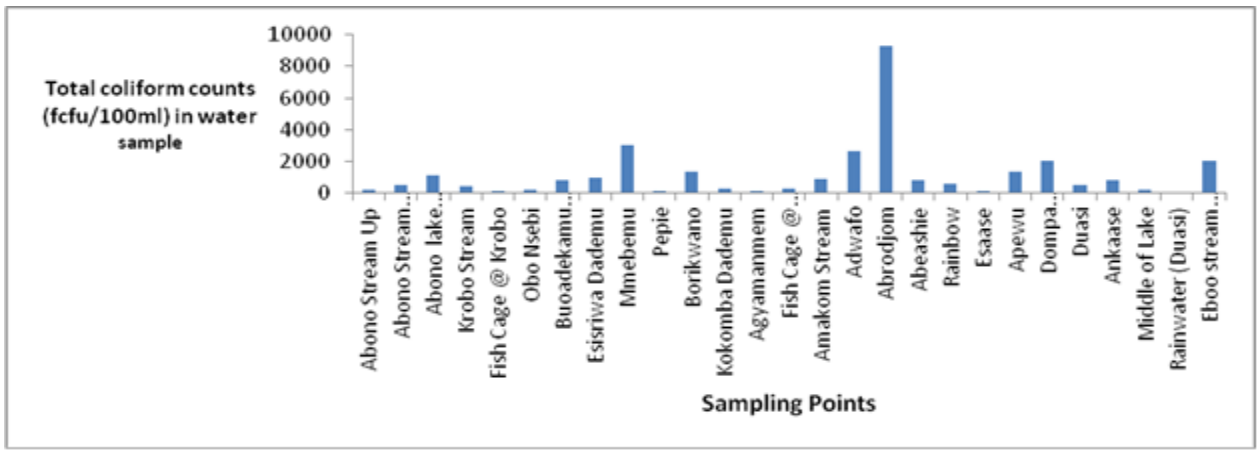


Figure 33: Total coliform counts in water samples

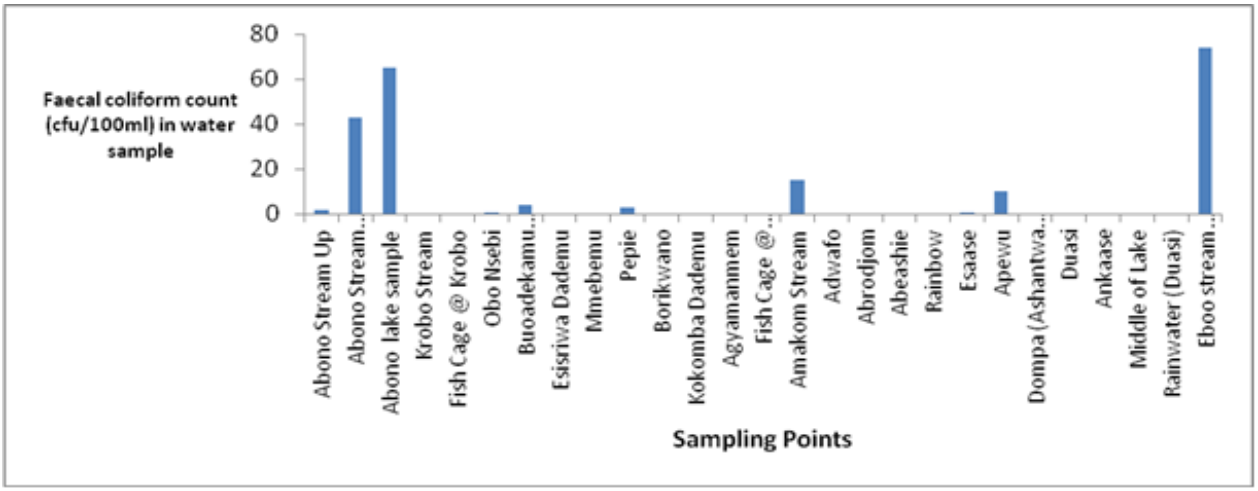


Figure 34: Faecal coliform counts in water

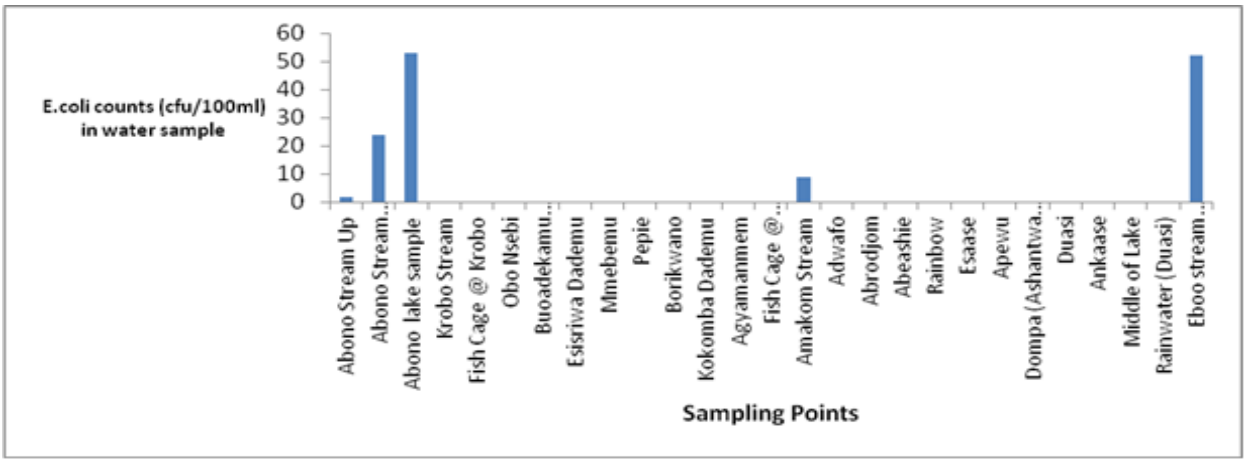


Figure 35: *E.coli* counts in water

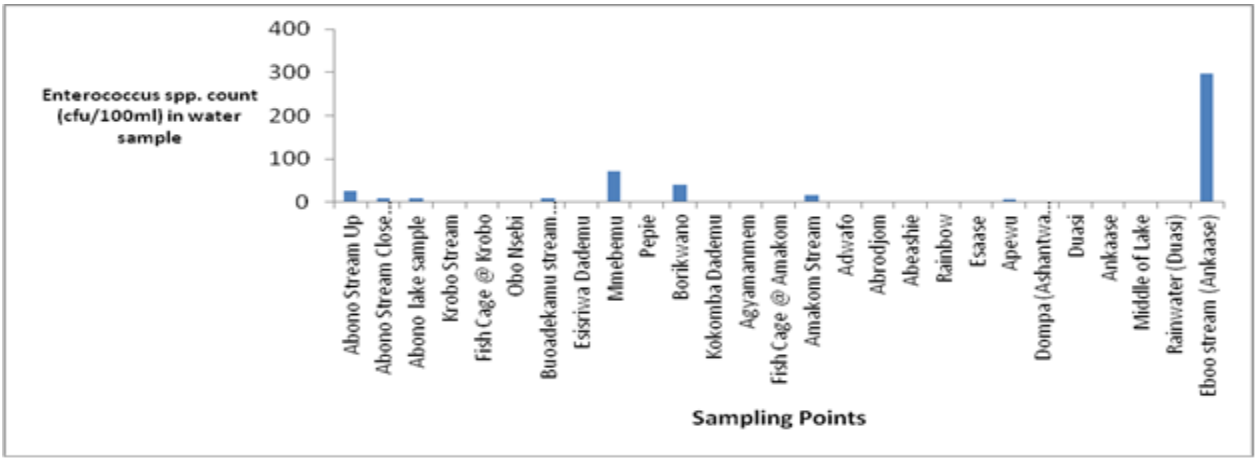


Figure 36: *Enterococcus* spp counts in water samples

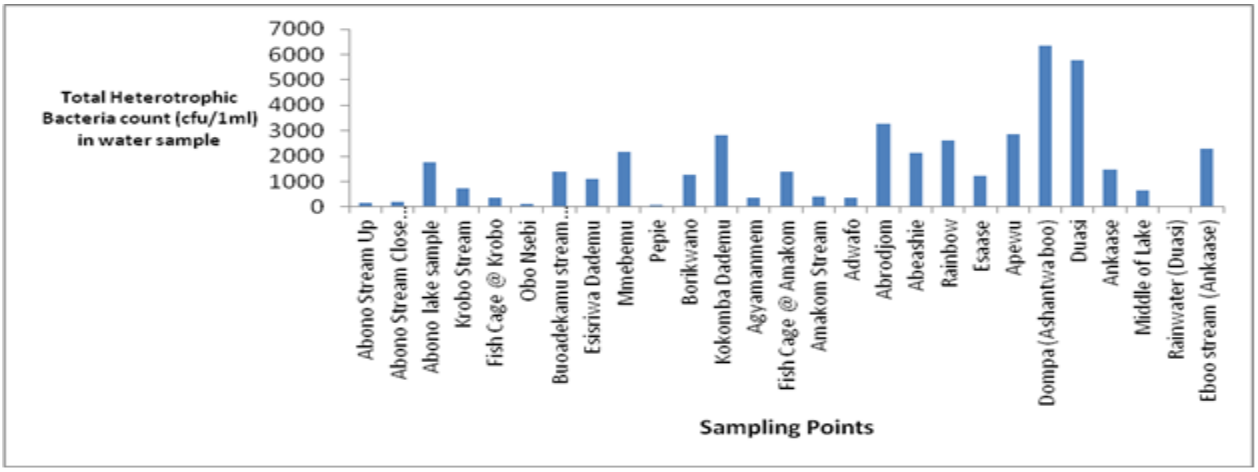


Figure 37: Total Heterotrophic bacteria (THB) in water samples

3.5.5 Volta 3-Towns Water Supply Assessment

(Project Staff: Ms. Deborah Ofori – Research Scientist, Mr Fred Logah – Research Scientist, Dr. K. Kankam-Yeboah – Principal Research Scientist and Mr. F. Oblim – Technical Officer)

The study started in 2011 and ended in the reporting year. The overall objective was to assess the Juapong, Kpeve and Hohoe treatment works based on physical state of infrastructure; water supply and demand; and available water resources.

Activities undertaken during the reporting period included collection and review of relevant literature, maps, engineering drawings and documentation on the water supply systems, the Volta Lake and River Dayi; population analysis for selected communities under the Juapong, Kpeve and Hohoe water service areas; water supply and demand analyses; field visit to assess the water supply systems at the respective headworks and transmission mains; hydrological and water quality analyses of raw water sources for the headworks; and design of proposed abstraction rates for current and future water demands on the existing water treatment plants.

Field inspection and information garnered on treatment plant/units indicated that the Juapong, Kpeve and Hohoe headworks capacities were all far below both current and future water demands. Less than 50 % of the plants demand were met and treatment units/equipments were either broken down or not functioning efficiently. Based on water demand estimates and hydrological analysis performed for the Volta Lake, the Lake could supply both the Juapong and Kpeve headworks for the 2025 and 2050 planning years. The combined demand of the headworks for the 2011, 2025 and 2050 planning years were approximately 0.3 %, 0.4 % and 0.7 %, respectively of 90 % dependability volume of water in the Volta Lake. On the other hand, at 90 % dependability volume (i.e. 4,493 m^3/day), the Dayi River could meet 90 – 92 % of the current water demand on the headworks. Water production from the river is hence unsustainable with respect to future water demands of 6,879 m^3/day and 10,165 m^3/day for 2025 and 2050 planning years, respectively (Tables 24 and 25).

At the end of the study, supplementary raw water source, either surface or groundwater sources or the conjunctive use of both were proposed for future exploitation for supply to Hohoe. Rehabilitation works and system expansion capacities of 11,500 m^3 and 4,500 m^3 with

distribution networks of 109 km and 17 km were proposed for Kpeve and Hohoe headworks, respectively. A completely new treatment plant and water storage facility of 2,700 m^3 expansion capacity and 93 km transmission/distribution mains were also proposed for Juapong Township, Akwamufie, Asikuma and Frankadua (Proposed Juapong system).

Table 24: Minimum flow requirement for raw water sources

Headwork	Raw water source	Dependability flow	
		90 %	95 %
Kpeve	Volta Lake[1]	74.5 x 10^9 m^3	71.43 x 10^9 m^3
Juapong	Volta Lake[1]	74.5 x 10^9 m^3	71.43 x 10^9 m^3
Hohoe	Dayi River[2]	4,493 m^3/day	1,555 m^3/day

[1] Daily dependability values for the Volta Lake in terms of volume of water
[2] Baseflow contribution to the Dayi River is approximately 6%

Table 25: Population/water Supply and demand analyses for headworks and major service areas

Headwork	Service Area	Population 2000	Projected Population			Water Supply (m^3/day)	Water Demand (m^3/day)		
			2011	2025	2050	2011	2011	2025	2050
Juapong	Juapong	21,420	26,347	34,291	54,894	750 - 980	2,057	2,677	4,286
Kpeve	Kpeve and Have	16,381	20,149	26,223	41,980	1,000 - 2,000	2,250	2,928	4,687
	Ho Municipality	104,621	180,163	234,479	375,369	6,500 - 7,000	18,287	23,801	38,101
	Peki	20,574	32,899	42,817	68,545	1,000 - 1,500	2,569	3,343	5,352
Hohoe	Hohoe	35,277	52,070	77,934	124,761	1,500 - 2,500	4,879	6,879	10,165

3.5.6 Groundwater in Sub-Saharan Africa: Implications for Food Security and Livelihood (GWSSA)

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist, Ms. Deborah Ofori – Research Scientist, Mr. Collins Okra – Research Scientist and Mr. Collins Kusi-Asante – Principal Technical Officer)

In collaboration with the University for Development Studies (UDS), Tamale , and the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, this study was initiated in 2009 and ended in the reporting year to enhance the role of groundwater in providing improved food security and livelihoods in Sub-Saharan Africa. The objective was to investigate the physical groundwater resource potential for irrigation and its sustainability under current conditions and future development scenarios in the Talensi-Nabdam and Bawku West districts of the Upper East Region of Ghana. The specific objectives were to:

- characterize the groundwater aquifer systems (hydraulic conductivity, transmissivity, storativity, specific yield, water levels, etc) of the study area via review of existing literature, analysis of secondary data and field investigations at selected locations;
- estimate recharge to groundwater in the project areas;
- evaluate the suitability of groundwater for agricultural use via water sampling and quality analysis;
- estimate the extent of groundwater use by the various sectors (domestic, agriculture including livestock and cattle, and industrial) in the study area;

- estimate the total volume of groundwater currently being used in agriculture and in comparison with total agricultural water use in the study area;
- evaluate the potential for using groundwater to expand agriculture under present condition and future development scenarios;
- estimate water storage in the Volta Basin; and
- undertake literature review of groundwater status in Ghana, Burkina Faso, Niger and Mali.

Activities undertaken in the reporting year included field data collection and analysis, hydrological modelling, preparation and submission of project reports and manuscripts.

Results of the geophysical survey indicated that the thickness of the aquifers varied from 1.4 m to 18.7 m in the Zalerigu area and from 0.8 m to 15.1 m in the Sapeliga area. The total volume of groundwater that could be stored in Zalerigu and Sapeliga each year were estimated to be 286.5 million cubic meters (MCM) (2,428.0 mm) and 200.5 MCM (2,331.4 mm), respectively. The long-term recharge to the groundwater aquifers was quantified to be 7.6 MCM (63.4 mm) in the Zalerigu area and 4.3 MCM (50.2 mm) in the Sapeliga area. Presently, the total volume of groundwater abstracted for multi-purpose use was estimated to be 0.49 MCM for the Zalerigu area and 0.36 MCM for the Sapeliga area. The abstracted volume represented 0.17 % and 6.4 % of the groundwater storage potential and recharge, respectively in the Zalerigu area. In the Sapeliga area, the abstracted volume represents 0.18 % of the groundwater storage potential and 8.4 % of the recharge. The results revealed that the abstracted groundwater in the study areas was largely used for domestic purposes including drinking, cooking, bathing and washing. About 67 % of the abstracted groundwater in the Zalerigu area was used for domestic water supply. Agriculture and industrial uses accounted for 31 % and 2 %, respectively. Of the agriculture component, irrigated agriculture mainly vegetable production comprised 27 % while livestock watering was 4 %. For the Sapeliga area, domestic water supply accounted for 71 % of all groundwater uses. This was followed by irrigated agriculture (22 %), livestock watering (5 %) and industry (2 %). The groundwaters in the study areas were largely of good quality for multi-purpose use including drinking and irrigation.

Analysis of groundwater potential in the Volta Basin showed that the Soil and Water Assessment Tool (SWAT) model was well able to simulate the major hydrological fluxes in the basin (including total water yield, total aquifer recharge and soil moisture) with performance statistics (coefficient of determination -R^2, Nash-Sutcliff model efficiency -NSE, and volume bias - PBAIS) well above the suggested minimum requirement for successful calibration (R^2 > 0.6, NSE > 0.5, PBAIS $\pm$ 25 %). The total water yield, total aquifer recharge and soil moisture constituted 10 %, 9 % and 7 %, respectively of the mean annual rainfall (about 967 mm) for the 1990 to 1999 decade. For the 2000 to 2009 decade, the total water yield, total aquifer recharge and soil moisture constituted 11 %, 10 % and 7 %, respectively of the mean annual rainfall (about 989 mm). There appeared to be an increase in all the water fluxes in the recent decade (2000 – 2009) relative to the 1990 – 1999 decade with important increases of 15 %, 13 % and 14 % in the total water yield, total aquifer recharge and soil moisture, respectively.

It was concluded that there was large potential to expand groundwater irrigation beyond Zalerigu and Sapeliga due to the large storage capacity and recharge volumes of the aquifers being far more than current abstraction. However, lack of appropriate technologies for drilling wells, lack of credit facilities, limited accessibility to land and lack of access to stable market were some challenges identified. These seriously limited the number of farmers and the land area cropped. The estimated groundwater demand or abstraction in the Volta Basin constituted

only 2.6 % of the total aquifer recharge and the large groundwater potential of the basin could be tapped to improve domestic water supply and agriculture in the basin.

It was however recommended that affordable mechanical technologies for drilling wells and credit facilities to purchase small size and efficient motorized pumps for irrigation should be made available to farmers to expand groundwater irrigation to cover upland areas at the study sites to improve food security and livelihoods.

3.5.7 Eco-health approach to the control of Onchocercaisis in the Volta Basin of Ghana

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist and Mr. Collins Kusi-Asante – Principal Technical Officer)

This study started in 2009 and ended in the reporting year. The goal was to understand how future climate change scenarios could influence Onchocerciasis transmission (for better or for worse) in the Volta Basin. It was a collaborative study with the Noguchi Memorial Institute for Medical Research, Institute of Statistical, Social and Economic Research (ISSER), Natural Resources Institute – University of Greenwich, UK, Ghana Meteorological Agency (GMET), and Institute of Mathematical Sciences. The specific objectives included:

- analysing historic and future climate data over two sub-basins of the Volta Basin (Pru and Black Volta);
- adapting a hydrological model to the two sub-basins for the purpose of simulating their river flows;
- estimating climate change impact on river flow in the study basins; and
- providing climate and river flow data to the entomology group for the analysis of black fly population dynamics under present and future climate conditions.

During the reporting year, climate data collected were analysed and project reports and manuscripts prepared. Analysis of projected (future) climate data from multi-model regional climate model (RCM) ensemble from the ENSEMBLES project revealed that the mean daily temperature and annual total rainfall in the Black Volta Basin would increase in the near future (2011 – 2040) by 1.1 ^{o}C and 3.1 %, respectively, relative to the baseline (1961 – 1990). For the Pru basin, increases in the daily temperature and annual rainfall were projected to be 0.7 ^{o}C and 2.3 %, respectively. The four RCMs that constitute the multi-model ensemble used in the study were unanimous in projecting increasing trend in temperature though they differ in the magnitude of increase. For rainfall, the ensemble members disagreed in trend and magnitude of the change. However, the ensemble mean showed slight increases in the annual rainfall for the future in the two (2) basins. An assessment of the impacts of climate change on river flow based on the integration of downscaled future climate projections from the multiple regional climate models (ensemble mean) and the Soil and Water Assessment Tool (SWAT) hydrological model showed that the mean annual river flow in the Pru and Black Volta basins would rise by 1.8 % for the Pru Basin and 0.8 % for the Black Volta Basin.

It was concluded from the study that the Black Volta and Pru river basins climate would become warmer and slightly wetter towards the middle of this century. The change in climate would impact on the hydrology of the basins, resulting in the availability of slightly more water in both basins towards the middle of the century.

3.5.8 CPWF-V4 Sub-basin Management and Governance of Rainwater and Small Reservoirs

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist and Mr. Collins Kissi Asante-Sasu – Principal Technical Officer)

This project was initiated in 2010 to improve rainwater and small reservoir management to contribute to poverty reduction, and improved livelihoods resilience and people's well-being in the dry lands of Burkina Faso and Northern Ghana while taking account of implications for downstream water users including ecosystem services. It was in collaboration with IWMI; CIRAD (UMR Green); Secrétariat Permanent au Plan d'Action et de Gestion Intégrée des Ressources en Eau (SP-PAGIRE), Burkina Faso; Water Resource Commission-White Volta Basin Board (WRC-WVBB), Ghana; and the University for Development Studies (UDS-Tamale). The specific objectives were to undertake bio-physical modelling of water resources and erosion (or sedimentation) within the two project pilot sub-basins in Ghana and Burkina Faso; and test the impacts of various scenarios on addressing key water resources challenges (e.g., erosion and flooding) in the two sub-basins. It is expected to end in 2013.

Activities undertaken in the year under review included field visits and collection of additional data for modelling work; adoption of two (2) bio-physical models (SWAT and WEAP) to the two project pilot sub-basins ("Zebila basin", a sub-basin of the White Volta basin in Ghana; and Bolgiba 7, a sub-basin of the Black Volta basin in Burkina Faso) for the purposes of quantifying available water resources and the extent of soil erosion/sedimentation in the project basins; developing, simulating and analyzing biophysical scenarios for addressing key water challenges in the project sub-basins; presentation of results and preparation of draft manuscript on modelling work; and preparation of outline of final project report.

Sediment yield in the basin was computed as a function of the catchment area. The average annual sediment yield in the Zebila catchment was estimated at 3.4 t/ha. About 70 % of this was contributed by the cropland/woodland which was one of the two dominant land-use types in the catchment. The other dominant land use type, Savannah, contributed 30 % of the annual sediment yield. The average sediment yield in reservoirs in the catchment was estimated at 0.012 t/ha/yr. This was significantly lower compared to the average yield of 9 t/ha/yr for Africa and the global average yield of 15 t/ha/yr. The preliminary analysis of modelling work showed that the total annual water yield in rivers and streams in the Zebila catchment of the White Volta Basin in Ghana was about 1.4 billion cubic meters (BCM). About 11 % (0.16 BCM) of this volume was generated from within the basin. The remaining 89 % (1.24 BCM) was generated from upstream of the catchment. This clearly indicated that any efforts at addressing water management issues in the Zebila catchment must necessarily involve stakeholders in upstream sub-basins to ensure success.

3.6 COMMERCIALIZATION AND INFORMATION DIVISION

The Commercialization and Information Division promotes commercialisation of research and development activities of the Institute. The specific objectives that guide the Division's activities are:

- developing programmes and strategies for commercialization;
- providing requisite information and documentation on the Institute;
- providing specialized services in support of research and development;
- performing public relations functions; and
- organizing open days and internal seminars on research and development activities of the Institute.

3.6.1 Cartography Section

During the period under review, hydrogeological maps and borehole profiles were provided by the Cartography Section to support research and consultancy services. Some old hydrogeological maps and graphs were updated and detailed layouts of selected structures for renovation such as WRI conference room expansion and hatchery structure for WRI Tamale Office were prepared. A total of twenty-five (25) drawings were prepared for four (4) of the six (6) Research Divisions, Commercialization and Information Division and the Estate Section as detailed in Figure 38.

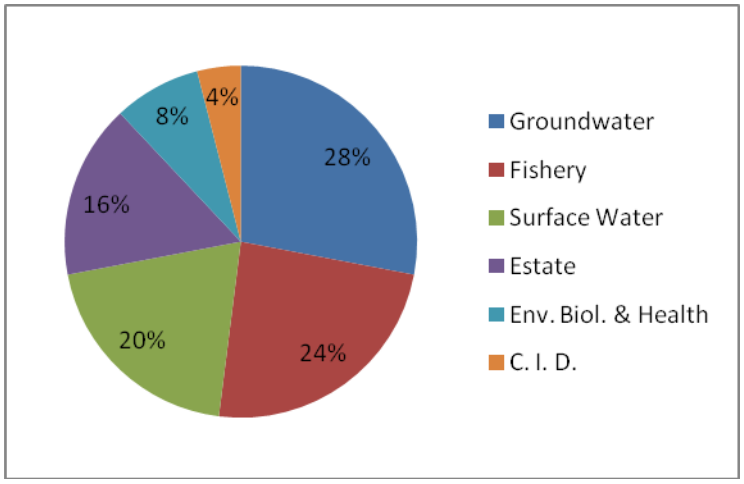


Figure 38: Percentage composition of cartographic drawings prepared during the year 2012

Hydrogeological maps of Greater Accra, Volta, Eastern, Ashanti, Western and Central regions of Ghana are available for sale to groundwater consultants, institutions and individuals.

3.6.2 Development of Research Library and Water Resources Documentation System

A total of 243 books and journals were received stamped, catalogued, accessioned, classified and added to the library's stock during the year under review. Gazettes, Acts and other government publications were purchased and shelved. The total library user visits stood at 2,442 constituting 1,820 internal users and 622 external users. Out of the total internal user visits, 1,085 were Senior Members, 525 were Senior Staff and 210 were Junior Staff. The total library user visits in 2012 was about 4 % more compared to user visits in 2011. Data on technical and

consultancy reports, books and theses were entered into the CDS/ISIS database for easy and fast retrieval of documents. Current Awareness Services were also provided for both internal and external users. The library continued to benefit from some on-line bibliographic resources such as Access to Global Research in Agriculture (AGORA), Online Access to Research in the Environment (OARE) and Health Internetwork and Research Institstute (HINARI) free of charge. Publications such as the Daily Graphic and Ghanaian Times for 2011 were bound into volumes by the Institute's Printing section.

3.6.3 Internal Seminars

Six seminars were organized during the reporting year to provide fora for participants to discuss and also bring into the public domain current research activities of the Institute. A total of 14 presentations on various research topics being addressed by the Institute were made (Table 26). Scientists from allied institutions and the media attended.

Table 26: Internal seminars 2012

Month	Presenters/Speakers	Topics
March	Dr. Mrs. R. E. M. Entsua-Mensah, Dr. O. D. Ansa-Asare, Dr. Antwi, Dr. F. M. Tetteh, Dr. D. Blay and Dr. J. A. Ampofo	Impact of small-scale mining activities on our land and water
April	Mrs. Regina Banu	Analysis of sachet water samples selected from neighbourhoods in Accra
	Mr. Ebenezer D. O. Ansah	The role of macro-invertebrates in the removal of faecal coliforms in natural treatment systems.
	Dr. B. A. Amisigo	Rethinking water storage for climate change adaptation in the Volta Basin of Ghana
	Mr. Francis A. Anani	Soft drinks (soda) and their effects on human health
May	Dr. Fred Amu-Mensah, Dr. B. A. Amisigo and Ms. Deborah Ofori	Rainwater harvesting programme at CSIR WRI
July	Dr. B. A. Amisigo and Mr. Fredrick Y. Logah	Hydrologic Modelling framework in the URAdapt project
	Dr. H. R. Dankwa	Catch composition of major fishing gears used in the Volta Lake - implications for managing the lake fisheries.
	Mr. Francis A. Anani	Heat treatments of fish feed ingredients: effect of apparent digestibility in the Nile Tilapia, *Oreochromis niloticus*, and African Catfish, *Claris gariepinus*, cultured in Ghana.
September	Dr. Anthony Duah	Sustainable groundwater utilization under climate change
	Mr. Humphrey Darko and Dr. O. D. Ansa-Asare	A number description of Ghanaian water quality – A case study of the Southwestern and Coastal river systems of Ghana
	Mr. Francis A. Anani	Effect of varrying feeding rates on survival, growth and sex reversal of the Nile Tilapia, *Oreochromis niloticus*, in hapas
	Mr. Humphrey Darko and	Physico-chemical assessment of groundwater quality in Accra Metropolis
October	Dr. Mike Osei-Atweneboana	Phenotypic responses of *Onchocerca volvulus* to Ivermectin treatment in onchocerciasis patients

3.6.4 Industrial Visits

Students of the Greater Accra Regional Science, Technology and Mathematics Innovations Education (STMIE) Camp (Figure 39) and MSc. Geophysics students of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, visited the Institute on Thursday 9th August 2012 and 26th September 2012, respectively, to have practical demonstrations on topics read at their various institutions.

Figure 39: Students of the Greater Accra Regional STMIE Camp having practical lessons at the CSIR WRI hydro-meteorological station

3.6.5 Exhibitions

Some major and current research activities and findings of the Institute were showcased during exhibitions organised during the year to bring to the public domain how these technologies could be accessed. These were during:

- Third National Policy Fair (8th March, 2012);
- 17th Faculty of Science Colloquium (21st - 23rd March, 2012);
- 28th National Farmers Day (2nd November, 2012); and
- 23rd Annual General Meeting of the CSIR Research Staff Association (RSA) (6th - 8th November, 2012).

During such exhibitions, the Institute's stand was patronised by dignitaries, farmers, students and others from all walks of life (Figure 40). Some later came for consultation and collaborative research work after the exhibitions.

3.6.6 Award

In recognition of the Institute's research and development activities pertaining to the fast growing new breed of tilapia called the Akosombo Strain of the Nile Tilapia, *Oreochromis niloticus*, the Institute was honoured with the Best Agric Researcher Award during the 28th National Farmers Day event (Figure 41). The new breed of tilapia grows about 30% faster than those in the wild. Under cage culture condition or system, it takes about six (6) months for the new strain to reach a mean weight of 420 g from an initial stocking weight of 15 g. Hence, a farmer who cultivates the new breed is sure to harvest in 6 month's time. Apart from its fast-growing nature, the new breed has a higher survival rate. The technology, therefore, has the potential to contribute significantly to fish farming in Ghana. Currently, the new breed continues

to attract the attention of fish farmers and hatchery managers in the country and within the West African sub-region.

Figure 40: Some participants at WRI's stand during the 28th National Farmers Day event

Figure 41: The Best Agric Researcher Award received by the CSIR WRI during the 28th National Farmers Day event

3.7 CONSULTANCY AND OTHER SERVICES

3.7.1 Consultancy and Advisory Services

Consultancy and advisory services were carried out by the Institute for various donor agencies, corporate bodies, governmental and non-governmental organizations, universities and polytechnics, public and private sector institutions as well as individuals. The significant ones included:

- Ecological study of the water storage facility and its impacts on the Awonsu stream and the Tano River (Client: Newmont Ghana Gold Limited)
- Advisory services on fish farming (Client: Small-scale fish farmers)
- Advisory services on how to avoid microbial contamination of water sources (Client: Sachet water producers)
- Assessment of the quality of wastewater discharged by Ghana Carton Boxes Manufacturing Company Limited (Client: Ghana Carton Boxes Manufacturing Company Limited)
- Physico-chemical and bacteriological quality of boreholes and tap water (Client: Oyibi Water and Sanitation Development Board)
- Assessment of final effluent quality (Client: Pioneer Food Company Limited)
- Assessment of final effluent quality (Client: Phyto-Riker)
- Potable water quality studies (Client: Pioneer Food Company Limited)
- Investigation of drinking water quality in Sekondi-Takoradi Metropolis (Client: Public Utilities Regulatory Commission)
- Investigation of drinking water quality in the Eastern Region (Client: Public Utilities Regulatory Commission)
- Water quality analysis (Client: Sachet water producers)
- Borehole water quality analysis (Client: World Vision International)
- Borehole water quality analysis (Client: NORST)
- Physico-chemical and bacteriological assessment of raw and treated water (Client: Vicco Ventures Limited)
- Physico-chemical and bacteriological tests on potable and swimming pool water (Client: Golden Tulip Hotel)
- Tilapia culture in concrete ponds (Client: Individual fish farmers)
- Advisory services on fish cage culture systems (Client: African Connections Ghana Ltd.)
- Geophysical Investigation for borehole siting within the premises of Ghana Standards Authority (Client: Ghana Standards Authority)
- Consultancy service for the provision of ten (10) boreholes in selected communities in the Ajumako-Enyan-Esiam District of the Central Region (Client: Ajumako-Enyan-Esiam District Assembly)
- Pumping test on an existing borehole at the premises of Christ Congregation Presby Church, Adenta (Client: Christ Congregation Presby Church)
- Geophysical exploration for drilling ten (10) boreholes in selected communities in the Assin-North Municipality (Client: Assin-North Municipality)
- Hydrogeological studies for the drilling of five (5) boreholes in five selected communities in the Gomoa District of the Central Region (Client: Gomoa District Assembly)
- Geophysical studies for the selection of drilling sites within the premises of six (6) SSNIT facility sites in Accra (Client: SSNIT)
- Borehole drilling and pumping test at Nankese (Client: Sircool Mineral Water Factory)

3.7.2 Training Services

Through the Technical Divisions of the Institute, individual research and technical staff offered training in various forms to individuals, groups, non-governmental organizations and students of the Universities and Polytechnics. Among them were:

- Part-time lectureship at the Environmental Science Program, University of Ghana, Legon
- Part-time lectureship at the African Regional Programme for Insect Science, University of Ghana, Legon
- Part-time lectureship at the Graduate School of Nuclear and Allied Sciences (SNAS), University of Ghana, Legon
- Supervision of M.Phil. students of the SNAS, University of Ghana, Legon
- Supervision of WASCAL Ph.D. student of the Kwame Nkrumah University of Science and Technology, Kumasi
- Supervision of post-graduate students research, University of Ghana, Legon
- External examination of theses of M.Phil. Environmental Science, School of Graduate Studies, University of Ghana, Legon
- Supervision of students from the Department of Environmental Science, Kwame Nkrumah University of Science and Technology, Kumasi
- External examination of theses of students of School of Graduate Studies, University of Ghana, Legon
- External examination of theses of students of School of Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi
- External examination of theses of students of African Regional Programme for Insect Science, University of Ghana, Legon

4.0 FINANCE

A total amount of GH¢6,903,018.87 was received for the year 2012. Out of this amount, 77.54 % represented government subvention, 14.31 % represented internally generated funds and 8.15 % represented donor assistance to the Institute.

4.1 Government Release in 2012

Receipt for recurrent expenditure was GH¢5,352,463.00. This constituted Personnel Compensation and Goods and Services during the year. The total Government release for the year constituted 77.54 % of total receipt for the year.

4.2 Internally Generated Funds (IGF) in 2012

An amount of GH¢987,942.56 was generated from consultancy services out of which an expenditure of GH¢791,807.43 was made. The IGF constituted 14.31 % of total receipts for the year.

4.3 Donor Assisted Projects in 2012

Receipt for donor assisted projects was GH¢562,613.31 during the year. However, an expenditure of GH¢306,897.75 was made. Donor assistance receipts represented 8.15 % of total receipts for the year.

APPENDICES

APPENDIX I - Membership of the Management Board

1.	Prof. C. Dorm-Adzobu Chairman	-	Dean, Faculty of Arts and Social Sciences, Central University College
2.	Dr. R. E. M. Entsua-Mensah (Mrs) Member	-	Deputy Director-General, CSIR Research and Development
3.	Mr. Christopher Manu Member	-	Technical Co-ordinator, Friends of the Earth - Ghana
4.	Mr. Edward O. Nsenkyire Member	-	Director, West Africa Fish Limited
5.	Mr. Emmanuel Gaze Member	-	Director, Community Water and Sanitation Agency
6.	Mr. Eugene Atiemo Member (Cognate Director)	-	Director, CSIR Building and Road Research Institute
7.	Dr. J. A. Ampofo Member	-	Director, CSIR Water Research Institute
8.	Margaret Azara Sedziafa (Mrs) Secretary	-	Head of Admin., CSIR Water Research Institute

APPENDIX II - Membership of the Internal Management Committee

1.	Dr. Joseph A. Ampofo	-	Director (Chairman)
2.	Dr. Philip Gyau-Boakye	-	Deputy Director
3.	Dr. K. Kankam-Yeboah	-	Head, Surface Water Division
4.	Dr. Alex A. Opoku	-	Head, Environmental Biology and Health Division
5.	Dr. William A. Agyekum	-	Head, Groundwater Division
6.	Dr. Osmund D. Ansa-Asare	-	Head, Environmental Chemistry Division
7.	Dr. H. R. Dankwa	-	Head, Fishery Division
8.	Marian A. Jiagge (Mrs.)	-	Head, Commercialization and Information Div.
9.	M. Azara Sedziafa (Mrs.)	-	Head, Administration Division
10.	Mr. Paul Fabalona	-	Head, Finance Division
11.	Dr. Felix Y. Attipoe	-	Officer-In-Charge, ARDEC-Akosombo
12.	Dr. K. Kwarfo-Apegyah	-	Officer-In-Charge, WRI Tamale
13.	Mr. Anthony Karikari	-	Representative, Research Staff Association (RSA)
14.	Mr. James Owusu	-	Representative, Senior Staff Association (SSA)
15.	Mr. Francis A. Boakye	-	Representative, TUC (Local Union)
16.	Mrs. Claudia Bentum	-	Secretary

APPENDIX III - Staff Distribution among the Divisions and Sections

Division/ Section	**Senior Members**	**Senior Staff**	**Junior Staff**	**Total**
Directorate	2	-	-	**2**
Surface Water	7	3	-	**10**
Groundwater	5	4	2	**11**
Environmental Chemistry	11	14	2	**27**
Environmental Biology & Health	11	9	-	**20**
Fishery Division	12	6	6	**24**
Commercialization and Information Division				
• *Scientific Secretariat Section*	3	1	-	**4**
• *Library Section*	2	1	1	**4**
• *Printing Section*	-	1	1	**2**
• *Cartographic Drawing Office Sect.*	-	3	-	**3**
• *Computer Section*	-	1	2	**3**
Finance Division	2	13	2	**17**
Administration Division				
• *Personnel Section*	1	14	9	**24**
• *Transport/Mech. Workshop Section*	-	9	17	**26**
• *Estate Section*	--	3	26	**29**
• *Security Section*	-	2	24	**26**
Temporary Staff	3	6	6	**15**
Contract Appointment	1	1	-	**2**
Total	**60**	**91**	**98**	**249**

List of Senior Members

Name	Designation	Qualification
Joseph A. Ampofo	Director	B.Sc. (Hons) Botany & Dip. Ed. (UCC) MPhil. Botany (Microbiology) (Legon) Ph.D Botany(Bacteriology) (Legon)
Philip Gyau-Boakye	Chief Research Scientist Deputy Director	B.Sc. (Hons) Civil Eng. (UST) M.Sc. Water & Waste Eng. (L'borough) Ph.D. Hydrology (Bochum, Germany)
Benony K. Kortatsi	Chief Research Scientist	B.Sc. (Hons) Physics/Maths, (Legon) M.Sc. Hydrogeol. (Univ. of B'ham) Ph.D Geology (Univ. of Ghana)
Osmund D. Ansa-Asare	Principal Research Scientist	B.Sc. (Hons) Chem. Dip.Ed. (UCC) P.G. Dip. Water Quality Mgt. (Delft) PhD. Env. Chem. (Aberdeen)
Kwabena Kankam-Yeboah	Principal Research Scientist	BSc. Agric. & Dip. Ed. (UCC) MSc. Tropical Agric. (KULeuven, Belgium) MSc. Irrig. Eng. (KULeuven, Belgium) PhD. Earth Science & Env. Eng. (Okaya., Japan)
Isaac O.A. Hodgson	Principal Research Scientist	B.Sc. (Hons) Chem.Eng. (UST), MSc. Chem. Eng. (UBC, Canada) PhD Chem. Eng. (LU, UK)
Hederick .R. Dankwa	Principal Research Scientist	BSc. (Hons) Zool./Bot. (Legon) MSc. Marine Ecol. (Brussels) Dip. Fish Mgt. PhD Fish Biol./Aquac. (UCC)
Alex A. Opoku	Senior Research Scientist	BSc. (Hons) Biology (UST) Dip. Env. Mgt. (TU Dresden) Dip. Insect Taxomology (Cardiff) PhD Applied Entomology (Cardiff)
Joseph K. Ofori	Senior Research Scientist	BSc. (Hons) Biology (UST) MTech. Aquaculture (Port Harcourt) PhD Biol. Sciences (UST)
Frederick K. Amu-Mensah	Senior Research Scientist	BSc. Agric Eng. (UST) MSc. Soil & Water Eng. (Wageningen) PhD. Bioenv. Science (Tottori, Japan)
Barnabas A. Amisigo	Senior Research Scientist	BSc.(Hons) Agricultural Eng. (UST) MSc. Water Res. Eng. (Guelph) PhD. Hydrology/Water Res. Eng. (Delft)
Collins Tay	Senior Research Scientist	B.Sc. Chem. KNUST M.Sc. Env. Res. Mgt. KNUST
Anthony Y. Karikari	Senior Research Scientist	B.Sc. (Hons) UST MSc. Chem. (Univ. of Ryukyus, Japan)
Kwadwo A. Asante	Senior Research Scientist	B.Sc. (Hons) Chem.(UST) Cert. Protection & Utilization Of Oceans (Hamburg) MS.c. Env. Chemistry and Exotoxicology (Ehime Univ., Japan)

Name	**Designation**	**Qualification**
Margaret Azara Sedziafa	Senior Administrative Officer	BA (Hons) English & Hist.Dip.Ed. (UCC) Graduate Dip. in Library Std. (Legon) MBA Human Resource Mgt. (Legon)
Asmah Ruby (Mrs)	Senior Research Scientist	B.Sc. (Hons) Chem. (UST) M.Sc. Ecol. Marine Mgt. (Brussels, Bel.) Ph.D Aquaculture (Stirling, UK)
Mike Osei-Atweneboana	Senior Research Scientist	BSc. Biological Scien/Nursing (Legon) MPhil Zoology (Legon) Ph.D Medical Parasitology (McGill, Can)
Francis Y.K. Amevenku	Senior Research Scientist	BSc. (Hons) Nat. Res. Mgt. (UST) MPhil. Agric. Economics (UG, Legon)
Felix Akpabey	Senior Research Scientist	BSc Zoology/Botany (UCC) & Dip.Ed. (UCC) MSc Entomology (UG) Ph.D Entomology (Rhodes Univ., Graham Town, SA)
Victoria Afutu-Vanderpuye	Research Scientist	B.Sc. (Hons) Zoology/Bot. (Legon). M.Sc. Med. Ento. (Pondcherry)
Emmanuel O. Bekoe	Research Scientist	BSc. Agric. Eng. (UST) MSc. Soil & Water Eng. (Wageningen, Neth.) PhD. Water & Environment (Cranfield, UK)
Fredrick Yaw Logah	Research Scientist	BSc. Agric. Eng. (KNUST) MSc. Water Res. Eng. (KULeuven, Belgium)
Emmanuel Obuobie	Research Scientist	BSc. Agric Eng. (UST) MSc. Soil & Water Eng. (Wageningen, Neth.) PhD. Natural Science (Univ. Bonn, Germany)
William A. Agyekum	Research Scientist	B.Sc. Geol. Eng. (UST) M.Eng. (Delft) PhD Geology (Univ. of Gh.)
Anthony A. Duah	Research Scientist	B.Sc. (Hons) Geol. Eng (UST) M.Sc.Hydrogeology & Remote Sensing (ITC) PhD Hydrogeology (Univ. of Western Cape, South Africa)
Patrick A. Mainoo	Research Scientist	BSc Physics (KNUST) MSc Physics (KNUST)
Collins Okra	Research Scientist	BSc (Physics) & Dip. Ed. (UCC) MSc Geophysics (KNUST)
Joyce Amoako (Mrs.)	Research Scientist	BSc Chem. (UST) MSc Env. Sanitation (Belgium)
Humphrey F. Darko	Research Scientist	B.Sc. Chem. UCC. MSc Ecological Marine Management

Name	**Designation**	**Qualification**
Samuel Obiri	Research Scientist	BED Chemistry/Integrated Science MPhil Inorganic/Analytical Chemistry
Gloria D. Addico	Research Scientist	BSc. (Hons) Nat. Res. Mgt. (UST) M.Phil. Biological Sciences (UST) Ph.D Biological Sciences (Robert Gorden Univ. ,Aberdeen-Scotland)
Ebenezer D. O. Ansah	Research Scientist	BSc. Zoology (Legon) M.Phil. Zoology (Legon)
George T. Mensah	Research Scientist	BSc. (Hons) Biol. Sciences (KNUST) MPhil Zoology (Legon) P.G. Dip. In Education (UCC)
Regina Banu (Mrs)	Research Scientist	BSc Botany (Legon) MPhil Botany (Legon)
Samuel Armoo	Research Scientist	BSc. Zoology (Legon) MPhil. Public Health (Legon)
Joseph N. Padi	Research Scientist	BSc. (Hons) Zool./Bot (Legon) MSc. Aquaculture (Auburn) PhD Aquaculture (Auburn)
Felix Y.K. Attipoe	Research Scientist	BSc. (Hons) Zool/Bot. (Legon) MSc. Aquaculture (Stirling, UK) Ph.D Zoology (UCC)
Theodore Quarcoopome	Research Scientist	BSc. (Hons) Nat. Res. Mgt. (UST) MPhil Biological Sciences (UST)
Seth K. Agyakwah	Research Scientist	BSc. (Hons) Biological Sci. (UST) MPhil Fisheries Science (UG) PhD Fisheries Science (UG)
Francis Assogba Anani	Research Scientist	BSc Zoology(UG, Legon) MPhil Fishery Science(UG, Legon)
Marian A. Jiagge (Mrs.)	Librarian	BLS. (A.B.U Zaria-Nigeria) MLS (UG, Legon)
Marian Amu-Mensah (Mrs.)	Research Scientist	BSc. Art (UST) MPhil Sociology (UG)
Benson Kwabena Owusu	Scientific Secretary	BEd. Science (UCC) MPhil Env. Science (Legon)
Paul Fabalona	Accountant	BSc. Accounting (IPS) Chartered Accountant(ICA-Gh.)

Name	**Designation**	**Qualification**
Deborah Ofori	Research Scientist	BSc. Civil Engineering (KNUST) MSc. Env. Res. Eng.(Suny-esf-Syracuse, N.Y.)
Gerard Quarcoo	Research Scientist	B.Ed. Science (UCC) MPhil Env. Science, U.G
Agbeko Etornyo	Research Scientist	BSc. Agric Technology (UDS) MPhil. Fisheries Science (UG)
Akongyuure Daniel	Research Scientist	BSc. Agric Technology (UDS) MPhil. Fisheries Science (UG)
Akrong Mark Osa	Research Scientist	BSc. Biological Sciences (KNUST) MPhil. Environmental Science (UG)
Solomon A. Owiredu	Research Scientist	BSc. Oceanography & Fisheries (UG) MPhil. Fisheries Science (UG)
Saada Mohammed	Research Scientist	BSc. Chemistry (UCC) MSc. Pharmaceutical Analysis & Qual. Control (KNUST)
Mensah Tetteh-Doku Emmanuel	Research Scientist	BSc. Oceanography & Fisheries (UG) MPhil. Fisheries Science (UG)
Kumi Michael	Research Scientist	BSc. Chemistry (UCC) MSc. Env. Science & Tech. (Mid. Sweden Univ.)
Evans Manu	Research Scientist	BSc. Physics (UCC) MSc. Geophysics (KNUST)
Godwin Dorhetso	Accountant	BSc. Accounting (IPS) EMBA Finance (UG)
Thomas K.F. Adom	Asst. Marketing Officer	B. A. Dip. Educ.(UCC) CIM (UK)-Advanced Cert.
Georgina Badu (Mrs)	Assistant Librarian	Dip. Library & Info.Sci. (Legon) BA – Information Studies & Religions (UG)

List of Senior Staff

Name	Designation	Qualification
Patience Atsakpo (Mrs)	Chief Technologist	Higher Dip.Microbio. Lab. Techq. (UG)
Wilhemina Tetteh	Principal Technologist	Higher Dip.Microbio. Lab. Techq. (UG)
Kenneth N. Atsakpo	Principal Technologist	H.Dip. Analytical Chem. Lab. Techq. (UG)
Grace Dartey (Ms)	Principal Technologist	Higher Dip.Microbio. Lab. Techq. (UG)
Michael Dorleku	Senior Technologist	BSc. Laboratory Technology (UCC)
Nana Y. Biritwum	Chief Stores Superintendent	Cert. Storekeeping(IPS)
Rex John Sapah	Chief Draughtsman	Snr. Sup. Cert. Civil-Building/Roads(ITS-Weija)
James Owusu	Chief Technical Officer	Cert. Gen. Drilling Theory/Practice (UMaT)
Mohammed M Bello	Chief Technical Officer	HND. Science Lab. Tech. (Accra Poly)
Kwame Osei-Mensah	Chief Accounting Asst	BSc. Accounting (IPS)
Charles K. Dzokoto	Chief Accounting Asst	HND Accounting (Tamale Poly)
Johnson C.K. Eworde	Chief Admin. Asst.	GCE 'O' Level
Ahmed Hawa	Principal Tech. Officer	BSc. Biological Sciences, KNUST
William E. Arko	Principal Technical Officer	BSc. Chemistry (UCC)
Martha D. Agyemang	Principal Technical Officer	BSc. Chemistry (KNUST)
Zita Naangmenyele	Principal Technical Officer	BSc. Applied Chemistry (UDS)
Salifu Abdul-Latif	Prin. Technical Officer	HND Ind. Chemistry (Inst. Of Chem.-Cuba)
Harrison Komladzei	Principal Draughtsman	Snr. Sup. Cert. Civil-Building/Roads(ITS-Weija)
Sampson Siaw Krodua	Principal Draughtsman	Snr. Sup. Cert. Civil-Building/Roads(ITS-Weija)
Collins K. Asante-Sasu	Principal Technical Officer	BSc. Agric. Eng. (KNUST)
Sena Niampomah	Principal Technical Officer	GCE "A" Level
Lady A. Frimpong	Principal Technical Officer	BSc. Botany (UG)

Name	**Designation**	**Qualification**
Ruth Amole (Mrs)	Prin. Technical Officer	Dip. Nat. Res. Mgt. (KNUST)
Edward Jenner Tettevi	Prin. Technical Officer	BSc. Molecular Bio. & Biotech. (UCC)
Lilly K. Osei	Principal Technical Officer	BSc. Biological Science (KNUST)
Edem K. Amerdome	Technologist	Higher Dip. Microbiol. Techniques (UG)
Sylvia Amponsah	Principal Technical Officer	BA. Political Science (India)
John H. Baffoe	Principal Accounting Asst.	RSA Stage III Accounting
Johnson-Ashun Mercy	Principal Technical Officer	BSc. Fisheries & Aquatic Science (UG)
Claudia Bentum (Mrs)	Principal Admin. Asst.	BA Public Admin. (GIMPA)
Joyce Osibo	Principal Admin. Asst. (Sect)	Cert. Private Secretary
Millicent Adu-Boakye	Principal Technical Officer	BSc. Chemistry (UCC)
Godfried P.K. Acquaah-Arhin	Prin. Admin. Asst.	BBA Management (VVU)
Linda A. Nuamah	Prin. Technical Officer	BSc. Biological Sciences (UCC)
Christopher Nfojoh Yom	Prin. Technical Officer	BSc. Environmental Science (KNUST)
Quansah Jude Ofei	Prin. Technical Officer	BSc. Chemistry (KNUST)
Benedicta Osei-Tutu	Prin. Admin. Asst.	BSc Human Res. Mgt. (Pent.Univ. Col.)
Emmauel A. Ayizemi	Prin. Technical Officer	Cert. Gen. Drilling Theory/Practice (UMaT)
Alexander A. Dei	Prin. Accounting Asst.	RSA Stage III Accounting
Rebecca Yankson	Senior Admin. Asst (Sect)	RSA Stage III Secretaryship
Vivan Osae	Senior Admin. Asst (Sect)	HND Secretaryship & Mgt. (Accra Poly)
Emmanuel Adu-Ofori	Asst. Technologist	H.Dip. Analytical Chem. Lab. Techq. (IST)
Michael Dankwa Afram	Senior Technical Officer	HND. Science Lab. Tech. (Accra Poly)
Francis Annor Boakye	Senior Technical Officer (Systems Admin.)	City & Guilds. Infor. Technology

Name	**Designation**	**Qualification**
E. Nii. Dodoo Koranteng	Senior Accounting Asst.	DBS Accounting (Accra Poly)
John A. Akuoko-Baafi	Senior Accounting Assistant	Cert. Procurement & Material Mgt. (GIMPA)
Esther Mate-Ahmed (Mrs)	Senior Accounting Assistant	DBS. (Accounting)
Kenneth K. Opare	Snr. Works Supt. (Auto)	Cert.(Jnr) Mech/Elect. Wrkshp. (ITS-Weija)
Eric J. Darko	Senior Technical Officer	Cert. Gen. Agric. (Damango. Agric. College)
Agnes Darko	Senior Admin. Asst. (Sect)	Dip. Management Studies (UCC)
Priscilla Ampofo-Yeboah (Mrs)	Senior Admin. Asst. (Sect)	HND Secretaryship & Mgt. (Accra Poly)
Martin A. Adakpeya	Senior Technical Officer	Cert. Gen. Agric. (Damango Agric. College)
Richard Kwapong Kwayisi	Senior Assistant Printer	Cert. Printing (ITS-Weija)
Gabriel Appiah	Technical Officer	HND. Civil Eng.(Cape Coast Poly)
Eva G. Agbozo (Mrs.)	Admin. Asst.	HND. Sect. & Mgt. (Adv. Bus. College)
Sowah Esther	Technical Officer	Laboratory Technician
Godwin Amegbe	Technical Officer	Higher Dip. Microbiol. Techniques (UG)
Matilda Tagoe	Accounting Assistant	DBS Accounting (Accra Poly)
Eric Yaw Darko	Technical Officer	HND. Civil Eng.(Takoradi Poly)
Dorothy Krodua (Mrs)	Admin. Asst. (Sect)	ABCE (Secretaryship)
Bernice Essegbey (Mrs)	Technical Officer	ABCE. Catering (Accra Poly)
Murjanatu Abdul-Hamid	Technical Officer	HND. Science Lab. Tech. (Accra Poly)
Genevieve G. Kwogana	Admin. Asst. (Sect)	DBS Secretaryship & Mgt. (Tamale Poly)
Alex Yeboah	Accounting Asst.	HND Accounting (Accra Poly)
Doris Ohene-Lartey (Mrs)	Accounting Asst.	ABCE (Accounting)
Mark Boateng Ofori	Stores Superintendent	HND Purchasing & supply
John K. Kpamah	Asst. Transport Officer	Cert. Of Att. Transport Mgt. (STC-Accra)

Name	**Designation**	**Qualification**
Alex A. Yeboah	Asst. Transport Officer	Cert. Of Att. Transport Mgt. (STC-Accra)
Samuel Annang	Asst. Transport Officer	Cert. Of Att. Transport Mgt. (STC-Accra)
Edem K. Ayegbe	Asst. Transport Officer	Cert. Of Att. Transport Mgt. (STC-Accra)
Matthew Kwara	Asst. Transport Officer	Cert. Of Att. Transport Mgt. (STC-Accra)
Samuel K. Nikoi	Asst. Transport Officer	Cert. Of Att. Transport Mgt. (STC-Accra)
Benjamin K. Kodjo	Works Superintendent	Cert. Wielding Technician
Samuel K. Osafo	Works Superintendent	Cert.(Jnr) Mech/Elect. Wrkshp. (ITS-Weija)
Simon K. Anane	Estate Assistant	Full Tech. Cert., Const. Tech. (Accra Poly)
Appiah-Odei Matilda (Mrs.)	Supt. Telephonist/Receptionist	Cert. Advance Customer Care (Gh. Telecom Univ. College)
Samuel Kanati	Administrative Assistant	Univ. Diploma – Public Admin. (UG)
Solomon Mensah	Technical Officer	Cert. General Drilling Theory & Pract.(UMT)
Frank Oblim	Technical Officer	HND Civil Engineering
Jonas Asamoah	Works Superintendent	Cert. Civil, Building/Road (ITS-Weija)
Ebenezer Mensah	Works Superintendent	Cert. Effective Practice of Supt. (Weija)
Ex. WO1 Samuel D.N. Kotei	Security Officer	MSLC
Anthony Arko	Security Officer	MSLC

APPENDIX IV: Human Resource Activities

New Appointment

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Appointment
1	Dr. Joseph Addo Ampofo	Director	Senior Member	Directorate	01/01/12
2	Dr. Philip Gyau-Boakye	Deputy Director	Senior Member	Directorate	01/01/12

Temporary Appointment

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Appointment
1	Nkansah Edwin (Dr.)	Research Scientist	Senior Member	Env. Biology & Health	15/6/12
2	Ofori-Agyeman Michael Carl	Research Scientist	Senior Member	Groundwater (Tamale)	1/9/11
3	Osae-Sekyi Rhoda Lims (Mrs.)	Research Scientist	Senior Member	Fishery	1/5/12
4	Appiah SerapisAsiedu	Principal Technical Officer	Senior Staff	Env. Chemistry	4/6/12
5	Mante Victor	Principal Technical Officer	Senior Staff	Env. Chemistry	20/7/12
6	Agadzi Yaa Asabea	Senior Technical Officer	Senior Staff	Fishery (Tamale)	1/9/12
7	Appiah Joyce Ofosuah	Administrative Assistant	Senior Staff	Administration (ARDEC, Akosombo)	19/11/12
8	Abdulai Salima	Administrative Assistant	Senior Staff	Administration (Tamale)	1/08/12
9	Niekye Mike Ben	Security Officer	Senior Staff	Security (ARDEC, Akosombo)	1/5/12
10	Amenyo Millicent	Caretaker	Junior Staff	Administration (ARDEC, Akosombo)	16/5/12
11	Adjei Enoch	Labourer	Junior Staff	Estate (ARDEC, Akosombo)	1/11/12
12	Goka Frank K.	Security Assist. Gd.I	Junior Staff	Security	10/7/12
13	Lopez Amedorme	Security Assist. Gd.II	Junior Staff	Security (ARDEC, Akosombo)	20/9/12
14	Morkeh Anthony Kolora	Security Assist. Gd.I	Junior Staff	Security	10/7/12
15	Zoka Moses	Security Assist. Gd.II	Junior Staff	Security (ARDEC, Akosombo)	20/9/12

Contract Appointment

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Appointment
1	Godfred Yeboah	Senior Technical Officer	Senior Staff	Fishery	1/11/12

Promotions

Senior Members

No.	Name	Division/Section	From	To	Effective Date of Promotion
1	Hederick R. Dankwa (Dr.)	Fishery	Senior Research Scientist	Prin. Research Scientist	1/1/10
2	Benony K. Kortatsi (Dr.)	Groundwater	Prin. Research Scientist	Chief Research Scientist	1/1/09
3	Philip Gyau-Boakye (Dr.)	Directorate	Prin. Research Scientist	Chief Research Scientist	1/1/11
4	Isaac O.A. Hodgson (Dr.)	Env. Chemistry	Senior Research Scientist	Prin. Research Scientist	1/1/08
5	Francis Amevenku	Fishery	Research Scientist	Senior Research Scientist	1/1/11
6	Ruby Asmah (Dr.)	Env. Chemistry	Research Scientist	Senior Research Scientist	1/1/10
7	Mike Osei-Atweneboana	Env. Biology & Health	Research Scientist	Senior Research Scientist	1/1/11

Senior Staff

No.	Name	Division/Section	From	To	Effective Date of Promotion
1	Patience Atsakpo (Mrs.)	Chemistry	Principal Technologist	Chief Technologist	1/1/10
2	Grace Dartey	Chemistry	Senior Technologist	Principal Technologist	1/1/10
3	Ken Atsakpo	Fishery	Senior Technologist	Principal Technologist	1/1/10
4	Wilhelmina Tetteh	Env. Biology & Health	Senior Technologist	Principal Technologist	1/1/10
5	Emmanuel Ayizemi	Groundwater	Senior Technical Officer	Principal Tech. Officer	1/1/12
6	Eric Justice Darko	Groundwater	Technical Officer	Senior Technical Officer	1/1/11
7	Alexander Dei	Accounts	Senior Accounting Asst.	Prin. Accounting Asst.	1/1/12
8	Solomon Mensah	Groundwater	Senior Tech. Asst.	Technical Officer	1/1/12
9	Priscilla Ampofo-Yeboah	Administration	Administrative Asst	Senior Admin. Asst.	1/1/12
10	Martin Adakpeya A.	Fisheries (Tamale)	Technical Officer	Senior Technical Officer	1/1/12
11	Richard K. Kwayisi	CID	Printing Assistant	Senior Print. Asst.	1/1/12
12	Matilda Appiah-Odei (Mrs.)	Administration	Principal Telephonist	Supt. Telephonist	1/1/12
13	Matilda Tagoe	Accounts	Senior Accounts Clerk	Accounting Assistant	1/1/12
14	Eva Gertrude Agbozo (Mrs.)	Administration	Senior Clerk	Admin. Assistant	1/1/09
15	Ebenezer Dickson Mensah	Estate	Foreman	Works Superintendent	1/1/12
16	Jonas Asamoah	Estate	Foreman	Works Superintendent	1/1/12

Junior Staff

No.	Name	Division/Section	From	To	Effective Date of Promotion
1	Eric Pappoe	Transport/Workshop	Driver Grade I	Driver Inspector	1/2/12
2	Kingsley Okyere	Transport/Workshop	Driver Grade I	Driver Inspector	1/1/12
3	Kennedy Asante	Transport/Workshop	Driver Grade I	Driver Inspector	1/1/12
4	Lawson Maximillian	CID	Tech. Assist. GD.II	Tech. Asst. GD.I	1/1/12
5	John Adjei	Estate	Tradesman Gd. II	Tradesman Gd.I	1/1/12
6	Daniel Aboagye	Security	Security Asst. Gd.I	Snr. Security Asst.	1/1/12
7	Jones Ofori	Security	Security Asst. Gd.II	Security Asst. Gd.I	1/1/12
8	Charles Bonful	Security	Security Asst. Gd.II	Security Asst. Gd.I	1/1/12
9	Cephas Dzah	Security	Security Asst. Gd.II	Security Asst. Gd.I	1/1/12
10	Robert Soh	Fishery	Fishing Asst. Gd.I	Snr. Fishing Asst.	1/1/12

Upgrading

Senior Staff

No	Name	Division/Section	From	To	Effective Date of Promotion
1	Godwin Amegbe	Env. Biology & Health	Senior Tech. Asst.	Technical Officer	1/2/12
2	Agnes Darko (Mrs.)	Administration	Administrative Asst.	Senior Admin. Asst.	11/10/09
3	Benedicta Osei-Tutu(Mrs.)	Administration	Senior Admin. Asst	Principal Admin. Asst	2/8/11
4	Godfried Acquaah-Arhin	Administration	Senior Admin. Asst	Principal Admin. Asst	27/11/11

Junior Staff

No.	Name	Division/Section	From	To	Effective Date of Promotion
1	Joseph Arhin	Estate	Headman Ordinary	Senior Headman	1/1/12
2	Daniel Tagoe	Estate	Headman Ordinary	Senior Headman	1/1/12
3	Rockson Ofosu	Estate	Cleaner	Headman Ordinary	1/1/12
4	Richard Kumi	Estate	Senior Headman	Supervisor Grade II	1/1/12
5	Peter Ayadao	Estate	Cleaner	Headman Ordinary	1/1/12
6	Samuel Abbey	Estate	Senior Headman	Supervisor Grade II	1/1/2008
7	Peter Amina	Estate	Senior Headman	Supervisor Grade II	1/1/10
8	Kofi Asante	Estate	Senior Headman	Supervisor Grade II	1/1/09
9	Sumani Abdul-Fatawu	Estate	Senior Headman	Supervisor Grade II	1/1/11

10	Abraham Tetteh	Estate	Senior Headman	Supervisor Grade II	1/1/11
11	Jonas Darkey	Estate	Cleaner	Headman Ordinary	1/1/11
12	Stephen Agyeman	Estate	Headman (Ordinary)	Senior Headman	1/1/11

Leave-Without-Pay

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Leaving
1	Joyce Amoako (Mrs)	Research Scientist	Senior Member	Env. Chemistry	09/11/11

Transfers

No.	Name	Designation	Category of Staff	Division/Section	Organization
1	Dr. Benony K. Kortatsi	Prin. Res. Scientist	Senior Member	Groundwater	Min. of Env. Science & Technology
2	Samuel Kotey Nikoi	Asst. Transport Officer	Senior Staff	Transport/Workshop	CSIR-Head Office

Compulsory Retirement

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Retirement
1	Dr. Benony K. Kortatsi	Chief Research Scientist	Senior Member	Groundwater	31/07/12
2	Sampson Akrasi	Snr. Research Scientist	Senior Member	Surface Water	31/04/12
3	Joshua Osuteye	Prin. Stores Supt.	Senior Staff	Finance-Stores	31/04/12
4	Samuel Baah	Chief Tech. Officer	Senior Staff	Surface Water	31/08/12
5	Robert Azongo	Snr. Works Supt.	Senior Staff	Workshop	30/06/12
6	Samuel O. Agyei	Asst. Transport Officer	Senior Staff	Transport	30/06/12
7	Samuel Teivi	Prin. Works Supt.	Senior Staff	Transport	31/07/12
8	Sampson Dorgbadzi	Supervising Watchman	Junior Staff	Estate (ARDEC, Akosombo)	30/02/12
9	Martin Dorgbadzi	Supervising Watchman	Junior Staff	Estate (ARDEC, Akosombo)	31/08/12
10	Daniel Aboagye	Security Assistant Gd.I	Junior Staff	Security	31/09/12
11	Abubakari Agumah	Supervising Watchman	Junior Staff	Estate	31/04/12
12	Mama Sisala	Supervising Watchman	Junior Staff	Estate	30/06/12
13	Richard Amekudzi	Senior Headman	Junior Staff	Estate	28/02/12
14	Busanga Abdulai	Supervising Watchman	Junior Staff	Estate	30/06/12

Deaths

No.	Name	Designation	Category of Staff	Division/Section	Date of Death
1	Mahama Salifu Forko	Junior Foreman	Junior Staff	Estate	22/01/12
2	Gladys Hagan (Mrs.)	Snr. Clerk (Secretarial)	Junior Staff	Administration	17/2/12

APPENDIX V: Staff Pursuing Courses

No.	Name of Officer	Designation	Division/Section	Training Instituition	Course Title	Duration	Date Started	Expected Date of Return	Sponsorship Status
1	Kwadwo A. Asante	Snr. Res. Scientist	Environ. Chemistry	Ehim Univ. - Japan	**PhD**-Env. Chem. & Ecotoxicology	3 years (ext. 1yr)	Apr-09	Mar. 2013	Ehim Univ. & CSIR
2	Anthony Y. Karikari	Snr. Res. Scientist	Environ. Chemistry	KNUST	**PhD**- Aquaculture & Env. Management	3years	Dec-2012	Dec. 2015	CSIR
3	George T. Mensah	Research Scientist	Env. Biology & Health	UG Medical School	**PhD**-Microbiology	3years	Aug. 2010	Jul. 2013	CSIR
4	Collins Tay	Snr. Res. Scientist	Environ. Chemistry	Univ. of Ghana	**PhD**-Environmental Science	3years	Jan. 2011	Jan.2014	CSIR
5	Bernice K. Essegbey (Mrs)	Technical Officer	CID-Library	Inst. of Prof. Stds	**BSc**-Marketing	4years	Aug. 2009	Aug. 2013	CSIR
6	Alfred A. Adjei	Snr. Accts. Clerk	Finance	Inst. of Prof. Stds	**BSc**-Accounting	4years	Aug. 2009	Aug. 2013	CSIR
7	Michael A. Danquah	Senior Tech. Officer	Environ. Chemistry	UCC	**BSc.**-Science Lab. Tech.	2years	Aug. 2012	July 2014	CSIR
8	Harrison Komladzie	Prin. Draughtsman	CID-Cartography	Gh. Sch. Of surveying and Mapping	**HND**-Surveying & Mapping	2years	Aug. 2011	Jul. 2013	CSIR
9	Francis Anani Assogba	Research Scientist	Fishery	Univ. of Ghana	**PhD**-Fisheries Science	3years	Aug. 2011	Jul. 2014	CSIR
10	Mustapha B. Mohammed	Chief Tech. Officer	Env. Biology & Health	Accra Poly	**BTech**-Science Lab. Technology	18months	Nov. 2011	Mar. 2013	CSIR
11	Zita Naangmenyele	Prin. Tech. Officer	Environ. Chemistry	Inst. Of Water Education, Delft-Netherlands	**MSc**-Environmental Science	2years	Oct. 2012	Sept. 2014	UNESCO-IHE

APPENDIX VI: National Service and Industrial Attachment

National Service Personnel Posted to the Institute in 2012

No.	Name	Institution	Division/Section Attached to
1	Adomako Randy	KNUST	Environmental Chemistry
2	Lee Angela	University of Ghana	Environmental Chemistry
3	Ansong Eunice Acheama	KNUST	Environmental Chemistry
4	Nortey Lionel	KNUST	Environmental Chemistry
5	Emmanuel Ahenkora	Accra Polytechnic	Environmental Chemistry
6	Asuo Grace Baffour	University of Cape Coast	Environmental Chemistry
7	Francis Danso	Accra Poly	Environmental Chemistry
8	Eva Dzadey	Accra Polytechnic	Environmental Chemistry
9	Ahmed Munir	University of Cape Coast	Surface Water
10	King-Brain Ziwu	Accra Polytechnic	Commercialization & Information
11	Marble Anderson	IPMC	Commercialization & Information
12	Attoh Oko Michael	Central University College	Commercialization & Information
13	Gakpa Gifty Yayra	University of Cape Coast	Environmental. Biology & Health
14	Ayikpoe Richard Selorm	University of Ghana	Environmental Biology & Health
15	Osei Sylvester	Inst. Of Professional Studies	Finance
16	Rita Atiemo	Koforidua Poly	Finance
17	Dennis Nyarko	Centre for Business Studies	Finance
18	Bernard Mensah Kwakye	Pre-Meridian University	Finance
19	Sambo Janet	All Nations Univ. College	Fishery, ARDEC-Akosombo
20	Nartey Richard	University of Cape Coast	Fishery, ARDEC-Akosmbo
21	Chuku Ernest	University of Cape Coast	Fishery, ARDEC-Akosombo
22	Appiah O. Theophilus	KNUST	Fishery, ARDEC-Akosombo
23	Agbo Jean O.	University of Cape Coast	Fishery, ARDEC-Akosombo
24	Ofori-Duodu Henry	University of Cape Coast	Fishery, ARDEC-Akosombo

25	Adjei-Addo Joycelyn	Ho Polytechnic	Fishery, ARDEC-Akosombo
26	Papa Teming	University of Cape Coast	Fishery, ARDEC-Akosombo

Attachment Personnel Posted to the Institute in 2012

No.	Name	Institution	Course	Division/Section Attached to
1	Cynthia Samman	Central University	BSc. Accounting	Accounts
2	Obeng Kate	Ho Poly	Accountancy	Accounts
3	Emelia Asabouk	Cape Coast Poly	Accountancy	Accounts
4	Owusu Nyarko Obed	KNUST	Accountancy	Accounts
5	Bernard Akrong	Accra Poly	Accountancy	Accounts
6	Fauzuah Mohammed Seidu	IPS	Management	Administration
7	Esther Adu-Boahen	Central University	BSc. Human Resource Mgt.	Administration
8	Gifty Annang	UCC	B.A (Eng. & History)	Administration
9	Rita Acheampong	Valley View University	Business Admin. Mgt.	Administration
10	Bright Asare	UCC	Fisheries & Aquatic Sciences	Administration
11	Diana K. Fobi	Govt. Sect. School	Stenographer Gd. II	Administration
12	Sika Menka	University of Ghana	BSc. Chemistry	Environmental Chemistry
13	Griffiths Sena K. Dzotepe	KNUST	Chemical Engineering	Environmental Chemistry
14	Emmanuel Salifu	UCC	Laboratory Technician	Environmental Chemistry
15	Asare Nsiah	UCC	Lab. Tech.	Environmental Chemistry
16	Hayford Kenneth	UCC	Lab. Tech.	Environmental Chemistry
17	Abraham Oko Etse	Accra Poly	Laboratory Technician	Environmental Chemistry
18	Masawudu Razak	Accra Poly	Laboratory Technician	Environmental Chemistry
19	Aborgeh Godwin	UCC	Chemistry	Environmental Chemistry
20	Amo-Koi Seth	UCC	Lab. Tech.	Environmental Chemistry
21	Birikorang Boah B. Junior	KNUST	Chemistry	Environmental Chemistry
22	Larkai Kiven L. Nii Nonoo	KNUST	Environmental Chemistry	Environmental Chemistry

No.	Name	Institution	Course	Division/Section Attached to
23	Komfa Arnold	Accra Poly	Lab. Tech.	Environmental Chemistry
24	Hormeku Hope	Accra Poly	Lab. Tech.	Environmental Chemistry
25	Priscilla Lomokua-Amlalo	Accra Poly	Lab. Tech.	Environmental Chemistry
26	Frank Oppong Twumasi	Accra Poly	Lab. Tech.	Environmental Chemistry
27	Freda Kwarteng Boampong	Accra Poly	Lab. Tech.	Environmental Chemistry
28	Edward Gomado	Kumasi Poly	Chemical Engineering	Environmental Chemistry
29	Eugenia Tenkorang	University of Ghana	Information Studies	Commercialization & Information
30	Nii Lamptey Badu	Pent. Univ. College	Eng. Health & Computing	Commercialization & Information
31	Akagbo Godwin	Ho Poly	Marketing	Commercialization & Information
32	Abigail Anne Bimpeh	University of Ghana	Linguistics/Classics	Commercialization & Information
33	Edna Adjei-Bruce	Univ. of Mines & Tech.	Computer Science Engineering	Commercialization & Information
34	Kenny Mensah Graham	KNUST	Earth Science	Groundwater
35	Martey Derrick	Accra Poly	Mechanical (Auto)	Transport
36	Godo Michael	Accra Poly	Mechanical (Auto)	Transport
37	Fatao Abudu	Accra Poly	Mechanical (Auto)	Transport
38	Richard Opoku Asare	UCC	Biological Sciences	Environmental Biology & Health
39	Elorm Attah	UCC	Biological Sciences	Environmental Biology & Health
40	Derrick Appo-Biney	UCC	Biological Sciences	Environmental Biology & Health
41	Miranda C. Cudjoe	KNUST	Biological Sciences	Environmental Biology & Health
42	Kabotey Perpetual Delight	KNUST	Environmental Science	Environmental Biology & Health
43	Francis Lamptey	KNUST	Agric. Engineering	Environmental Biology & Health
44	Abena Afra Twumasi	KNUST	Environmental Science	Environmental Biology & Health
45	Koranteng Nancy Adwoa	KNUST	Environmental Science	Environmental Biology & Health
46	Amponsah Aquilla Kweku	KNUST	Engineering	Surface Water
47	Lenteh Sebastian	KNUST	Civil Engineering	Surface Water
48	Biney Rachel Kwaafoa	KNUST	Agric. Engineering	Surface Water

No.	Name	Institution	Course	Division/Section Attached to
49	Elton Jackson	KNUST	Engineering	Surface Water
50	Linda Kyei	KNUST	Environmental Science	Surface Water
51	Edward Atakorah	KNUST	Agric. Engineering	Surface Water
52	Elsie Akusika Debrah	UCC	Fisheries & Aquatic Sciences	Fishery
53	Afriyie Charles Gyedu	University of Ghana	Fisheries & Aquatic Science	Fishery
54	Sarpong Sefa Michael	University of Ghana	Fisheries & Aquatic Science	Fishery
55	Mark Appiah Kusi	UCC	Fisheries & Aquatic Sciences	Fishery
56	Yvonne Wemegah	UCC	Fisheries & Aquatic Sciences	Fishery

Appendix VII: List of Staff Publications

Conference Papers

Amu-Mensah, F. K. (2012) Rainwater harvesting, engineering considerations for national rollout. Paper presented at the 43rd Engineering Week Celebration and Annual Conference, 28 – 30 March 2012, Accra.

Amevenku, F. K. Y., Kankam-Yeboah, K., Oboubi, E., Namara, R. and Bangwe, M. L. (2012) Assessment of innovative institutional arrangements: The case of Integrated Tamale Fruit Company (ITFC) in Ghana. Paper presented at the annual african technology policy conference and workshop, 19 – 22 November 2012, Addis Ababa.

Ansa-Asare, O. D. (2012) Water resources and water conservation in West Africa: case study of Ghana. Paper presented at the University of Reading, June 2012 UK.

Ansa-Asare, O. D. (2012) The status of CSIR Water Research Institute's laboratory and its capabilities. Paper presented at the workshop for laboratory managers in the African region, 25 – 27 June 2012, The Hague, The Netherlands.

Darko, H. F. and Ansa-Asare, O. D. (2012) Water quality and sources of water pollution in Ghana. Paper presented at the Engineering Week Celebration of the Ghana Institution of Engineers, 29 March 2012, Accra.

Addico, G. (2012) Hepatotoxic-microcystins in two drinking water reservoirs in the Central Region of Ghana. Paper presented at the 17th Faculty of Science Colloquium, University of Ghana, 21 – 23 March 2012, Accra.

Kankam-Yeboah, K. (2012) Ghana country report. Paper presented at the UNESCO Africa regional international hydrological programme meeting, 2 – 27 April 2012, Dar-es-Salam, Tanzania.

Obuobie, E., Kankam-Yeboah, K. and Amisigo, B. (2012) Impacts of population growth and climate change on water availability in the Pra River Basin, Ghana. Paper presented at the International Alumni Summer School, 'water resources and management in a changing world', 24 September – 5 October 2012, University of Bonn, Bonn.

Consultancy Reports

Ansa-Asare, O. D., Okrah, C., Darko, H., Adico, G. N. D., Duah, A. A., Mainoo, P. A. and Agyekum W. A. (2012) Basin level and national IWRM plan – Monitoring groundwater resource occurrences and their quality in the Tano and Pra River Basins with surface water quality monitoring in the South-western, Coastal and Volta Rivers Basins, Vol.1, CSIR-WRI, Accra.

Ansa-Asare O. D., Okrah C., Darko H., Adico G. N. D., Duah A. A., Mainoo P. A. and Agyekum W. A. (2012) Basin level and national IWRM plan – Monitoring groundwater resource occurrences and their quality in the Tano and Pra River Basins with surface water quality monitoring in the South-western, Coastal and Volta Rivers Basins, Vol.2, CSIR-WRI, Accra.

Agyekum W. A. and Okrah C. (2012) Report on pumping test on an existing borehole at the church premises – Christ Congregation Presby Church, Adenta, CSIR WRI, Accra.

Kankam-Yeboah, K., Logah, F. Y. and Ofori, D. (2012) Surface water resources of Northern, Brong-Ahafo and Volta regions of Ghana, CSIR WRI, Accra.

Kankam-Yeboah, K. and Logah, F. Y. (2012) Surface water resources of Tordzie River Basin in the Volta Region of Ghana, CSIR WRI, Accra.

Mainoo, P. A. and Agyekum, W. A. (2012) Hydrogeological and drilling supervision services for two small towns (Wapuli and Wonjuga – Kudani) in Saboba and Chereponi districts of the Northern Region of Ghana, CSIR WRI, Accra.

Mainoo, P. A., Agyekum, W. A. and Duah, A. A. (2012) Report on drilling and construction of boreholes to establish sources of potable water supply in 14 small towns in six selected districts in Brong-Ahafo Region of Ghana, CSIR WRI, Accra.

Manu, E., Agyekum, W. A. and Okrah, C. (2012) Geophysical investigation for borehole siting at the premises of Ghana Standards Authority in Accra, CSIR WRI, Accra.

Okra, C., Ofori Agyeman, C., Mainoo, P. A., Agyekum, W. A. and Duah, A. A. (2012) Geophysical investigation to locate suitable sites for borehole drilling in four selected communities in the Awutu-Senya District using electromagnetic and resistivity geophysical techniques, CSIR WRI, Accra.

Okrah, C., Manu, E., Duah, A. A. and Agyekum, W. A. (2012) Geophysical investigation for borehole drilling at Asiafo-Amanfro in the Yilo Krobo District, CSIR WRI, Accra.

Okrah, C., Agyeman, C. O., Agyekum, W. A., Duah, A. A. and Mainoo, P. A. (2012) Geophysical exploration for borehole drilling site at Atomic-Hills Estate, Accra, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Geophysical investigations for borehole site selection at Ashalebotwe-Malejor, Accra, CSIR WRI, Accra.

Okrah, C., Agyekum, W. A. and Manu, E. (2012) Geophysical investigation for borehole siting at the premises of six SSNIT properties in Accra, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Borehole drilling at a private development site, New-Ashalebotwe, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Geophysical siting of ten boreholes in the Assin-North Municipal using electromagnetic (EM) and resistivity geophysical techniques, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Drilling report on ten boreholes in the Assin-North Municipal, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Geophysical siting of ten boreholes in the Ajumako/Enyan/Esiam District using electromagnetic (EM) and resistivity geophysical techniques, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Drilling report on ten boreholes in the Ajumako/Enyan/Esiam District, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Geophysical siting of five boreholes in the Gomoa West District using electromagnetic (EM) and resistivity geophysical techniques, CSIR WRI, Accra.

Okrah, C. and Agyekum, W. A. (2012) Drilling report on five boreholes in the Gomoa West District, CSIR WRI, Accra.

Okrah, C., Agyekum, W. A. and Manu, E. (2012) Six boreholes drilling at the premises of six SSNIT properties in Accra, CSIR WRI, Accra.

Okrah, C., Manu, E., Duah, A. A. and Agyekum, W. A. (2012) Borehole drilling at the Ghana Standards Authority (GSA) premises, Accra, CSIR WRI, Accra.

Okrah, C., Manu, E., Duah, A. A. and Agyekum, W. A. (2012) Assessment of the groundwater potential to select borehole drilling point on the adjoining plot of the CSIR Sircool Factory, CSIR WRI, Accra.

Journal Papers

Adjei, K. A., Ren, L., Appiah-Adjei, E. K., Kankam-Yeboah, K. and Agyapong, A. A. (2012) Validation of TRMM data in the Black Volta Basin of Ghana, *Journal of Hydrologic Engineering, ASCE, doi:10.1061/*(ASCE)HE.1943-5584.0000487, 647-653.

Agyekum, W., Klitten, K., Armah, T., Banoeng-Yakubo, B. and Amartey, E. (2012) Geophysical borehole logging for control of driller's records – hydrogeological case study from Voltaian sedimentary rocks in Northern Ghana. *Journal of Applied Water Science.*

Akongyuure, D. N., Ofori-Danson, P. K. and Nunoo, F. K. E. (2012) Selectivity and fish catches of gillnets in stratum VII (Yeji sector) of Lake Volta for sustainable management. *Int. J. Fish. Aquaculture*, Vol. 4(3), pp. 41-54.

Akrong, M. O., Cobbina, S. J. and Ampofo, J. A. (2012) Assessment of heavy metals in lettuce grown in soils irrigated with different water sources in the Accra Metropolis. *Journal of Environmental and Earth Science* 4(5): 576-582 (May, 2012).

Akrong, M. O., Ampofo, J. A. and Danso, S. K. A. (2012) The quality and health implications of urban irrigation water used for vegetable production in Accra. *Journal of Environmental Protection*, 2012, 3, 1509-1518.

Amartey, E. O., Akiti, T. T., Armah,T., Banoeng-Yakubo,B., Osae, S., Agyekum, W. A., Mainoo,P., Asumadu-Sakyi, A. B., Adjei,C. A., Wordson, D. A. and Quashie, F. K. (2012) Defining fracture thickness in some crystalline basement rocks of Ghana using integrated surface geophysics and borehole logging techniques. *Journal of Applied Water Science.*

Amevenku, F. K. Y., Kortastsi, B. K. and Anornu, G. K. (2012) Water resource assessment of the Manya Krobo District of Ghana. *Global Journal of Researches Incorporated (GJRE)*. Vol. 12 Issue 3 version 1.0

Amu-Mensah F. K., Yamamoto T. and Inoue M. (2012) Investigating rainwater harvesting on highly permeable soils - baseline conditions, *Ghana Journal of Science* (In Press)

Amu-Mensah F. K. and Yamamoto, T. (2012) Improving soil surface conditions for enhanced rainwater harvesting on permeable soils, *Ghana Journal of Science* (In Press)

Ansa, E. D. O., Allotey, G. K., Lubberding, H. J., Ampofo, J. A. and Gijzen, H. J. (2012) Performance of a hybrid algal and duckweed pond system treating raw domestic wastewater. *Ghana Journal of Science,* Vol 52.

Ansa, E. D. O., Acheampong, M. A**.,** Nkrumah, F. K., Dorgbetor, W. H. K. and Boakye-Yiadom, S. (2012) Faecal coliform attachment to algae and suspended solids in natural wastewater treatment systems. *Ghana Journal of Science,* Vol 51.

Ansa, E. D.O, Lubberding, H. J., Ampofo, J. A, Amegbe, G. and Gijzen, H. J. (2012) Attachment of faecal coliform and macro-invertebrate activity in the removal of faecal coliform in domestic wastewater treatment pond systems. *Ecological Engineering*, 42: 35-41.

Asante, K. A., Agusa, T., Biney, C. A., Agyekum, W. A., Bello, M., Otsuka, M., Itai, T., Takahashi, S. and Tanabe, S. (2012) Multi-trace element levels and arsenic speciation in urine of e-waste recycling workers from Agogbloshie, Accra in Ghana. *Journal of the Total Environment,* 424 (2012), pp 63-73.

Asare-Nkansah, S., Kwakye, J. K. and Mohammed, S. (2011) Compounds chemically related to Analyte as surrogate reference standards in quantitative HPLC: Preliminary study and proof of hypothesis. *International Journal of Pure & Applied Chemistry*. Vol. 6. 3, 253-264.

Bekoe, E. O., Logah, F. Y., Kankam-Yeboah, K. and Amisigo, B. (2012) Low flow characterization of a coastal river in Ghana. *International Journal of Modern Engineering Research (IJMER)* Vol. 2. Issue 5, Sept-Oct, pp-3210-3219. ISSN: 2249-6645.

Boamponsem, G. A., Kumi, M. and Debrah, I. (2012) Heavy metals accumulation in cabbage, lettuce and carrot irrigated with wastewater from Nagodi mining site in Ghana. *International Journal of Science and Technology Research.*Vol.1, Issue 11. Pg 124-129.

Cobbina, J. S., Nyame, F. and Obiri, S. (2012) Multivariate statistical assessment of groundwater quality in the Tolon – Kumbugu District, Ghana. *Res. J. Environ. Earth Sciences*. Vol. 4(1), pp 88 – 98

Gyampo, M. A., Ntiforo, A. and Kumi, M. (2012) Assessment of heavy metals in wastewater irrigated lettuce in Ghana: The case of Tamale Municipality. *Journal of Sustainable Development.* vol 5, No. 11; pg 93-102.

Gyau-Boakye, P. and Ofori, D. (2012) Climate change and water management in communities to adapt to declining water resources in Ghana. *Journal of Science* (In-Review).

Kankam-Yeboah, K., Obuobie, E., Amisigo, B. and Opoku-Ankomah, Y. (2012) Impact of climate change on streamflow in selected river basins in Ghana, *Hydrological Sciences Journal,* HSJ-2011-0262.R2.

Kumi, M. and Agyekum, W. (2012) Modelling the success rate of borehole drilling in Northern Ghana. *Ghana Journal of Science*.

Lawton, L., Edwards, C. and Addico, G. N. D. (2012) Hepatotoxic-microcystins in two drinking water reservoirs in the Central Region of Ghana. *University of Ghana Science Journal*.

Obiri, S., Armah, F. A. and Luginaah, I. (2012) Assessing environmental exposure and health impacts of gold mining in Ghana. *Toxicol. Environ. Chemistry*. Vol. 1, pp 1 – 13

Obiri, S., Armah, F. A., Cobbina, J. S. and Luginaah, I. (2012) Assessment of cancer and non – cancer health risks from exposure to PAHs in street dust in the Tamale Metropolis, Ghana. *J. Env. Science and Health.*

Obuobie, E., Ofori, D., Agodzo, A. and Okra, C. (2012) Groundwater potential for dry season irrigation in Northern Ghana, *Water International* (In-Review).

Obuobie, E., Kankam-Yeboah, K., Amisigo, B., Opoku-Ankomah, Y. and Ofori, D. (2012) Assessment of vulnerability of river basin in Ghana to water stress conditions under climate change. *Journal of Water and Climate Change,* 3(4), pp 276-286.

Obuobie, E., Diekkrueger, B., Agyekum, W. and Agodzo, S. (2012) Groundwater level monitoring and recharge estimation in the White Volta River Basin of Ghana. *Journal of African Earth Sciences,* 71-72 (2012) 80-86.

Wilson, M. D., Osei-Atweneboana, M., Boakye, D. A., Osei-Akoto, I., Obuobie, E., Wiafe, C. and Kiszewski, A. (2012) Efficacy of DEET and non-DEET-based insect repellents against bites of *Simulium damnosum* vectors of Onchocerciasis. *Medical and veterinary entomology*, doi: 10.1111/j.1365-2915.2012.01054.x

Technical Reports/Papers

Agyekum, W. A. (2012) Borehole drilling and pumping test supervision for Berekum (Adom, Kato and Jendede communities), CSIR WRI, Accra.

Akpabey, F. J. (2012) Quantification of the cross sectional impact of water weeds and their control in Ghana, CSIR WRI, Accra.

Ansa, E. D. O. (2012) Seasonal comparison of the diversity of macro-invertebrates in the Odaw River, CSIR WRI, Accra.

Ansa, E. D. O. and Ampofo, J. A. (2012) A survey of molluscan snails along the Weija Lake and its health implications, CSIR WRI, Accra.

Darko, H. F. and Hodgson, I. O. A. (2012) Characteristics of cocaine, sodium bicarbonate and sodium carbonate, CSIR WRI, Accra.

Duah, A. A. (2012) Final report on groundwater development in ten selected communities as addendum to the fifteen communities in the Fanteakwa district under the local service delivery and governance programme, CSIR WRI, Accra.

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