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QUALITY RESEARCH

SUSTAINABLE WATER FOR DEVELOPMENT

CSIR WATER RESEARCH INSTITUTE

ACCRA, GHANA

ACRONYMS

AAS	-	Atomic Absorption Spectrophotometer
AEO	-	Agricultural Extension Officer
AGRA	-	Alliance for Green Revolution in Africa
AIWMS	-	Agro-forestry and Integrated Water Management Specialists
AMA	-	Accra Metropolitan Assembly
ARDEC	-	Aquaculture Research and Development Centre
ARR	-	Acute Risk Ratio
ASFA	-	Aquatic Sciences and Fisheries Abstract
ASTI	-	Agricultural Science Technology and Innovations
BDC	-	Basin Development Challenges
BMZ	-	German Federal Ministry for Economic Cooperation and Development
BOD	-	Biochemical Oxygen Demand
CIDA	-	Canadian International Development Agency
COD	-	Chemical Oxygen Demand
CPUE	-	Catch Per Unit Effort
CPWF	-	Challenge Programme on Water and Food
CSIR	-	Council for Scientific and Industrial Research
CWSA	-	Community Water and Sanitation Agency
DANIDA	-	Danish International Development Agency
DO	-	Dissolved Oxygen
EIA	-	Environmental Impact Assessment
EPA	-	Environmental Protection Agency
FAO	-	Food and Agriculture Organization
FC	-	Forestry Commission
FCR	-	Food Conversion Ratios
FDB	-	Food and Drug Board
GAA	-	Ghana Aquaculture Association
GCLME	-	Guinea Current Large Marine Ecosystem
GEF	-	Global Environment Facility of the World Bank
GGL	-	Goldfields Ghana Limited
GIDA	-	Ghana Irrigation Development Authority
GIS	-	Geographic Information System
GIZ	-	Gesellschaft für International Zusammenarbeit
GMA	-	Ghana Meteorological Agency
GOPDC	-	Ghana Oil Palm Development Company
GWCL	-	Ghana Water Company Limited
GWD	-	Ghana Wildlife Division
HDLV	-	High Density Low Volume
HSD	-	Hydrological Services Department
IAB	-	Institute of Aquatic Biology
ICATWS	-	International Conference on Appropriate Technology for Water and Sanitation
IGF	-	Internally Generated Funds
IHP	-	International Hydrological Programme
IOC	-	Intergovernmental Oceanographic Commission
ISSER	-	Institute of Statistical, Social and Economic Research

IUCN	-	World Conservation Union
IWMI	-	International Water Management Institute
IWRM	-	Integrated Water Resources Management
IWT	-	Institute of Water Technology
IMC	-	Internal Management Committee
KCCR	-	Kumasi Centre for Collaborative Research
KNUST	-	Kwame Nkrumah University of Science and Technology
MC	-	Minerals Commission
MEST	-	Ministry of Environment, Science and Technology
MoFA	-	Ministry of Food and Agriculture
MWRWH	-	Ministry of Water Resources Works and Housing
NAP	-	National Action Plan
NGO	-	Non-Governmental Organization
NMIMR	-	Noguchi Memorial Institute for Medical Research
NTDs	-	Neglected Tropical Diseases
RLWRDS	-	Research Library and Water Resources Documentation System
ROI	-	Return on Investment
SDRCP	-	Sustainable Development of Research Capacity Programme
SNAS	-	School of Nuclear and Allied Sciences
SSA	-	Sub-Saharan Africa
SWAT	-	Soil and Water Assessment Tool
TDA	-	Transboundary Diagnostic Analysis
TDS	-	Total Dissolved Solids
TWQR	-	Target Water Quality Range
UDS	-	University for Development Studies
UNEP	-	United Nations Environment Programme
UNESCO	-	United Nations Education, Scientific and Cultural Organisation
UNIDO	-	United Nations Industrial Development Organisation
UNU/INRA	-	United Nation University – Institute for Natural Resource in Africa
VBA	-	Volta Basin Authority
VLTC	-	Volta Lake Transport Company
VRA	-	Volta River Authority
WARDA	-	West Africa Rice Development Agency
WATSAN	-	Water and Sanitation
WHO	-	World Health Organisation
WRC	-	Water Resources Commission
WRI	-	Water Research Institute
WRRI	-	Water Resources Research Institute
WRIS	-	Water Resources Information Services
WSF	-	Water Storage Facility
ZEF	-	Centre for Development Research of the University of Bonn, Germany

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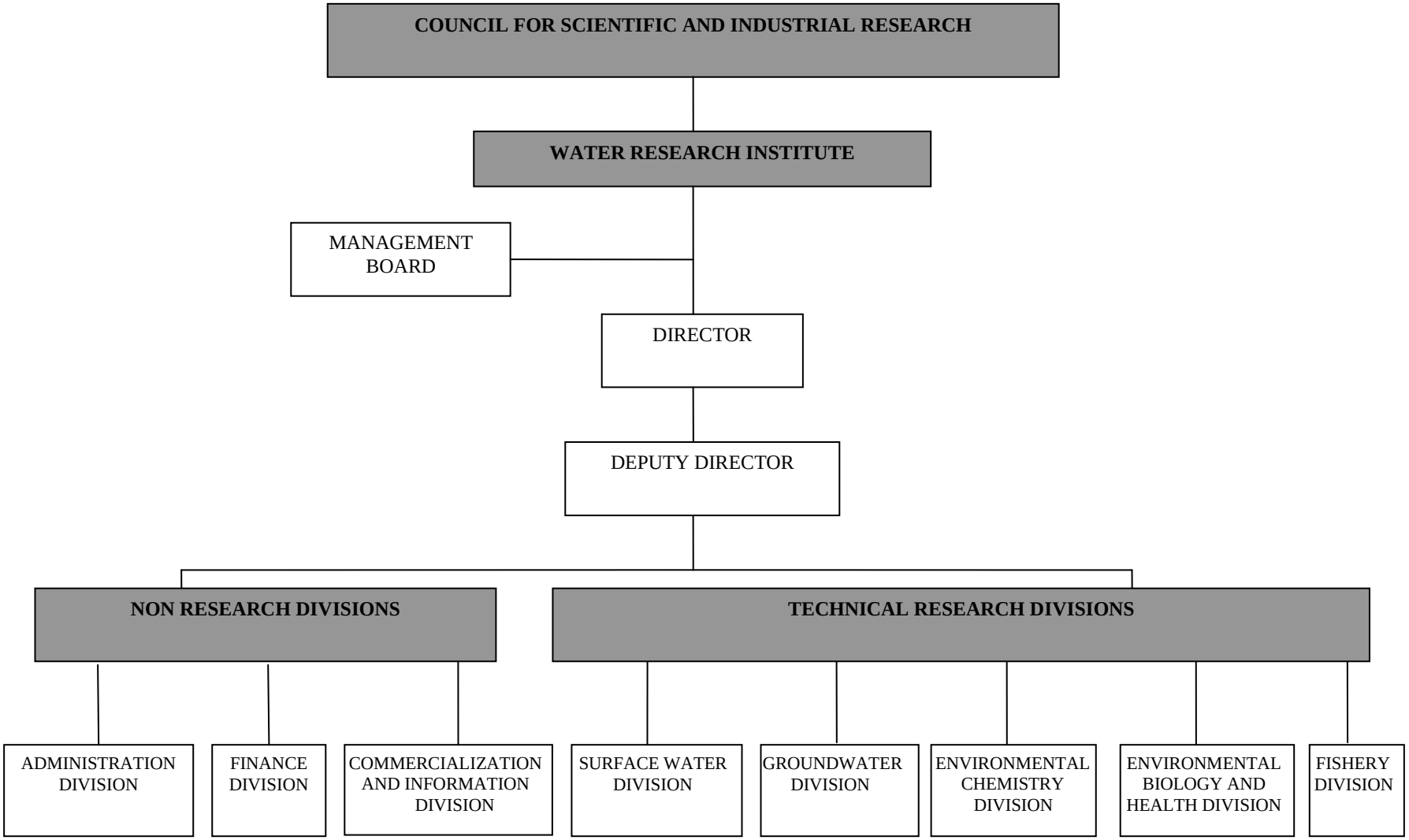


EXECUTIVE SUMMARY

Introduction

CSIR Water Research Institute is one of the 13 institutes of the Council for Scientific and Industrial Research (CSIR). Its mandate is to conduct research into water and related resources through the generation and provision of scientific information, strategies and services towards the rational development, utilisation and management of water resources of Ghana in support of socio–economic advancement of the country.

The mandate of the Institute is realized through the research and development activities of eight (8) Divisions namely Groundwater Division, Surface Water Division, Environmental Chemistry Division, Environmental Biology and Health Division, Fishery Division, Commercialization and Information Division, Administration Division and Finance Division. For the year 2010, summaries of the research activities of the five (5) technical Divisions of the Institute included the following:

SURFACE WATER DIVISION

1. Hydro-Meteorological Database Management

The hydro-meteorological data base management system was instituted by the CSIR Water Research Institute (WRI) to generate and provide hydro-meteorological data from the Institute's synoptic station (05° 35705N, 00° 11105W; altitude 45.72 m) to support the Institute's research activities and that of other research agencies. The main parameters measured and compiled in the reporting year were rainfall, temperature, evaporation, sunshine duration and wind-run.

Evaporation was generally higher than rainfall. Comparatively, the total annual rainfall for the year was 815 mm while the highest total annual rainfall since the inception of the station (1976 – 2010) was 1284 mm in 2002.

2. Climate Change Effects on Hydrology and Water Resources and Adaptation Strategies in Ghana

This project focused on the impact of climate change on watershed hydrology and surface water resources in Ghana. The main objective of this project was to generate scientifically based impact-specific information that could be used to directly inform the preparation of local and national action plans on climate change adaptation in Ghana.

In the year under review, SWAT was successfully set-up, calibrated and validated for the White Volta and Pra River basins using measured streamflow data for the stream gauges at Nawuni (White Volta basin) and Twifo Praso (Pra basin). Monthly calibration and validation showed that the R^2 and NSE were greater than 0.70 and 0.68 respectively, for the two basins. Under the assumption of 100 % water usage in the two basins, the White Volta basin would experience water stress before 2020 and water scarcity after 2020, with or without climate change. However, with the effects of climate change, the basin would experience absolute scarcity condition before 2050. With the current water stress condition of the Pra basin, it is expected to aggravate to water scarcity conditions before 2020, with or without climate change. It was recommended that integrated water resources management (IWRM) is needed to ensure a holistic and sustainable management and use of water resources.

3. Groundwater in Sub-Saharan Africa: Implications for Food Security and Livelihood

The overall goal of the project was to enhance the role of groundwater in the provision of improved food security and livelihood in Sub-Saharan Africa and particularly, in AGRA countries including Ghana.

Activities undertaken during the reporting year included selection of groundwater based irrigation sites in the Upper East Region, baseline study, hydrogeological surveys and preparation of country reports on groundwater status in Ghana, Burkina Faso, Mali and Niger. The study showed that groundwater availability in many places in Ghana and Burkina Faso is attributed to fractures, faults and weathering of the rocks and aquifer yields are generally low (average of 2 m^3/h). However, high yields of 100 m^3/h or more are found in the Continental Terminal aquifers in northwestern Burkina Faso and in the Coastal aquifers in southeastern Ghana.

4. Eco-Health Approach to the Control of Onchocerciasis in the Volta Basin of Ghana

The goal of this project was to study how the effects of onchocerciasis could be reduced in Ghana through sustainable community-directed environmental management in ivermectin-resistant areas.

The scope of work in the reporting year included field visits to hydro-meteorological observatory stations in the Pru and Black Volta basins, analysis of trends in extreme climate events, pre-processing of various data for modeling, initial set up of the hydrological model SWAT (Soil and Water Assessment Tool) and training of Graduate students in hydrological modeling. Preliminary results for the Atebubu climate station showed increasing trend in the total annual precipitation, maximum of the daily maximum temperature, minimum of the daily maximum temperature, maximum of the daily minimum temperature and minimum of the daily minimum temperature. With the exception of the annual precipitation, all the increases obtained were significant at 95 % confidence level.

5. Rethinking Water Storage for Climate Change Adaptation in Sub-Saharan Africa

As part of Adaptation of African Agriculture to Climate Change program, this study was initiated to improve the livelihood and increase resilience of the rural poor in Sub-Saharan Africa (SSA) vulnerable to climate change risks through better water storage mechanisms, improved investments and institutional support. Activities carried out in the year under review included field surveys on efficiency and performance of water storage systems at Vea in the Upper East Region, Golinga in the Northern Region and Sata in the Ashanti Region of Ghana.

The commonest water storage systems identified were dams, boreholes, hand-dug wells and rainwater harvesting systems. The available storage systems were generally inadequate, poorly managed and needed urgent rehabilitation. The status of the systems indicated that they lacked the necessary resilience to population increase and impacts of environmental and climate change. It was recommended that external financial assistance would be required to adequately handle broken down pumps and dilapidated dam structures and canals so as to increase the resilience of the systems to both human and environmental change impacts.

6. Update on Flood Phenomenon in Ghana

The goal of the study was to enable decision makers prevent, mitigate and manage flood disasters in Ghana to minimize their potential impacts on life and property. During the reporting year, hydrometeorology and hydrological data were collected and analysed. Poor

and/or lack of drainage systems, building in water courses, siltation and improper waste (especially plastic waste) management were identified as the primarily causes of flood in the capital of Ghana. Estimations from the extreme value distribution shows that there was a 100 % chance that streamflows (floods) with magnitudes 650.6 m^3/s, 296.4 m^3/s and 36.50 m^3/s would occur any day during the year in the Volta, South Western and the Coastal river systems, respectively. Similarly, streamflow of magnitudes 3529 m^3/s, 561.0 m^3/s and 105.0 m^3/s could occur once during any day in 10 years in the Volta, South Western and Coastal river systems, respectively.

GROUNDWATER DIVISION

7. Isotope Techniques for Groundwater Assessment of the Central Region

The objective of this study was to solve groundwater problems in the Central Region using integrated conventional and isotope techniques. Isotope techniques in ground and surface water studies could lead to identifying the sources of major ions in these waters and delineate high chloride areas which are major problems in the Central Region. During the year, water samples from selected water bodies such as rivers and boreholes were periodically collected and analyzed. The results indicated that groundwater in the area is weakly acidic with mean pH of 5.83 pH units. The principal hydrochemcal facies observed were Na-Cl, Na-Cl-HCO_3 and Na-HCO_3-Cl water types.

8. Groundwater Monitoring of Northern Ghana

This project started in 2005 to assess the groundwater of the three (3) Northern Regions of Ghana. During the year, 37 monitoring boreholes were visited in the dry and wet seasons to download the recorded groundwater fluctuation data. Samples of water were also taken from all the boreholes for physico-chemical analysis. The general observation was that groundwater levels have remained unchanged despite the general perception that they should rather decrease as a result of overexploitation, over-pumping and climate change impact over the years and this might be due to the deep aquifers within the study area. There was an increase in groundwater conductivity and total dissolved solids during the raining season and this could be the result of surface water infiltration into the groundwater system.

9. Geo-logging and Diver Installation of 15 Newly-Drilled Monitoring Boreholes

The purpose of the project was to obtain sub-surface information related to log-stratigraphy of the rocks penetrated during drilling and to determine the magnitude and vertical variation of groundwater salinity in the different rock types underlying the study area. Activities carried out included borehole logging and diver installation. The data obtained was analysed using '*Viewlog*' software. The results showed that in order to obtain potable water, the depths of boreholes drilled through shale, mudstone and siltstone rocks should not exceed 60 m.

ENVIRONMENTAL CHEMISTRY DIVISION

10. Industrial Water and Wastewater Studies

The study was aimed at generating relevant and comprehensive data on raw and spent water which could be used to implement rational water utilization and management programmes in the Cocoa Processing Company Limited (PORTEM), Cadbury Ghana Limited, Kasapreko Ghana Limited, Bamson Company Limited, Pioneer Food Cannery, Phyto-Riker Pharmaceuticals and Golden Tulip Hotel.

In the reporting year, water samples, raw and treated effluent samples were collected on monthly and sometimes on quarterly basis and analyzed. The data produced was used to design treatment plants in some of the industries such as the Cocoa Processing Company

Limited. The data was also used for developing environmental management plans for the industries.

11. Ground and Surface Water Quality Assessment

The objective of the study was to verify whether the activities of Goldfields Ghana Limited (GGL) have any negative impact on the communities' water resources. It was also to determine the effects of mining operations on the quality of surface waters, sediments and groundwater through drilled observation wells for monitoring.

In the reporting year, water and sediment samples were taken from 26 stream sampling sites; 31 boreholes; 21 treated seepage and leachate water sites; 35 Wells for potable use in Samanhu, Atuabo, Huniso and Esuman; and 30 Wells at Tebe, Abekoase and Pepesa. These samples were analysed using standard methodologies.

Results obtained from the surface water samples showed that the ionic dominance pattern observed in the Tarkwa area, $Na > K > Ca > Mg : HCO_3 > SO_4 > Cl$, did not conform to the ionic dominance pattern of $Ca > Mg > Na > K$ and $HCO_3 > SO_4 > Cl$ for freshwater. The high iron levels recorded could be due to the geology of the area. Analysis of the groundwater indicated that the pH values for 40 of the wells out of the 47 sampled fell below the WHO minimum limit of 6.5 pH units and this could be attributed to the geology of the area. Depending on environmental conditions, the acidic waters could leach trace metals from their surroundings. The nitrate-nitrogen concentrations in the boreholes gave no indication of contamination from the external environment and there were no adverse effects with respect to heap leaching in terms of contaminating the groundwater in the area.

It was recommended that communities living within the concession of Goldfields Ghana Limited should be educated to avoid pollution of surface waters (streams) through the impact of human activities.

12. Surface Water Quality Monitoring and Assessment of the Volta, Southwestern and Coastal River Systems

The project began in the reporting year to develop an efficient and effective management system for sustainable development of Ghana's water resources to ensure full socio-economic benefits for present and future generations. The scope of work included collection of water, sediment and fish samples for physico-chemical, metals, sediment quality and bacteriological analysis. The Water Quality Index classification of the waters indicated that most of the water bodies were in Class II, the "fairly good quality" state, but with seasonal variations in quality states. The overall characteristics of the water samples indicated that, the Volta River System was comparatively less polluted than the Southwestern and the Coastal River Systems.

13. Three Districts Water Supply Project

This study was aimed at assessing the quality and suitability of treated water for potable use in the Dangme East, Dangme West and North Tongu Districts. The scope of work included collection of water samples, laboratory analysis, data interpretation and preparation and submission of reports. The results of the physico-chemical and bacteriological examinations of the water samples indicated that the water from the stand pipes were suitable for domestic purposes based on WHO guideline and Ghana standards.

14. Limnological Study of Three Coastal Water Supply Reservoirs in Ghana

The study started in 2007 to monitor temporal changes in the water quality of the Inchaban, Brimsu and Weija reservoirs that supply water to the Sekondi, Cape Coast and Accra, respectively. During the reporting year, water samples were collected hourly in the day at the intake points of the reservoirs during the dry season and analysed using standard

methodologies. The study showed that the pH increased considerably in the late mornings and afternoons but decreased when sun was approaching and this could be due to changes in temperature of the reservoirs.

15. Sustainable Cage Aquaculture Development on the Volta Lake

This collaborative study with the Fisheries Commission started in 2009 to estimate the carrying capacity of the Volta Lake in relation to cage and pen aquaculture development. It was also aimed at assessing the socio-economic impact of cage aquaculture development in the Volta Lake and providing guidelines for sustainable cage aquaculture development in Ghana.

In the reporting year, water samples for physico-chemical analysis were collected from fifteen (15) locations on the Volta Lake with clusters of fish cages or pens including the gorge area, Atimpoku, Akuse and Sogakope.

The levels of trace metals were generally low and did not present any threat to biota. The observed low ionic content of the Lake is good for aquatic ecosystem use. Nutrient concentrations were generally low in areas with the fish cages except in the lower Volta area. Although, there were no immediate detectable impacts of fish farming on water quality of the Lake, the study recommended the need for regular water quality monitoring and the need to estimate the carrying capacity of the Lake to develop good water management practices to ensure sustainable use of the Lake.

16. Quality of Water Bodies in Mining and Non-Mining Areas within the Ashanti Gold Belt

The study was initiated in 2008 to assess the hydrochemical processes influencing water bodies and to identify and characterise the trace metal levels in water bodies within the Ashanti Gold Belt. A total of 113 samples were collected from boreholes, wells and streams in Obuasi and some communities within the Ashanti Gold Belt during the dry and wet seasons between 2008 and 2010.

The study showed that the chemical constituents of the study area were generally low with relative abundance of cations and anions in the order of $Ca^{+2} > Na^{+} > Mg^{+2} > K^{+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{-2} > NO_3^{-}$, respectively. The study also showed that, gypsum, anhydrite, calcite and dolomite dissolution were some of the processes influencing the water chemistry of the study area.

ENVIRONMENTAL BIOLOGY AND HEALTH DIVISION

The Environmental Biology and Health Division for the year 2010 dealt with the health of the individual in the use of water and from other associations with water. These included:

Regular monitoring of bottled and sachet waters for sale in the market by the Division for bacterial contamination led to improvement in sale of safe and good water in the market through recommendations given to the sachet and bottled water producers.

The assessment of quality of water for Cyanobacteria and other pathogenic organisms that are causative organisms for water borne diseases such as dysentery, cholera, typhoid, diarrhea and other gastro-enteritis continued. These assisted in the intensification of the application and enforcement of sound and safe practices that led to provision of safe and good water sources.

There was also study on the damage caused to the environment by small scale miners in many parts of the country. This has improved understanding of multiple-use of water by the communities.

There was study on methods to remove barriers to invasive plant management in Ghana in an effort to reduce the level of aquatic weeds (especially water hyacinth) infestation in our water bodies, notably the Oti arm of the Volta River. There has been general awareness of the threat of aquatic weeds in Ghana. Various control measures have been suggested to reduce the threat in the Volta River and the Abby lagoon.

There are five (5) distinct Sections making up the Division. These are Microbiology, Macro-Invertebrate, Hydrobotany, Entomology and Parasitology.

17. The Occurrence, Diversity and Ecological Attributes of the Blackfly in the River Densu Basin

This study was aimed at assessing the status of the blackfly and onchocerciasis in the River Densu Basin. In the reporting year, aquatic forms of immature simuliid were sampled from twigs, stems, stones and trailing vegetations in the flowing sections of the River Densu and its tributaries. The samples were examined and identified.
Simulium species identified in the study were *S. unicornutum, S. alcocki, S. damnosum s.l, S. adersi* and *S. cervicornutum*. The medically important species, *S. damnosum s.I*, occurred at sites with pH range of 6.6 – 6.8 pH units, flow rate range of 1.7 – 2.1ms^{-1} and mean dissolved oxygen levels above 60 % (>60 %) saturation. Hence, while the other species appeared to be tolerant of varying ecological characteristics of the rivers, the *S. damnosum s.l* appeared to exhibit some sensitivity.

18. The Role of Algae and Macro-Invertebrates in the Removal of Faecal Bacteria from Domestic Wastewater Using Natural Treatment Systems and Open Waters

The objectives of the project were to assess the performance and mechanism of faecal bacteria removal from a pilot scale hybrid algal and duckweed domestic wastewater treatment system; and to assess the ability of some gastropod mollusks of medical importance to withstand some environmental stresses and their contribution to the removal of faecal bacteria from open waters.
During the reporting year, the performance of a pilot-scale hybrid duckweed and algal domestic wastewater treatment plant under tropical conditions was investigated. In addition, the response of the macro-invertebrates, *Biomphalaria pfeifferi* and *Bulinus truncatus* to salinity stress was also investigated. Laboratory experiments were also conducted to investigate the role of *Melanoides tuberculata* and *Bulinus truncatus* in the removal of fecal bacteria from a polluted river modified for providing drinking water to nearby municipalities.
The results showed that invertebrates *Melanoides tuberculata* and *Bulinus truncatus* could play a role in the regulation of fecal bacteria numbers in ecosystems with significant leaf litter.

19. Management of Pulp Mulberry "*Broussonetia papyrifera*" in the River Afram Headwaters Forest Reserve, Ghana

The study was conducted to produce practical means of controlling *Broussonetia* reservoirs in Ghana in order to facilitate forest and biodiversity restoration, improve agricultural efficiency and reduce the rate of spread of the infestation.
In the reporting year, three experimental trial plots were demarcated and used for biodiversity restoration studies in the River Afram Headwaters Forest Reserve at Abofour in the Offinso

South Municipality of the Ashanti Region. The study showed that although there were some coppicing on trees treated with Glyphosate or Round-up, there was no coppicing on trees treated with Spear. Frilling with the herbicide, Spear appeared to be the most effective control strategy with trees dying relatively soon after application.

20. The Impact of Collection and Disposal of Solid Wastes on the Environment and on Health: The Case of Accra Metropolitan Area

This study was conducted in the Accra metropolis to investigate the impacts of solid wastes collection and disposal on the environment and on human health. It was also aimed at examining the effectiveness of the various solid wastes management systems put in place. Water, leachate and soil samples were collected from six sampling sites over a period of six months and analysed for coliform bacteria, helminthes or helminth eggs.

The total and faecal coliforms concentrations in the water samples ranged from 1.0 – 232.0 x 10^4 cfu/100 ml and 0.2 – 22.4 x 10^4 cfu/100 ml, respectively. The level of concentration of coliform bacteria could pose a major risk to human health and the environment. The social survey revealed that the increasing solid wastes generation in the Accra metropolis has not been accompanied with adequate sanitation facilities and management programmes. Some key problems identified included indiscriminate dumping and difficulties in the acquisition of suitable disposal sites.

To ensure effective and efficient solid wastes management in the Accra metropolis, some recommendations given were: the Environmental Health Directorate of the AMA should draw up a health education plan every year to educate the people on safe methods of wastes disposal; and policies on private participation in solid wastes management must be redesigned and implemented to address the solid wastes management issues within the study area.

21. Water Supply and Sanitation and their Effects on the Health Status of the People of Chorkor in the Ablekuma Sub-Metro of the Accra Metropolitan Assembly

This study was undertaken to identify the present water supply and sanitation situation and their effects on the health status of the people of Chorkor. In the reporting year, water samples were collected at vantage points from the distribution pipelines and analyzed. Social survey was also undertaken to assess the sanitary condition of the study area.

The analyses revealed that the physical and chemical parameters of most of the water sources in the community were within the WHO and Ghana standards with few sources having values that were quite high. However, the microbiological parameters of the water sources extremely exceeded the WHO and Ghana standards for permissible limits of Total Coliform, Faecal Coliform and Total Heterotrophic Bacteria for potable water. Practices such as poor sanitary conditions, burst and leaked pipelines, illegal connections and distribution pipelines laid through wastewater channels were responsible for the presence of *Vibrio cholera, Salmonella typhii*, diarrhoea and dysentery and malaria within the area and its catchments.

Some recommendations made were: there should be regular sanitary inspection by the Sub-metropolitan authorities to keep Chorkor clean; thorough microbiological examination of water from homes and water vendors should be conducted to ensure the safeness of drinking water; and there should be routine monitoring of distribution pipelines by Ghana Water Company Limited and its operating agencies to check on illegal connections, burst and leaking pipes.

22. Cattle-Grazing on Playing Fields: Source of Environmental Contamination to School Children in the Greater Accra Region

The aim of this study was to investigate the presence of pathogenic organisms in cattle dung and grass from playing fields used for cattle grazing. Two playing fields used for cattle grazing and one other playing field not used for cattle grazing (contral sample) were selected. Cattle dung and grass samples from the fields and finger/hand swab samples from children who played on the fields were collected on monthly basis in the dry and wet seasons for six (6) months and examined bacteriologically and for helminth.

The presence of *Salmonella, E. coli, Ascaris, Strongyloides* and Hookworm in the cattle dung was indication that other pathogens such as *Clostridia, Shigella, Giardia* and other helminths could be present in the dung. These were transferred onto the grass and were subsequently picked on the fingers/hands of the children who played on the fields.

Recommendations made included educating the cattle owners/farmers, schools and community leaders who have allowed their premises to be used for cattle grazing and the general public on the health hazards of their activities to the society; laws against cattle grazing in cities/towns should be revisited and enforced; and there should be further research to identify the other species of the pathogens present in cattle dung.

23. The Impact of Doxycycline Treatment on Transmission of *Onchocerca volvulus* in Communities Showing Sub-Optimal Response to Ivermectin Treatment

This study was aimed at determining whether the treatment of Ivermectin (IVM) sub-optimal responders with doxycycline would significantly impact on onchocerciasis transmission. The specific objectives were to assess vector abundance, densities and the man biting rate of *S. damnosum* in the study areas; determine the vector infection rates and transmission potential following treatment of sub-optimal responders with doxycycline; and assess the reduction in transmission of onchocerciasis following doxycycline treatment and determine whether possible disease recrudescence can be prevented using doxycycline.

Thirteen (13) onchocerciasis endemic communities showing sub-optimal response to IVM treatment were selected from Yeji, Kintampo and Tain districts of the Brong-Ahafo Region. A total of 3,790 and 14,555 blackflies were collected during the dry and wet seasons, respectively. They were identified and dissected on the same day to determine the fly parity and presence of the parasite larvae of *O. volvulus*.

Analyses of the entomological data collected before and after the doxycycline trial showed that the interventions with doxycycline had significant impact on onchocerciasis transmission in communities showing sub-optimal responses to IVM treatment. It was recommended that in endemic communities where onchocerciasis transmission is still relatively high, individuals responding sub-optimally to IVM treatment should be identified and treated with doxycycline.

FISHERY DIVISION

24. Population Characteristics of *Chrysichthys nigrodigitatus* in the Weija Reservoir in Ghana

This study was undertaken to provide information on the population characteristics of *Chrysichthys nigrodigitatus* which would be helpful in the conservation and sustainable management of the species for food security and socio-economic development.

During the reporting year, monthly fish sampling was undertaken from the Dam Intake, Machigani and Galilea. The fishes were identified and standard length and weight measured for the computation of length frequency, length weight relationships and condition factor. The Catch Per Unit of Effort and sexes of individual fishes were also determined.

Out of a total number of 549 specimen of *C. nigrodigitatus* examined, 39.89 % were males, 55.19 % were females while 4.92 % were undetermined. The largest male specimen measured 33.5 cm and weighed 1000 g while the largest female measured 30.5 cm and weighed 800.0 g. *C. nigrodigitatus* females were of better condition and were better suited to the Weija environment than males as indicated by the mean condition factor of 1.9648 and 2.0253 for males and females, respectively.

25. Production Parameters and Economics of Small-Scale Tilapia Cage Culture with Micro Credit Support in Two Communities of Asuogyaman District - Ghana

This study started in 2009 to establish production pattern and profitability of small-scale tilapia cage farming when micro-credit and technical knowledge is provided to small-scale farmers.

Activities carried out during the reporting year included selection of community members at Tusker and South Senchi, conducting interviews, training qualified and selected members in cage fish farming and small-scale business management and planning in preparation for the granting of micro-credit loan managed by the Asuogyaman Rural Bank for the purpose of farming fish in cages.

Profitability projections showed that small-scale cage culture could make a profit (GH¢ 325.00) when feed cost could be reduced by 25 % and FCR to less than 1.5. Ninety percent (90 %) fish survival/recovery further improved profit to GH¢ 650.00. Fish farmers could make appreciable yield and profits if they adhere to the use of good technical information and instructions provided to them in the choice of feed and its application to feeding fish. Furthermore, micro credit support properly packaged and extended could get poorly resourced farmers to undertake farming and improve their economic status.

26. Assessment of the Ecological and Public Health Status of a Water Storage Facility

The aim of the project was to assess the biological and environmental status of a Water Storage Facility (WSF) created by Newmont Ghana Ltd. with the view of enhancing its fish production. Activities carried out included fish sampling and identification, and measurement of fish length and weight. Five fish species caught during the study period were *Oreochromis niloticus, Clarias anguillaris, Clarias gariepinus, Parachanna obscura* and *Brycinus nurse*. The Nile tilapia, *O. niloticus*, was the predominant species in the WSF and constituted 93.2 % and 71.2 % by number and weight, respectively, of the total catch. This tilapia was followed by the catfish, *C. anguillaris*, and the snake head, *P. obscura*, which constituted 17.9 % and 9.7 %, respectively, of the total catch. The dominance of *O. niloticus* in the system could be explained by the stocking of the reservoir with *O. niloticus* after its formation. The diversity (H') and evenness (Ds) indices of 0.1323 and 0.1289, respectively, were low indicating poor diversity and distribution of species.

It was recommended that the water quality of the reservoir be improved by frequently diluting the water with fresh one while allowing some of the resident water out. Once the water quality is improved other species e.g, the Nile perch, *Lates niloticus* (carnivore), *Chrysichthys* spp and the bony tongue, *Heterotis niloticus*, could be introduced to ensure a more diversified and balanced fish community.

27. The Threat of Pesticide Residues to Fisheries of Bontanga Reservoir in Ghana

This study was undertaken to determine the impact of pesticide residues concentration on the condition factor of major fish species, namely, *Auchenoglanis occidentalis, Brycinus nurse, Clarias gariepinus, Hemichromis fasciatus, Marcusenius senegalensis, Oreochromis*

niloticus, Sarotherodon galilaeus and Tilapia zillii of Bontanga reservoir during the dry and wet seasons.
Pesticide residues in fish were analyzed using Gas Chromatography and Solid Phase Extraction (SPE) via Turbo Vap II. Sixteen (16) organochlorine (OC) pesticide residues were identified in the reservoir.
During the dry season, heptachlor, p,p'DDE and p,p'DDD recorded concentrations of 0.094 µg/l, 0.061 µg/l and 0.019 µg/l, respectively. In the wet season, concentrations of γ-HCH and heptachlor were 0.075 µg/l and 0.069 µg/l, respectively. The condition factor (K) of the major fish species did not fluctuate significantly ($P < 0.05$) around the mean K of the individual species during the wet and dry seasons. The calculated acute risk ratio of the pesticide residues was less than 1.0 indicating that the concentrations were below toxic level to the fishes. However, this is still of concern considering the bio-accumulative nature of organo-chlorine compounds.

28. Evaluation of Selected Commercial Fish Feeds

This study was carried out to determine the most cost effective feed, compared the different feeds currently available on the market to producers and suggest interventions that will lead to increased fish productivity and better the livelihood prospects of fish farmers.
During the reporting year, experimental data on the study were obtained and analysed. Depreciation was computed using the straight-line method based on the estimated economic life of the capital items. Costs and returns analysis was used to determine the return on investment (ROI) as a comparative indicator.
The capital outlay was valued at GH¢ 10,480.00. Food conversion ratios (FCR) of the feeds employed were estimated to range between 1.69 and 2.46. Crude protein varied from 30 – 36 % while the respective unit prices ranged between GH¢ 1.35 and GH¢1.80.

29. Catch Assessment and Reproductive Seasonality of Major Commercial Catfishes in Strata II and III of the Volta Lake

This study assessed the exploitation patterns of catfishes of the genera *Bagrus, Chrysichthys, Clarias* and *Synodontis* in the Volta Lake for sustainable management strategy development. Catch assessment was conducted by determining the composition of fish species by weight per major gear of commercial fishers, changes in relative abundance of fish species, length-frequency distribution, condition factor (K), catch per unit of effort (CPUE), seasonality of spawns, size at first maturity and relationship of catches and spawning activities with physico-chemical parameters of the lake. Fish species diversity and similarity between Dzemeni (Stratum II) and Kpando (Stratum III) study sites were conducted.
The total annual catfish production at Dzemeni was 806.19 tonnes while 443.53 tonnes was produced at Kpando-Torkor over the same study period. The clarotid catfishes of the genus *Chrysichthys* (i.e. *C. auratus, C. nigrodigitatus and C. walkeri*) dominated all catches in both Dzemeni and Kpando study areas. More than 50 % of claroteids were caught at sizes below 13.5 cm SL for *C. auratus* and below 17.5 cm SL for *C. nigrodigitatus* which suggested growth overfishing. At both study sites, only gillnet catches of *C. auratus* showed bi-modal length class distributions. The mochokids produced relatively higher numbers of eggs per female, ranging from 383 – 21,452 eggs. *S. schall* at Kpando (Stratum III) produced the least number of eggs among the mochokids as well as the highest number of eggs in the same Stratum III at Kpando. Diversity of fish species at Kpando-Torkor was significantly higher than at Dzemeni ($P < 0.05$). It was concluded that unapproved gillnet mesh sizes of less than 2 inches (51 mm) contributed to about 45 % of gillnet catfish landings of immature or first time spawning populations. Hence, Fishers should be identified by the gears they use, be

registered in their respective fishing communities and be monitored regularly to facilitate effective management of the fishery resources.

Other activities from the non-technical Divisions of the Institute included:

a. Public Education and Awareness Creation

Some of the major research and development activities of the Institute were showcased during exhibitions to increase awareness on the need for sustainable utilization, management and protection of water resources.

b. Consultancy and Advisory Services

A number of 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.

c. Administration

The Institute was managed by a 8-member Management Board chaired by Prof. C. Dorm-Adzobu, Dean of the Faculty of Arts and Social Sciences, Central University College, and a 20-member Internal Management Committee (IMC) chaired by the Director. Staff strength stood at 225 at the end of the reporting year. It was made up of 52 Senior Members, 76 Senior Staff and 97 Junior Staff. There were 24 promotions, 8 retirements, 9 temporary appointments, 1 contract and 1 death during the year.

d. Finance

The total receipts for the year was GH¢4,583,664.02. Out of this amount, 77.37 % represented government subvention mainly in the form of personal emoluments, 14.54 % represented internally generated funds and 8.09 % represented donor assistance to the Institute

Major Constraints

Major constraints faced by the Institute during the reporting year included lack of adequate equipment, chemicals and technical personnel at the laboratories. Financial constraints such as delays in release of funds for recurrent, research and developmental activities, and lack of adequate logistics for data collection also affected the programmes of the Institute negatively.

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 and was established in 1996 from the merger of the former Institute of Aquatic Biology (IAB) and the Water Resources Research Institute (WRRI) of the CSIR which were established in the 1960s.

1.2 Vision

To become a centre of excellence in water and related resources, research and development by generating appropriate technologies and providing services that are responsive to demands of the private sector and for socio-economic development of Ghana.

1.3 Mission

To conduct research into water and related resources through the generation and provision of scientific information, strategies and services towards the rational development, utilisation and management of water resources of Ghana in support of socio–economic advancement of the country, especially in the agriculture, environment, health, industry, energy, transportation, education and tourism sectors.

A river basin map of Ghana is presented in Fig. 1.

1.4 Key Objectives

- 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.

1.5 Divisions

- Surface Water Division
- Groundwater Division
- Environmental Chemistry Division
- Environmental Biology and Health Division
- Fishery Division
- Commercialisation and Information Division

- Administration Division
- Finance Division

1.6 Facilities and Equipment

- Laboratories for biochemical, microbiological and parasitological analyses
- Laboratories for physical and chemical analyses
- Laboratory for sediment studies
- Aquaculture Research and Development Centre with a hatchery for production of fish fingerlings
- Biosecure facilities for aquaculture research
- Laboratory for fish genetic studies
- Quarantine facility for holding fish
- State of the art water quality laboratories for drinking water quality and pollution assessments
- DIONEX Ion Chromatograph for analysis of cations and anions
- UNICAM 969 Atomic Absorption Spectrophotometers (AAS) fitted with furnace and hydride generation systems
- Remote Sensing and Geographical Information System laboratory for studies on impact of land use and other environmental changes on water resources
- 2D Lund Image Equipment (max. depth 70 m)
- 3D LS Resistivity Equipment (max dept 270 m)
- Loggers for continuous recording of environmental data
- Ultra-Violet Visible Spectrophotometers
- Gas Chromatograph/Mass Spectrometer (GC/MS)
- Flame Photometers
- Incubators
- Ovens
- Centrifuges
- Hydrometeorological station for weather monitoring
- Geologger for borehole logging
- Geophysical Instruments
- Computers and accessories
- Fleet of field vehicles (4x4)

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

1.8 Clientele

- Afariwa Estates Ltd.
- Agricultural Extension Officers
- Agro-forestry and Integrated Water Management Specialists
- AngloGold Ashanti Ghana Ltd.
- Association of Ghana Industries

- Bamson Company Ltd.
- Barry Callebaut Ghana Ltd.
- Benso Oil Palm Plantations Ltd.
- Bioland Company Ltd.
- Borehole Drilling Companies
- Bottled and Sachet Water Producers
- Cadbury Ghana Ltd.
- Catholic Relief Service
- CIDA-HAP
- Cob-A Industries Ltd.
- Coca-Cola Ghana Ltd.
- Cocoa Processing Company Ltd.
- Community Water and Sanitation Agency
- CSIR-OPRI
- Diplomatic Missions
- District and Municipal Assemblies
- Environmental Protection Agency
- Environmental Solutions
- Fish farmers
- Fisheries Commission
- Food and Drug Board
- Food and Beverage Industries
- GAFCO
- Ghana National Commission for UNESCO
- Ghana Oil Palm Development Company
- Ghana Water Company Ltd.
- Ghana Wildlife Division of the Forestry Commission
- Glowa Volta Project of ZEF
- Golden Hotel Ltd.
- Golden Tulip Hotel
- Goldfields Ghana Ltd.
- Groundwater Development/Management Consultants
- International Water Management Institute
- Irrigation Development Authority
- Jei River Farms Ltd.
- Koajay Co. Ltd.
- Major & Co Ltd.
- Minerals Commission
- Ministry of Environment, Science and Technology
- Ministry of Fisheries
- Ministry of Food and Agriculture
- Ministry of Health
- National Disaster Management Organisation
- National Onchocerciasis Secretariat
- Newmont Ghana Gold Ltd
- Nkulenu Industries

- Non-Governmental Organisations
- Plan Ghana Limited
- Phyto-Riker Pharmaceutical Ltd.
- Pioneer Food Cannery Ltd.
- Polykraft (Ghana) Ltd.
- Polytechnics
- Public and Private Universities
- Rice Farmers
- Rotary Club
- Senior High Schools
- Tesano Sports Club
- The Bible College of Ghana
- Twifo Oil Palm Plantations Ltd.
- UNESCO
- Vicco Ventures Ltd.
- Volta Lake Transport Company
- Volta River Authority
- Water Resources Commission
- West Africa Rice Development Agency
- World Vision
- WRIS/DANIDA

An overview of the major activities of the Institute during the year 2010 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

The Director,
CSIR Water Research Institute,
P.O. Box M 32,
Accra-Ghana

Telephone : ***(233-302) 775351, 775352, 779514, 779515, 775511***
Fax : ***(233-302) 777170, 761031***
E-mail : ***info@csir-water.com; wricidss@yahoo.com***
Website : ***www.csir-water.com***

Fig. 1: River basin map of Ghana

2.0 RESEARCH AND DEVELOPMENT ACTIVITIES

2.1 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 systems
- 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

Beneficiaries of the Division's research activities include the following:

- Water Management Specialists
- Environmental Protection Agency
- Ghana Water Company Ltd.
- Irrigation Development Authority
- Ministry of Food and Agriculture
- Non-Governmental Organizations
- Small-scale Farmers
- Volta River Authority
- Water Resources Commission
- UNESCO
- Internationsl Water Management Institute
- Alliance for Green Revolution in Africa

2.1.1 Hydro-Meteorological Database Management

(Project Staff: Dr. K. Kankam-Yeboah – Principal Research Scientist; Mr. S. Baah – Chief Technical Officer; Mr. S. B. Nobiya – Principal Technical Officer; Mr. A. A. Agyapong – Principal Technical Officer; Mr. C. K. Asante- Sasu – Principal Technical Officer; Mr. G. Appiah – Technical Officer)

The hydro-meteorological data base management system was instituted by the CSIR Water Research Institute to generate and provide hydro-meteorological data from the synoptic station of the Institute (05° 35705N, 00° 11105W; altitude 45.72 m) to support the Institute's research activities and that of other research agencies. The main parameters measured and compiled in the reporting year were rainfall, temperature, evaporation, sunshine duration and wind-run. The hydro-meteorological data collected and others obtained from the Hydrological Services Department (HSD) and Ghana Meteorological Agency (GMet) were electronically digitized and stored in the database.

The total annual rainfall for the year was 815 mm (Table 1) and the highest total annual rainfall since the inception of the station (1976 – 2010) was 1284 mm in 2002 (Fig. 2). The peak monthly rainfall for the year occurred in June (Fig. 3) while the peak monthly rainfall in 10 years was 514.1 mm in June 2002. Evaporation was generally higher than rainfall except in June 2010 (Fig. 4). The relationship between other meteorological parameters such as rainfall and relative humidity (RH) are shown in Figs. 5 and 6.

Table 1: Hydro-meteorological data (2010) at CSIR Water Research Institute's station, Accra

Parameters	**Jan**	**Feb**	**Mar**	**Apirl**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Rainfall (mm)	32.3	67.8	35.6	26.7	84.1	245.5	80.0	32.8	53.7	56.7	47.0	53.0	**815**
(rainday)	(2)	(3)	(3)	(8)	(10)	(16)	(6)	(7)	(12)	(10)	(8)	(2)	**85**
Rainfall (10yrs avg)	14.1	18.6	56.4	95.6	154	226	63.1	32.9	68.2	68.1	38.8	21.5	
Sunshine(hrs)	7.3	8.5	5.8	7.4	6.7	4.4	5.2	4.6	4.8	7.2	7.9	8.2	**78**
Temperature (°c)													
Mean Temp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Max. Temp	-	-	-	-	-	-	-	-	-	-	-	-	-
Min. Temp	25.7	26.0	26.6	26.5	25.9	24.6	24.0	23.9	24.2	24.4	24.5	24.8	
Windrun (knots)	2.37	2.81	2.40	2.47	2.2	2.30	3.11	3.29	3.00	2.53	1.71	1.70	
Evaporation(mm)/day	3.8	4.7	5.0	5.6	5.0	3.3	3.3	3.4	3.3	4.6	4.4	4.5	
RH (%)	78	77	76	77	79	86	84	85	85	81	81	80	

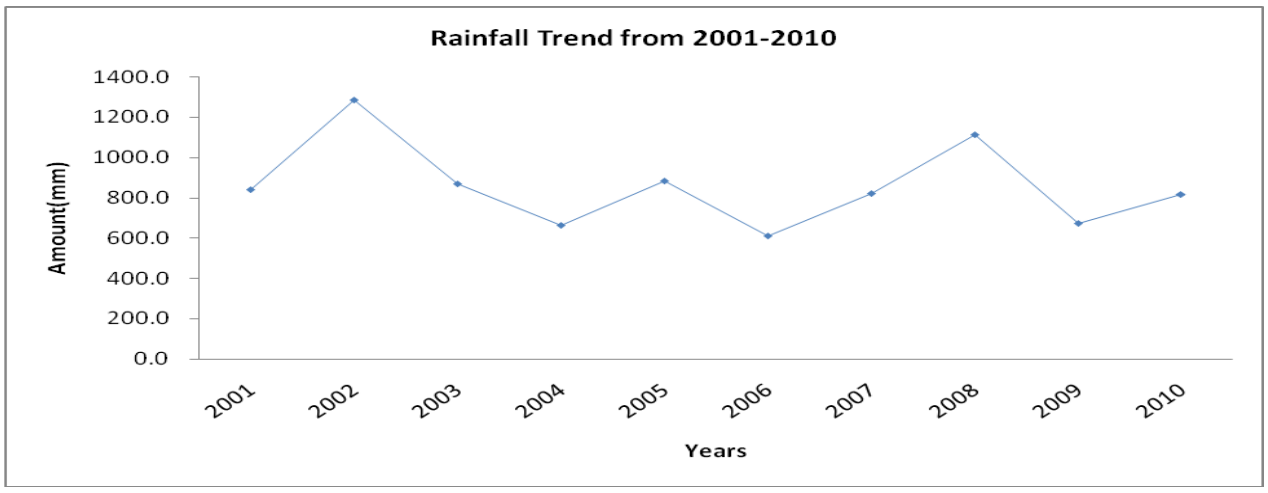


Fig. 2: Total annual rainfall trend from 2001-2010

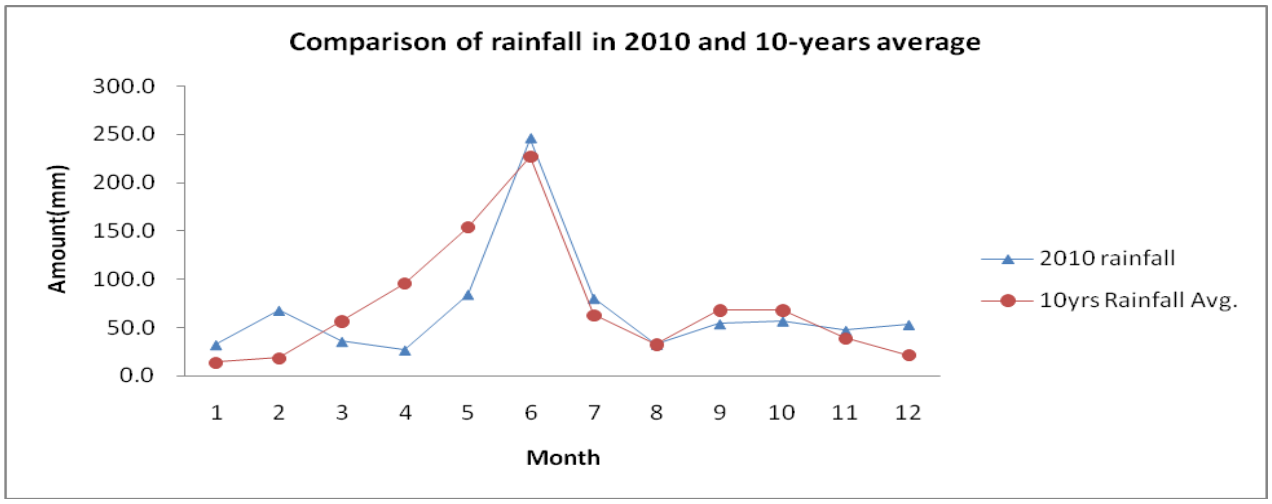


Fig. 3: Comparison of rainfall in 2010 and 10-years average

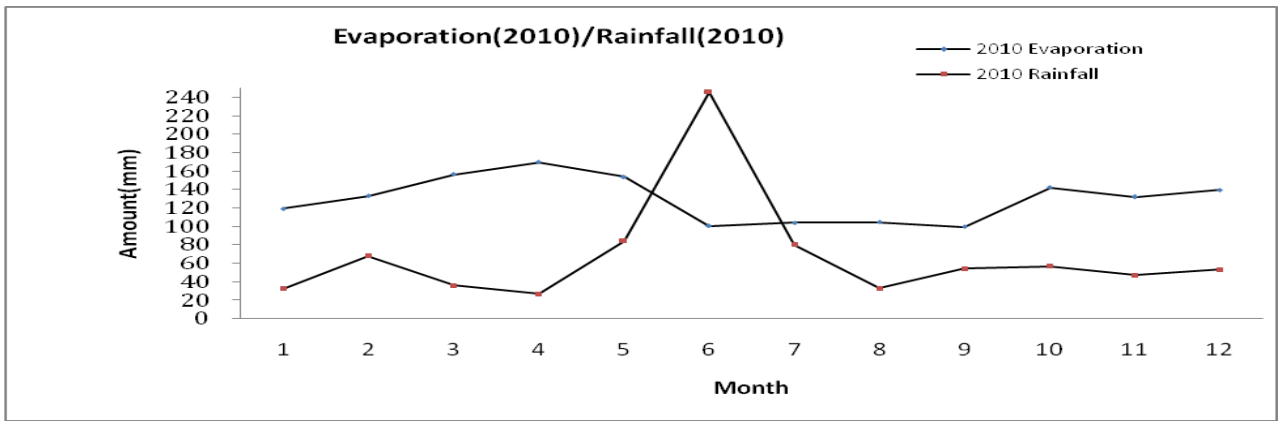


Fig. 4: Comparison of rainfall and evaporation in 2010

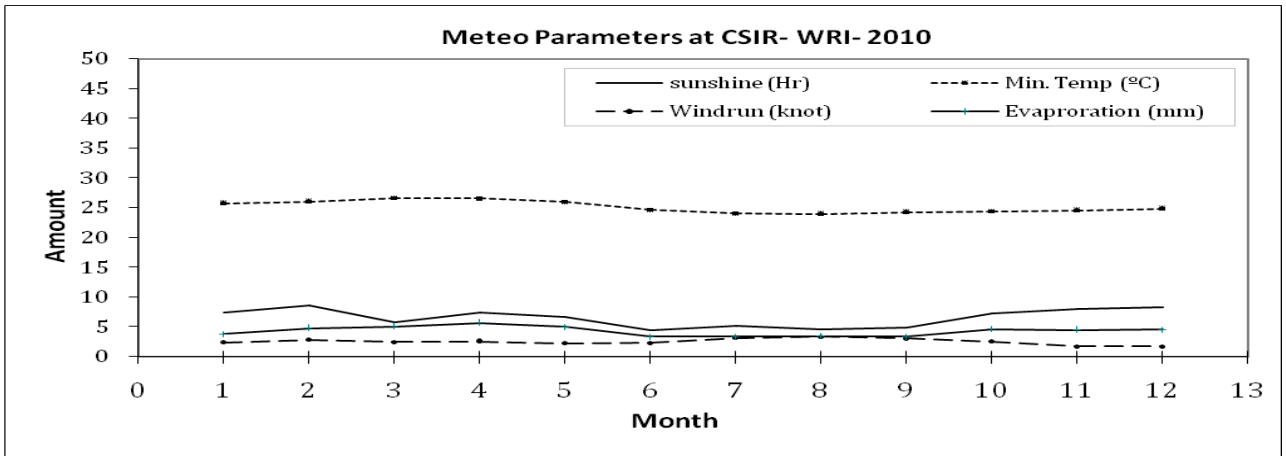


Fig. 5: Comparison of sunshine (Hrs), minimum temperature, windrun and evaporation in 2010

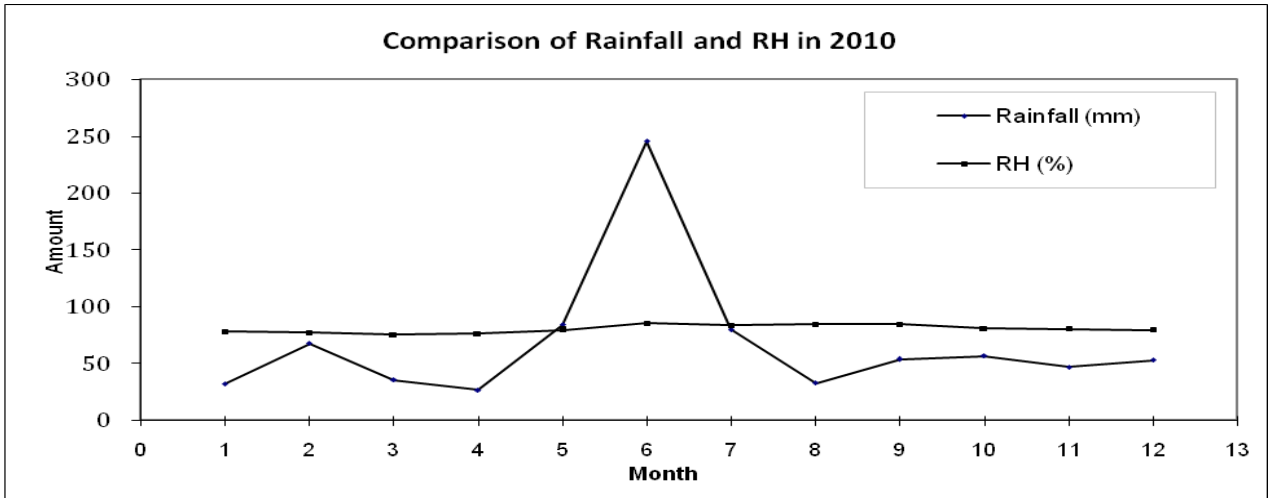


Fig. 6: Comparison of rainfall and relative humidity (RH) in 2010

2.1.2 Climate Change Effects on Hydrology and Water Resources and Adaptation Strategies in Ghana

(Project Staff: Dr. Kwabena Kankam-Yeboah – Principal Research Scientist; Dr. Barnabas Amisigo – Senior Research Scientist; Dr. Emmanuel Obuobie – Research Scientist and Dr. Yaw Opoku-Ankomah – Principal Research Scientist)

This project focused on the impact of climate change on watershed hydrology and surface water resources in Ghana. The project spanned a period of 1 year from 2009 to 2010 in collaboration with the Water Resources Commission, Volta Basin Authority, Hydrological Services Department, Irrigation Development Authority and Ghana Meteorological Agency. The main objective was to generate scientifically based impact-specific information that could be used to directly inform the preparation of local and national action plans on climate change adaptation in Ghana. The specific objectives were to:

- simulate the hydrology of the White Volta and Pra River basins using the semi distributed hydrological model Soil and Water Assessment Tool (SWAT);
- construct regional climate scenarios using the stochastic weather generator LARS-WG for climate change impact analysis;
- estimate the impact of climate change on streamflows;
- assess vulnerability of the study basins to water stress conditions; and
- recommend adaptation strategies for sustainable management of water resources under climate change.

In the year under review, SWAT was successfully set-up, calibrated and validated for the White Volta and Pra River basins using measured streamflow data for the stream gauges at Nawuni (White Volta basin) and Twifo Praso (Pra basin). Statistics of annual calibration and validation showed good agreement between simulated and observed streamflow in the two basins with coefficient of determination (R^2) greater than 0.80 and Nash-Sutcliffe model efficiency coefficient (NSE) greater than 0.70 (Table 2). However, monthly calibration and validation showed that the R^2 and NSE were greater than 0.70 and 0.68, respectively, for the two basins. Generally, SWAT overestimated the high flows and underestimated the low flows. The underestimation of the low flows could be due to more than one aquifer contributing to baseflow in the basin, a scenario not simulated in SWAT at present.

Table 2: Stream flow statistics obtained during calibration and validation of the SWAT model for the White Volta and Pra River basins

Basin	Drainage area (Km^2)	Simulation type	Period of simulation	Annual R^2	Annual NSE	Monthly R^2	Monthly NSE
White Volta	90,856	Calibration	1983 - 1993	0.78	0.78	0.76	0.76
		Validation	1994 - 2000	0.89	0.81	0.79	0.68
Pra	20,023	Calibration	1964 - 1978	0.83	0.70	0.80	0.79
		Validation	1979 - 1991	0.88	0.72	0.76	0.69

Compared to the baseline value, the mean annual streamflow estimated at Nawuni in the White Volta basin for 2020 and 2050 showed decreases of 22 % and 50 %, respectively while a similar estimation in the Pra basin showed reductions of 22 % and 46 %, respectively for the same periods. The significant estimated mean annual streamflow reductions in the two basins could be attributed to decrement in the mean annual rainfall and increment in the annual mean daily temperature projected by the Ghana Meteorological Agency using the ensemble of climate models (ECHAM4/MAGICC/SCENGEN) and based on IPCC SRE scenario A1F1.

Under the assumption of 100 % water usage in the two basins, the White Volta basin would experience water stress before 2020 and water scarcity after 2020, with or without climate change. However, with the effects of climate change, the basin would experience absolute scarcity condition before 2050, a situation that would have been prolonged beyond 2050 without climate change. With the current water stress condition of the Pra basin, it is expected to aggravate to water scarcity conditions before 2020, with or without climate change. The basin will experience absolute scarcity condition before 2050 and much earlier under climate change. Under a plausible level of water mobilization of 30 % in the two basins (100 % usage not possible due to constraints such as topography, technology availability, financial status, high evaporative losses and mandatory environmental requirements), the White Volta basin which is presently experiencing a water scarcity condition would be worsen to absolute water scarcity towards 2020 and beyond, with or without climate change. However, climate change will worsen the situation before the projected year. At the same 30 % level of mobilization, the Pra basin is already experiencing absolute water scarcity condition and the situation is expected to be worse under climate change.

It was recommended that integrated water resources management (IWRM) with emphasis on water use efficiency, water conservation, environmental integrity and equitable distribution of water resources should be adopted and implemented to promote awareness among stakeholders on the dangers posed by the impacts of climate change and thus ensure a holistic and sustainable management and use of water resources.

2.1.3 Groundwater in Sub-Saharan Africa: Implications for Food Security and Livelihood

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist and Dr. Benony Kortatsi – Principal Research Scientist)

This collaborative study with the International Water Management Institute (IWMI), University for Development Studies (UDS) and Kwame Nkrumah University of Science and Technology (KNUST) was initiated in 2009. The overall goal was to enhance the role of groundwater in the

provision of improved food security and livelihood in Sub-Saharan Africa and particularly, in AGRA countries including Ghana. The specific objectives were to assess groundwater availability and its current and potential use and impacts, including its role in adapting to climate change; identify opportunities and constraints in using groundwater and provide advice to investors in groundwater interventions; and support the evolvement of a groundwater strategy for Sub-Saharan Africa. It is expected to be terminated in 2011.

Activities undertaken during the reporting year included selection of groundwater based irrigation sites in the Upper East Region (Sapeliga and Zanlerigu in the Bawku West and Telensi Nabdam Districts, respectively) (Fig. 7), baseline study, hydrogeological surveys and preparation of country reports on groundwater status in Ghana, Burkina Faso, Mali and Niger.

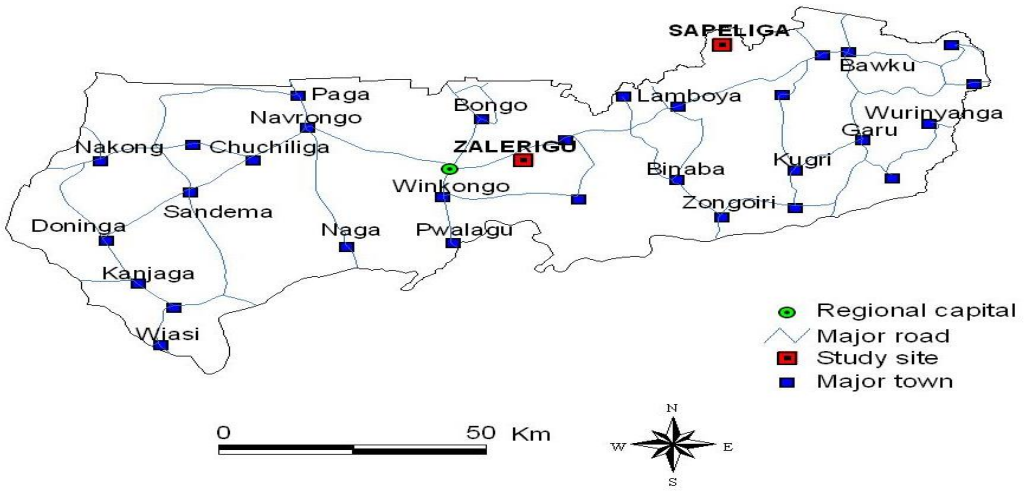


Fig. 7: Location of study sites (Sapeliga and Zalirigu) in the Upper East Region

The study showed that the geology of Ghana and Burkina Faso are dominated by the Precambrian crystalline basement rocks that consist of metamorphic and meta-igneous rocks, schists and granites, while that of Mali and Niger are dominated by unconsolidated sediments of Lower Cambrain and Palaeozoic age and consist mainly of sandstones with some argillaceous and carbonate horizons. The crystalline rocks have little or no primary porosity and therefore cannot store water. Groundwater availability in many places in Ghana and Burkina Faso are attributed to fractures, faults and weathering of the rocks and aquifer yields are generally low (average of 2 m^3/h). However, high yields of 100 m^3/h or more are found in the Continental Terminal aquifers in northwestern Burkina Faso and in the Coastal aquifers in southeastern Ghana. A large amount of the groundwater abstracted is used for domestic water supply in small towns and rural areas. Groundwater based irrigation is limited and informal. The potential to expand the use of groundwater for irrigation exists in all four (4) countries but this could be done if factors such as high cost of drilling boreholes, high initial and operational cost of water pumps, land ownership problems and the difficulty in accessing markets are properly addressed.

2.1.4 Eco-Health Approach to the Control of Onchocerciasis in the Volta Basin of Ghana

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist)

The Institute, in collaboration with Noguchi Memorial Institute for Medical Research, University of Ghana; Institute of Statistical, Social and Economic Research, University of Ghana; UK Meteorological Office Hadley Centre; Natural Resources Institute, University of Greenwich, UK; Ghana Meteorological Agency and Institute of Mathematical Science, Accra, started this project in the reporting year and is expected to end in 2012. The goal was to study how the effects of onchocerciasis could be reduced in Ghana through sustainable community-directed environmental management in ivermectin- resistant areas. The specific objectives were to:

- identify factors which explain the reasons why some areas in Ghana are developing resistance to the ivermectin control of onchocercaisis;
- identify vulnerable zones (e.g. mountainous areas where vectors could survive at higher altitudes with global warming or forest areas becoming savanna-like) and predict probable changes in vector ecologies, distributions and transmission efficiencies for policy attention;
- assess the suitability of mitigation measures to control onchocerciasis (e.g. sustained means of ivermectin distribution, vector control, immigration screening, afforestation or locally managed control measures at dams and other locations); and
- recommend adaptation strategies for endemic communities to enable them cope with the impacts of climate change on socio-economic activities.

The scope of work in the reporting year included field visits to hydro-meteorological observatory stations in the Pru and Black Volta basins (Fig. 8), analysis of trends in extreme climate events, pre-processing of various data for modeling, initial set up of the hydrological model SWAT (Soil and Water Assessment Tool) and training of Graduate students in hydrological modeling. Trends in extreme climate events under present and future climatic conditions were analyzed using RClimDex software with the aim of understanding how the extreme events in the study basins may be changing and how that change may be contributing to the occurrence and distribution of Onchocerciasis. Twenty indices were analyzed for each climate station in the study basins. Ten of the indices were temperature related while the other 10 were related to precipitation. The analysis covered the period 1965 – 2065. Data covering 2010 – 2065 were basically HADCM3 output for the IPCC scenario A1B that were downscaled with the stochastic weather generator LARS-WG.

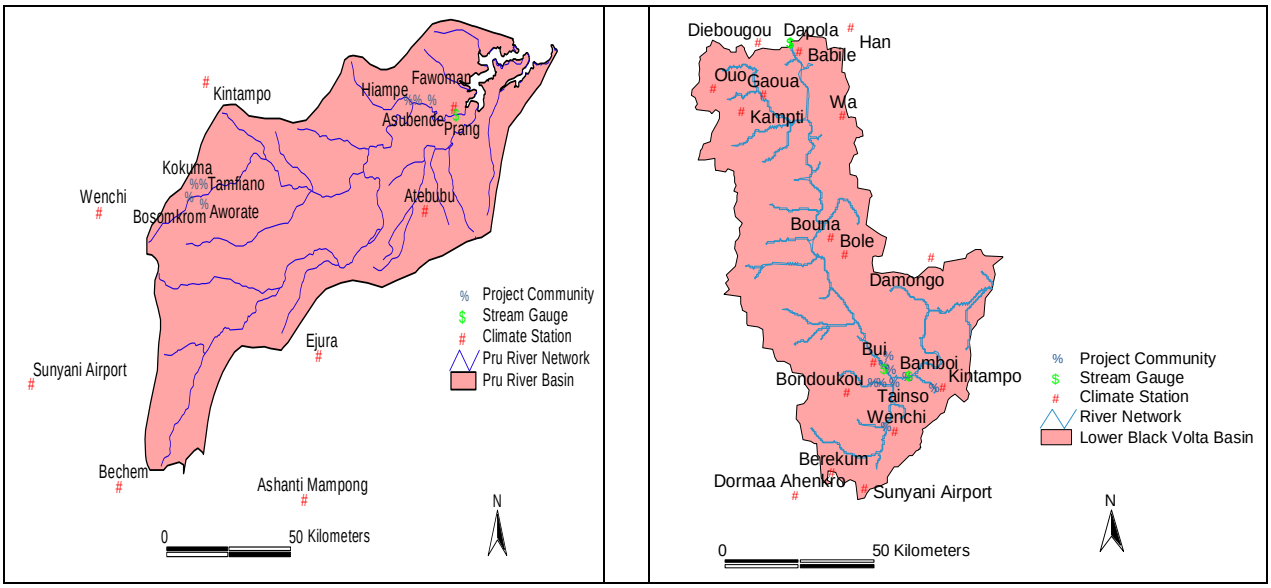


Fig. 8: Location of project communities and hydro-meteorological observational network in and around the Pru (left) and Black Volta (right) basins in Ghana

Preliminary results for the Atebubu climate station showed increasing trend in the total annual precipitation, maximum of the daily maximum temperature, minimum of the daily maximum temperature, maximum of the daily minimum temperature and minimum of the daily minimum temperature (Figs. 9 – 12). With the exception of the annual precipitation, all the increases obtained were significant at 95 % confidence level.

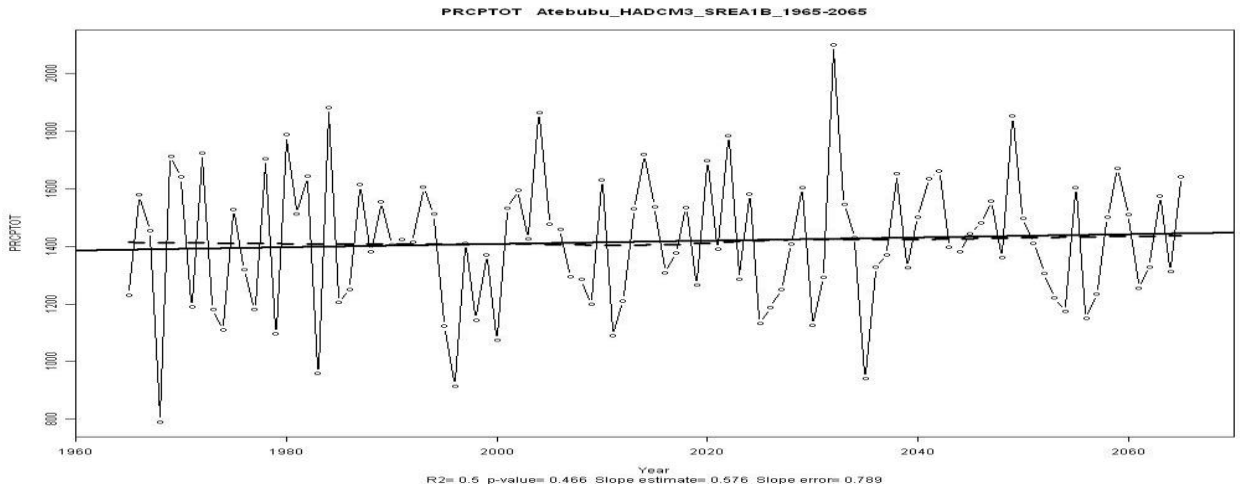


Fig. 9: Trend in total annual precipitation at the Attebubu weather station in the Pru Basin from 1965 to 2065

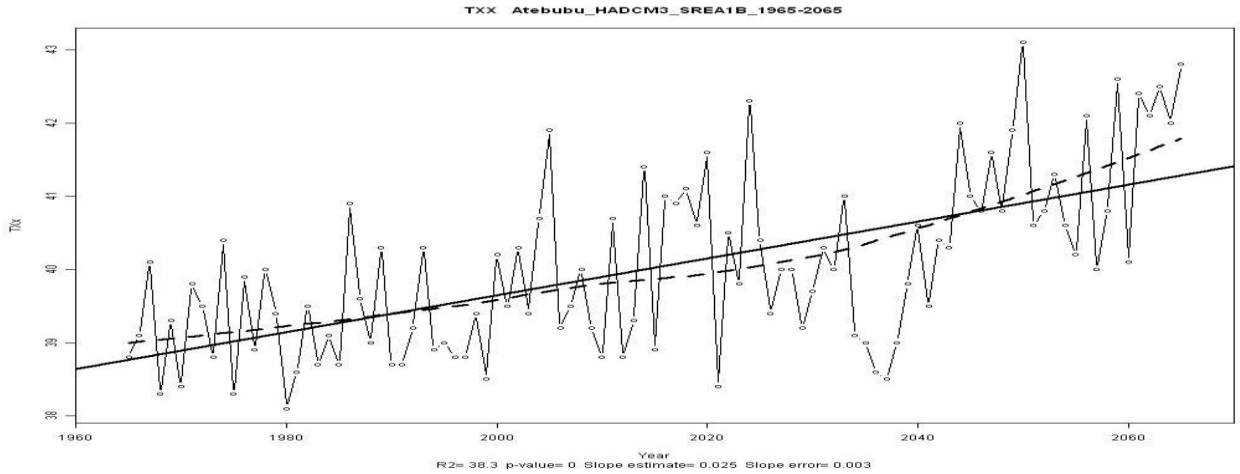


Fig. 10: Trend in the maximum of the daily maximum temperature at the Attebubu weather station in the Pru Basin from 1965 to 2065

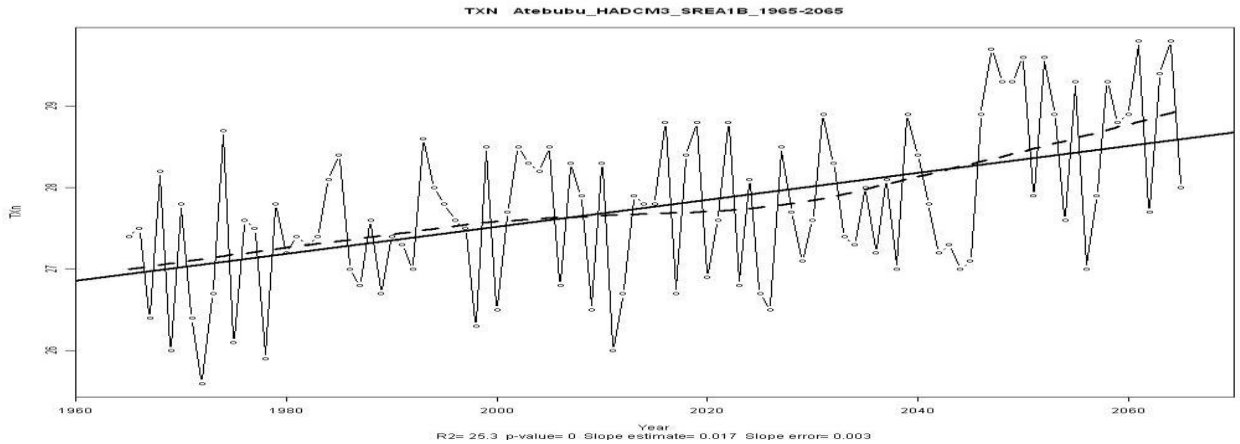


Fig. 11: Trend in minimum of the daily maximum temperature at the Attebubu weather station in the Pru Basin from 1965 to 2065

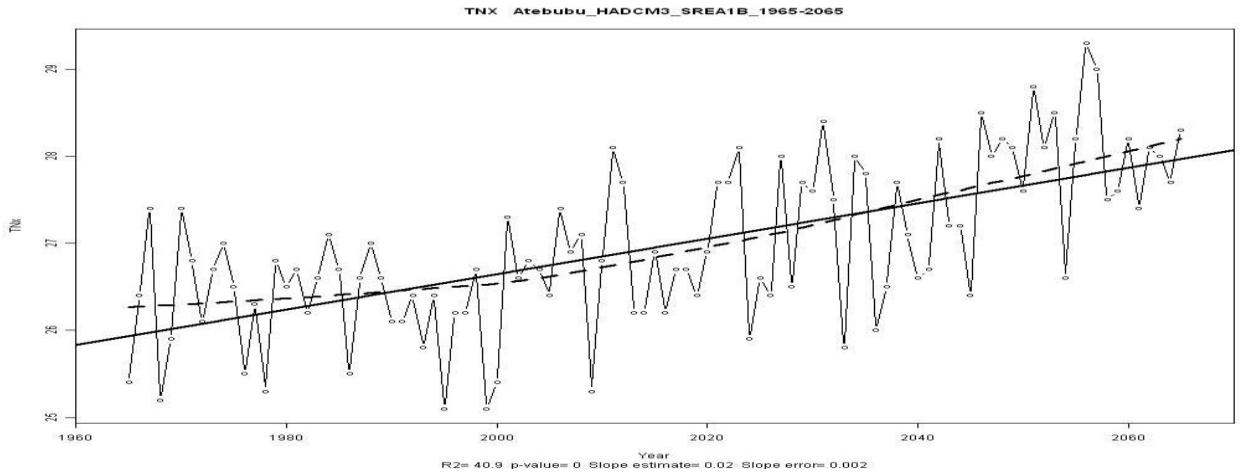


Fig. 12: Trend in maximum of the daily minimum temperature at the Attebubu weather station in the Pru Basin from 1965 to 2065

2.1.5 Rethinking Water Storage for Climate Change Adaptation in Sub-Saharan Africa

(Project staff: Dr. B. A. Amisigo – Senior Research Scientist; Dr. K. Kankam-Yeboah – Principal Research Scientist and Mr. Etornyo Agbeko – Principal Technical Officer)

As part of Adaptation of African Agriculture to Climate Change program, this study was initiated in 2008 in collaboration with IWMI; Centre for Development Reserarch (ZEF) of the University of Bonn, Germany; Institute of Water Technology, Arba Minch University, Ethiopia; Institute of Statistical, Social and Economic Research (ISSER), University of Ghana, Legon; and Gesellschaft für International Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The overall goal was to improve the livelihood and increase resilience of the rural poor in SSA vulnerable to climate change risks through better water storage mechanisms, improved investments and institutional support. It is expected to be completed in 2011. Activities carried out in the year under review included field surveys on efficiency and performance of water storage systems at Vea in the Upper East Region, Golinga in the Northern Region and Sata in the Ashanti Region of Ghana.

The commonest water storage systems identified in the study area were dams of various sizes and natural aquifers tapped by means of boreholes and hand-dug wells. Few roof rainwater harvesting systems were also identified. The dams were used for domestic water supply, livestock watering, irrigation and fishery while the other systems were mainly for domestic use. However, the available storage systems were poorly managed and generally inadequate to meet the water supply demand of the target populations, particularly during the dry season. Three large dams identified were among the 22 irrigation dams managed by the Ghana Irrigation Development Authority nationwide. The small dams, boreholes and hand-dug wells were community managed. Parts of the various dams identified and the canals delivering water to the irrigated fields were in bad condition and needed urgent rehabilitation. The lack of regular maintenance due to inadequate internally generated resources from water use fees has resulted in reduced functionality and efficiency of the systems. The status of the systems indicated that they lacked the necessary resilience to population increase and impacts of environmental and climate change.

It was recommended that external financial assistance would be required to adequately handle broken down pumps and dilapidated dam structures and canals so as to increase the resilience of the systems to both human and environmental change impacts.

2.1.6 Update on Flood Phenomenon in Ghana

(Project Staff: Dr. K. Kankam-Yeboah – Principal Research Scientist; Dr. P. Gyau-Boakye – Principal Research Scientist; Mr. F. Y. Logah – Research Scientist)

The goal of the study was to support decision makers manage flood disasters in Ghana and thus minimize their potential impacts on life and property. The specific objectives were to:

- give an overview of flooding situation in Ghana with particular attention on the capital city, Accra; and
- determine the occurrences, trends and magnitudes of flooding in Ghana.

During the reporting year, hydrometeorology and hydrological data were collected and analysed. Poor and/or lack of drainage systems, building in water courses, siltation and improper waste (especially plastic waste) management were identified as the primarily causes of flood in the capital of Ghana. Apart from the South Western River System which showed almost a no-change in the trend of high streamflow at Okyereko, the Volta (Fig 13) and the Coastal systems at

Bamboi and Okyereko, respectively, showed an increasing trend of high streamflow magnitudes with the Volta system showing higher rate of increase over the period of records.

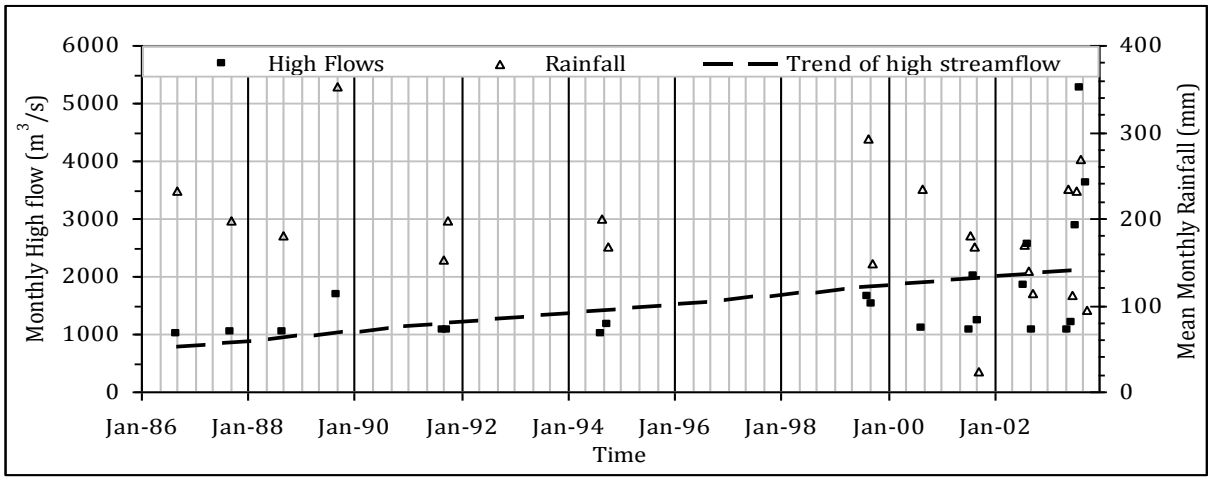


Fig. 13: Trends and magnitude of high stream flows in the Volta system at Bamboi

Estimations from the extreme value distribution showed that there was a 100 % chance that streamflows (floods) with magnitudes 650.6 m^3/s, 296.4 m^3/s and 36.50 m^3/s would occur any day during the year in the Volta, South Western and the Coastal river systems, respectively. Similarly, streamflow of magnitudes 3529 m^3/s, 561.0 m^3/s and 105.0 m^3/s could occur once during any day in 10 years in the Volta, South Western and Coastal river systems, respectively.

2.2 GROUND WATER 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.

Beneficiaries of the Division's research activities include:

- Borehole Drilling Companies
- Community Water and Sanitation Agency
- Groundwater Development/Management Consultants
- Irrigation Development Authority
- Minerals Commission
- Non-Governmental Organizations
- The Mining Industry
- Water Resources Commission
- Individuals

2.2.1 Isotope Techniques for Groundwater Assessment of the Central Region

(Project Staff: Dr. B. K. Kortatsi – Principal Research Scientist; Mr. Collins Tay – Research Scientist; Dr. Shilo Osae – GAEC)

This study started in 2009 and is expected to end in 2012. The objective was to solve groundwater problems in the Central Region using integrated conventional and isotope techniques. Isotope techniques in ground and surface water studies could lead to identifying the sources of major ions in these waters and delineate high chloride areas which are major problems in the Central Region especially in coastal areas. During the year, water samples from selected water bodies such as rivers, boreholes and hand dug wells in the area were periodically collected and analysed. The results obtained confirmed earlier results from the reconnaissance sampling which indicated that groundwater in the area is weakly acidic with mean pH of 5.83 pH units. The principal hydrochemcal facies observed were Na-Cl, Na-Cl-HCO_3 and Na-HCO_3-Cl water types.

2.2.2 Groundwater Monitoring in Northern Ghana

(Project Staff: Dr. William A. Agyekum – Research Scientist; Dr. S. Dapaah-Siakwan – Principal Research Scientist)

As part of the data gathering process to aid the development of a 'Decision Support System (DSS)' by Water Resources Commission (WRC) to promote Integrated Water Resources Management (IWRM) programme in the White Volta River Basin, the project started in 2005 to assess the groundwater of the three (3) Northern Regions. It would be terminated in 2011.

During the year, all the 37 monitoring boreholes were visited twice in July and December to download the recorded groundwater fluctuation data. The data was obtained from installed automatic recording logger and barometric divers on the boreholes. Changes in groundwater temperature were obtained every 6-hour interval. The water levels from each monitoring borehole were measured and recorded manually with a dip-meter. Samples of water were also

taken from all the boreholes for physico-chemical analysis. A geological map of the Northern Ghana showing the location of the monitoring boreholes is shown in Fig. 14.

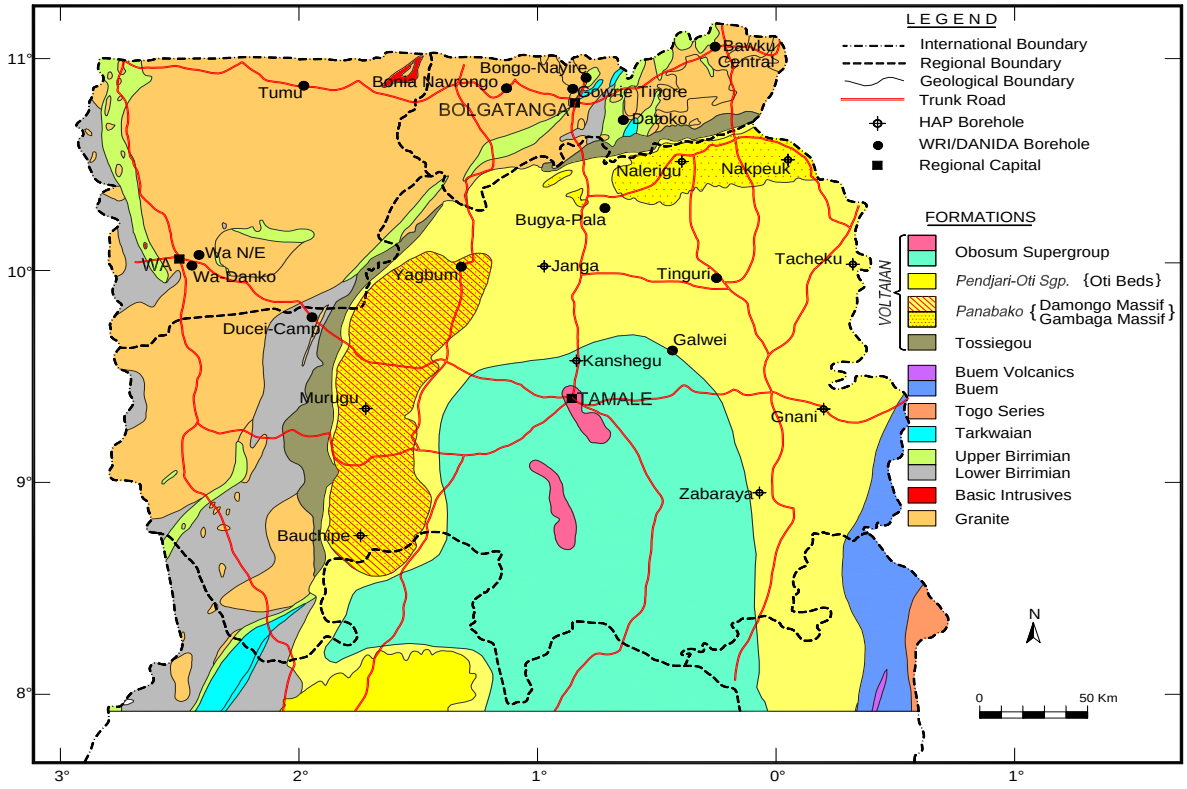


Fig. 14: Location map of DANIDA and CIDA-HAP monitoring boreholes

The compensated groundwater level fluctuation data as well as the manually-measured groundwater level data were plotted to depict changes in groundwater levels with time for each borehole. The plots of the compensated water levels corresponded favourably with the controlled dip-meter levels (master levels) for each of the monitoring boreholes. At each monitoring station, sinusoidal trend of groundwater levels, depicting the climatic pattern (rainy and dry seasons) of northern Ghana was observed. The general observation was that groundwater levels have remained unchanged despite the general perception that they should rather decrease as a result of overexploitation, over-pumping and climate change impact over the years and this might be due to the deep aquifers within the study area. Figs. 15 and 16 show the compensated water levels as well as the dip-meter levels of some selected monitoring boreholes in the project area. There was also an increase in groundwater conductivity and total dissolved solids during the raining season and this could be the result of surface water infiltration into the groundwater system.

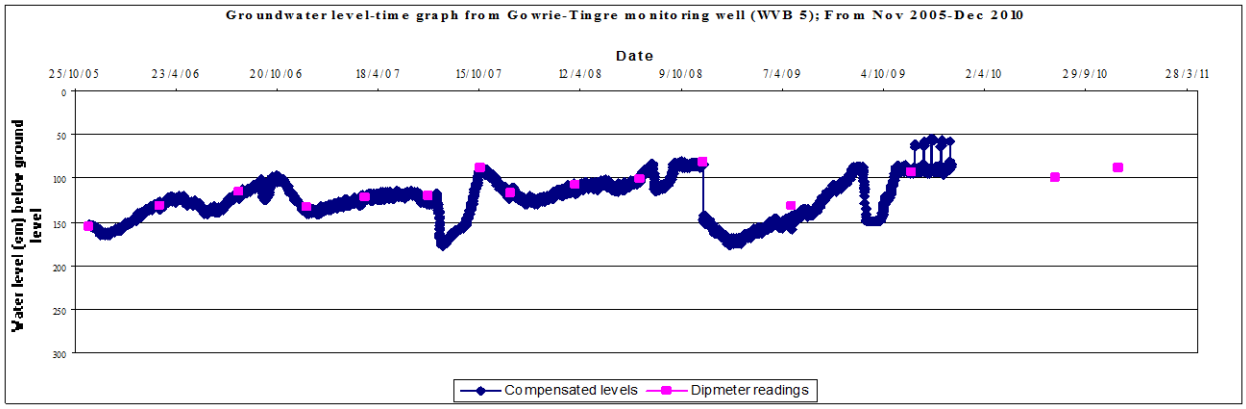


Fig. 15: Groundwater level plot from Gowrie-Tingre monitoring borehole (Nov 2005-Dec 2010)

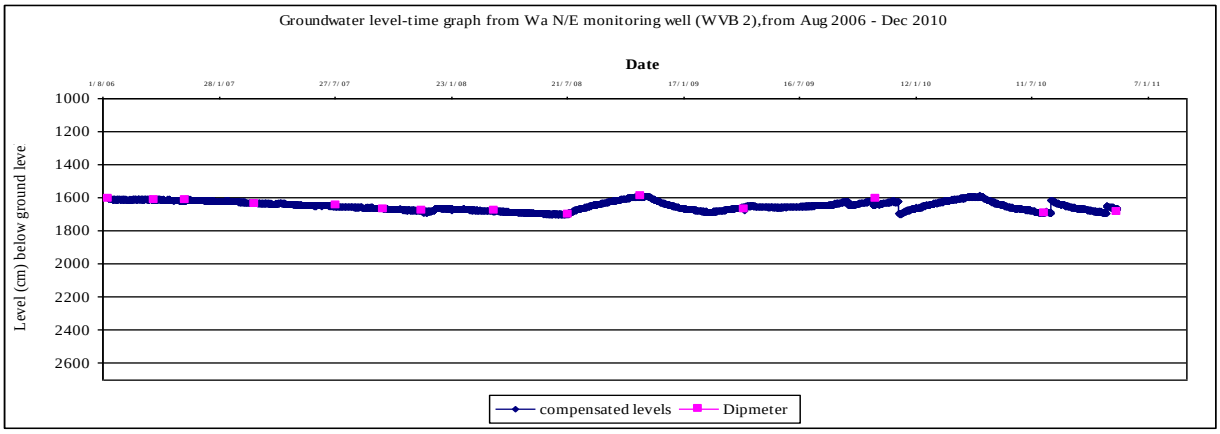


Fig. 16: Groundwater level plot from Wa-N/E monitoring borehole (Nov 2005-Dec 2010)

2.2.3 Geo-logging and Diver Installation of 15 Newly-Drilled Monitoring Boreholes

(Project Staff: Dr. William A. Agyekum – Research Scientist; Dr. S. Dapaah-Siakwan – Principal Research Scientist)

In collaboration with CIDA-HAP and WRC, this project started in the reporting year and is expected to end in 2011. The purpose was to obtain sub-surface information related to log-stratigraphy of the rocks penetrated during drilling and to determine the magnitude and vertical variation of groundwater salinity in the different rock types underlying the study area.

Activities carried out included borehole logging and diver installation. The 3-Arm Calliper (3-ACS), Temperature, Conductivity and Gamma (TCGS), Resistivity (GLOG), High Resolution Flow (HRFM) logging tools and the Robertson's geo-logging Software were used in the collection of the sub-surface data. Each tool was run down through the boreholes at a logging speed of 6 m/min. This activity was followed by installation of both logger and barometric divers on each of the boreholes. The automatic data recording frequency on the divers was programmed to be 6 hours. The data obtained was analysed using '*Viewlog*' software.

The results (Figs. 17 and 18) showed that whilst groundwater salinity levels of boreholes drilled through granite and sandstone rocks to a maximum depth of 120 m were lower than 1000 mg/l, those that penetrated shale, mudstone and siltstone rocks increased sharply from 2000 mg/l to

10000 mg/l at depths between 60 m and 120 m. This means that in order to obtain potable water, the depths of boreholes drilled through shale, mudstone and siltstone rocks should not exceed 60 m.

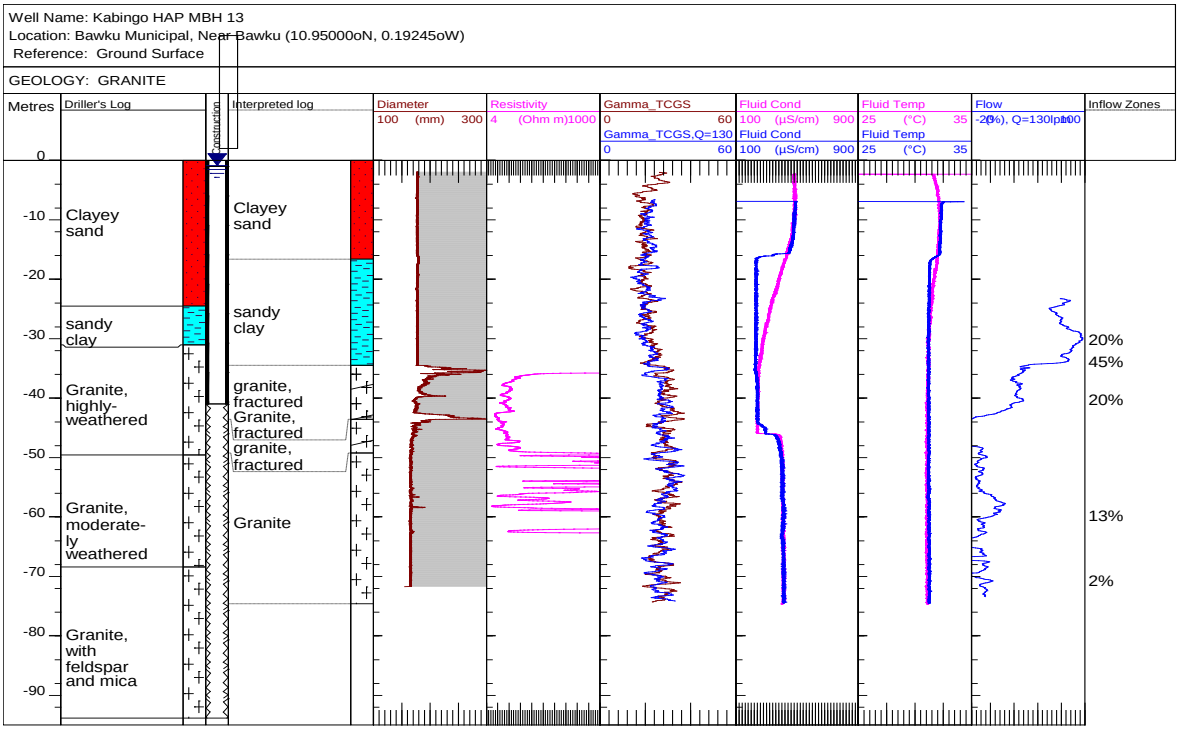


Fig. 17: Composite log of Kabingo monitoring borehole (HAP14)

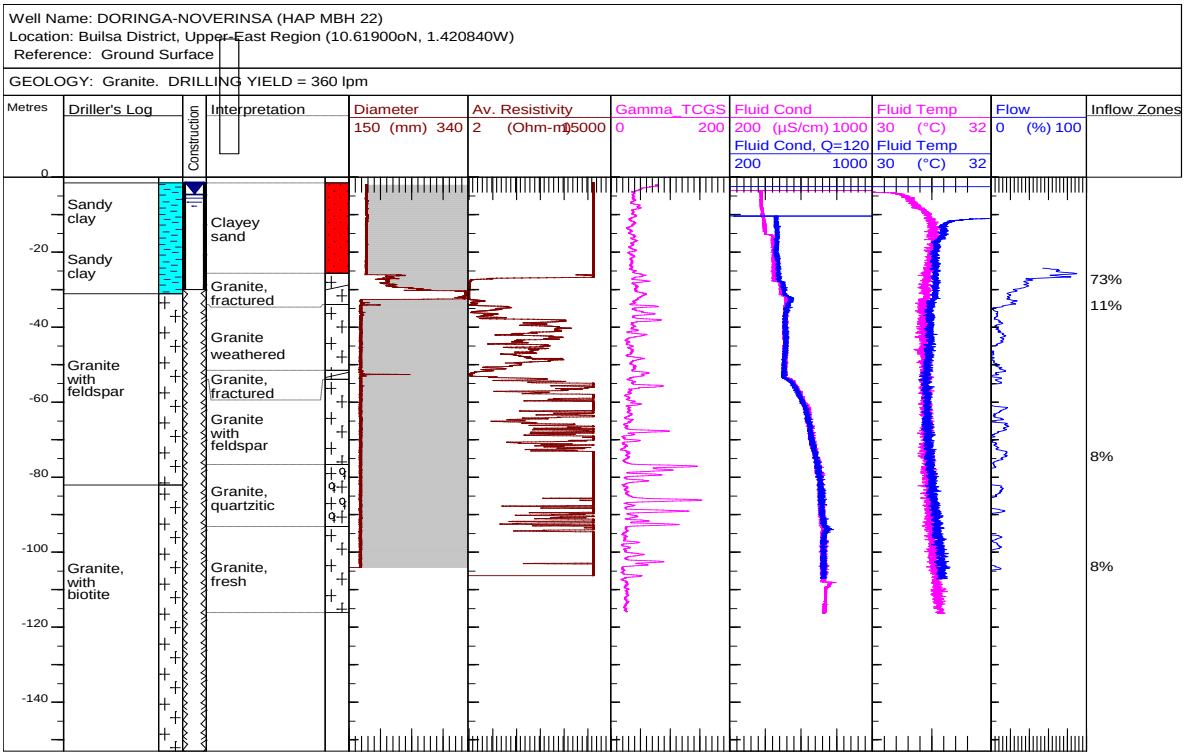


Fig. 18: Composite log of Doninga monitoring borehole (HAP22)

2.3 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
- Development of strategies for water pollution control

Beneficiaries of the Division's research activities include:

- Association of Ghana Industries
- Barry Callebaut Ghana Ltd.
- Benso Oil Palm Plantations Ltd.
- Cadbury Ghana Ltd.
- Cob-A Industries Ltd.
- Coca-Cola Ghana Ltd.
- Cocoa Processing Company Ltd.
- Community Water and Sanitation Agency
- District and Municipal Assemblies
- Environmental Protection Agency
- Environmental Solutions
- GAFCO
- Ghana Wildlife Division of the Forestry Commission
- Golden Tulip Hotel
- Goldfields Ghana Ltd.
- Koajay Co. Ltd.
- Major & Co Ltd.
- National Disaster Management Organisation
- Nkulenu Industries
- Non-Governmental Organisations
- Phyto-Riker Pharmaceutical Ltd.
- Pioneer Food Cannery Ltd.
- Polykraft (Ghana) Limited
- Sachet Water Producers and Consumers
- Twifo Oil Palm Plantations Ltd.
- Universities and Polytechnics
- Volta River Authority
- World Vision

2.3.1 Industrial Water and Wastewater Studies

(Project Staff: Dr. Isaac O. A. Hodgson – Senior Research Scientist; Mr. Anthony Y. Karikari – Senior Research Scientist; Mrs. Joyce Amoako – Research Scientist)

The study was aimed at generating relevant and comprehensive data on raw and spent water which could be used to implement rational water utilization and management programmes in the Cocoa Processing Company Limited (PORTEM), Cadbury Ghana Limited, Kasapreko Ghana Limited, Bamson Company Limited, Pioneer Food Cannery, Phyto-Riker Pharmaceuticals and Golden Tulip Hotel.

In the reporting year, water samples, raw and treated effluent samples were collected on monthly and sometimes on quarterly basis and analyzed. The data produced was used to design treatment plants in some of the industries such as the Cocoa Processing Company Limited. The data was also used for developing environmental management plans for the industries.

2.3.2 Ground and Surface Water Quality Assessment

(Project Staff: Dr. O. D. Ansa-Asare– Principal Research Scientist; Dr. Ruby Asmah – Research Scientist)

The objective of the study was to verify whether the activities of Goldfields Ghana Limited (GGL) have any negative impact on the communities' water resources. It was also to determine the effects of mining operations on the quality of surface waters, sediments and groundwater through drilled observation wells for monitoring.

In the reporting year, water and sediment samples were taken from 26 stream sampling sites; 31 boreholes; 21 treated seepage and leachate water sites; 35 Wells for potable use in Samanhu, Atuabo, Huniso and Esuman; and 30 Wells at Tebe, Abekoase and Pepesa. These samples were analysed using standard methodologies.

Results obtained from the surface water samples showed that the pH of 63 % of the rivers and streams in the operational area fell within the range of 6.5 – 8.5 pH units. However, the pH of about 19 % of the rivers and streams were below 6.0 pH units while a similar percentage exceeded the pH of 8.5 pH units. Conductivity of the streams ranged from 31.6 – 2010 µS/cm. There was a significant correlation between pH and conductivity (r^2 = 0.64, p <0.01), which implied that areas with higher conductivities had higher pH values and vice versa. The ionic dominance pattern observed in the Tarkwa area, Na > K > Ca > Mg : HCO_3 > SO_4 > Cl, did not conform to the ionic dominance pattern of Ca > Mg > Na > K and HCO_3 > SO_4 > Cl for freshwater. The dominance of Na over Ca could be attributed to human activities in the area. The highest nitrate concentration of 12.5 mg/l was recorded at station SP-2 and this could be attributed to pollution by human or animal waste, fertilizer run-off and human activities including mining. Iron level (10.4 mg/l) at SP-5 was above the background level. The high iron levels recorded could be due to the geology of the area. Mercury showed higher levels at AVS (0.0024 mg/l). Lead and copper were very low, mostly below their detection limits and this indicated that the streams were good for potable use and with no influence of the mining activities.

Analysis of the groundwater indicated that the pH of the selected wells ranged from 4.36 – 7.37 pH units with a mean value of 5.8 pH units, an indication that most of the pH values measured

were largely acidic. The wells with the lowest pH values (<5.00) were WPA 75 and WPA 79 located at Pepesa and WAO 70 located at Atuabo. The pH values for 40 of the wells out of the 47 sampled fell below the WHO minimum limit of 6.5 pH units and this could be attributed to the geology of the area. Depending on environmental conditions, the acidic waters could leach trace metals from their surroundings. The highest nitrate concentration (> 5 mg/l) observed in wells WAO 58 and WPA 58 was below the WHO maximum guideline value of 10.0 mg/l. The range of nitrite concentrations was 0.01 – 1.98 mg/l with some above the WHO recommended guideline value of 1.00 mg/l. Nitrite concentrations in wells WSU 36, WPA 10 and WPA 08 exceeded the maximum recommended level. Concentrations of lead were below detection (< 0.005 mg/l) in all the wells sampled. Mercury concentrations ranged from < 0.001 mg/l to 0.002 mg/l which were less than the WHO maximum guideline value of 0.006 mg/l for drinking water. Copper concentrations in the wells were also within the WHO recommended levels. Manganese concentrations in the wells ranged from 0.002 – 5.87 mg/l with a mean value of 0.41 mg/l as compared to the WHO maximum recommended level of 0.4 mg/l. The wells with manganese concentrations higher than the guideline value were WHO 14 (5.87 mg/l), WPA 10 (0.906 mg/l), WPA 75 (1.16 mg/l), and WPA 79 (3.14 mg/l). The nitrate-nitrogen concentrations in the boreholes gave no indication of contamination from the external environment and there were no adverse effects with respect to heap leaching in terms of contaminating the groundwater in the area.

It was recommended that:

- Communities living within the concession of Goldfields Ghana Limited should be educated to avoid pollution of surface waters (streams) through the impact of human activities.
- Trace metals such as iron, manganese and zinc which were due to the geology of the area could be removed by treating the water before drinking.
- At least, once a year monitoring by CSIR Water Research Institute to confirm finding of the regular monitoring of the Environmental Section of Goldfields Ghana limited is necessary to promote public confidence in the Company in terms of monitoring and environmental management.
- The environmental Audits of Mines in Ghana should be placed in the public domain to allow for public scrutiny.

2.3.3 Surface Water Quality Monitoring and Assessment of the Volta, Southwestern and Coastal River Systems

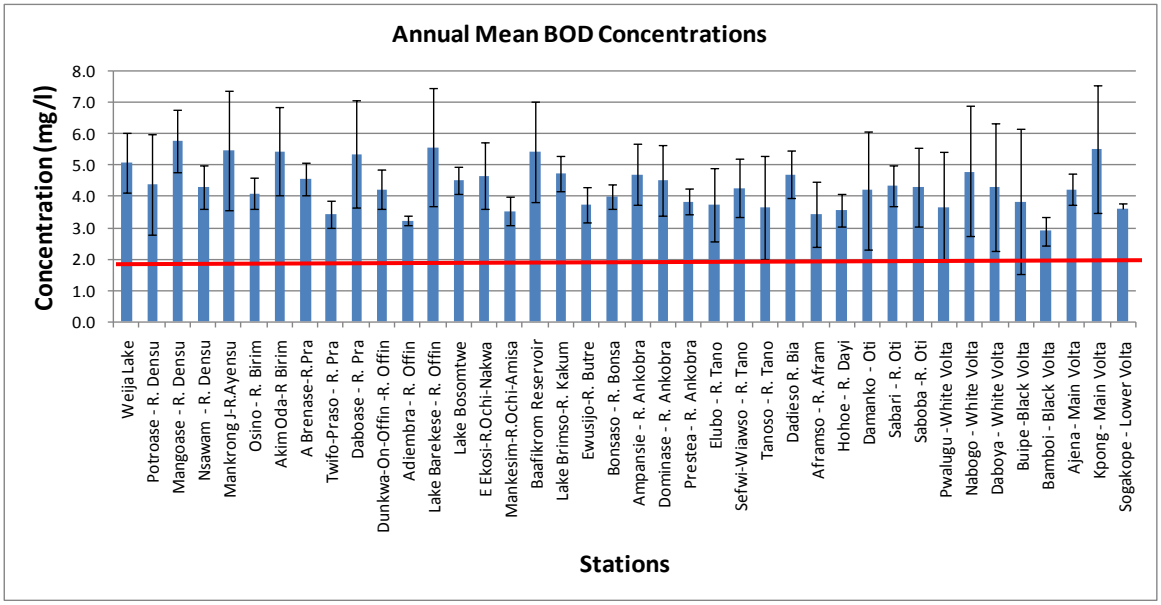
(Project Staff: Dr. O. D. Ansa-Asare – Principal Research Scientist; Mr. Humphrey F. Darko – Research Scientist)

The project began in the reporting year to develop an efficient and effective management system for sustainable development of Ghana's water resources to ensure full socio-economic benefits for present and future generations. It is expected to end in 2011.

The scope of work included collection of water samples, laboratory analysis, data interpretation, preparation and submission of reports. During the reporting year, three field visits were made to 40 stations in the Volta, Southwestern and Coastal River Systems and samples collected for analysis. The sampling campaigns were undertaken in the months of March, July and October

2010. Water, sediment and fish samples were collected for physico-chemical, metals, sediment quality and bacteriological analysis.

The range of pH (6.52 – 9.09 pH units) was within the Target Water Quality Range (TWQR) of 6.00 – 9.00 pH units. Dissolved oxygen concentrations ranged from 5.00 – 9.00 mg/l which indicated that the water was well oxygenated and could support fish survival. Biochemical Oxygen Demand (BOD) was high with annual mean values above the guideline value of 2.0 mg/l (Fig. 19). Levels of Pesticides and derivatives in the water samples were below their respective WHO guideline values, except Beta Endosulfan which was 0.109 µg/l and 0.124 µg/l in March at Twifo-Praso and Lake Barekese, respectively as against the WHO guideline of 0.030 µg/l. Beta Endosulfan levels in Lake Bosomtwe (0.154 µg/l), Sefwi-Wiawso (0.257 µg/l), Sabari (0.144 µg/l) and Buipe (0.214 µg/l) in October were all above the WHO guideline. Concentrations of trace metals in the waters were very low, except iron (0.369 – 7.02 mg/l) which was above WRC guideline value of 0.3 mg/l. The Water Quality Index classification of the waters indicated that most of the water bodies were in Class II, the "fairly good quality" state, but with seasonal variations in quality states. The overall characteristics of the water samples indicated that, the Volta River System was comparatively less polluted than the Southwestern and the Coastal River Systems.



Note: The red line indicates the annual mean guideline value of 2.0 mg/l

Fig. 19: Annual mean BOD concentrations of the Volta, Southwestern and Coastal river basins

2.3.4 Three Districts Water Supply Project

(Project Staff: Mr. Humphrey F. Darko – Research Scientist; Dr. I. O. A. Hodgson – Senior Research Scientist; Dr. J. A. Ampofo – Principal Research Scientist)

This study started in 2008 to assess the quality and suitability of treated water for potable use in the Dangme East, Dangme West and North Tongu Districts.

The scope of work included collection of water samples, laboratory analysis, data interpretation and preparation and submission of reports. At the project site at Aveyime where the Treatment

Plant is located, water samples were collected from the Raw Water Tank, Slow Sand Filtration Tank, Clear Water (Chlorinated) Tank, overhead tanks or booster stations and along the distribution lines from stand pipes in the different communities for analysis.

The pH ranged from 6.55 – 7.53 pH units and this was within the WHO (2006) drinking water guideline range of 6.5 – 8.5 pH units. The results of the physico-chemical and bacteriological examinations of the water samples indicated that the water from the stand pipes were suitable for domestic purposes based on WHO guideline and Ghana standards (Tables 3 and 4).

Table 3: Results of bacteriological quality of water samples from the sampling sites

Sample Identification	Total coliform (cfu/100ml)	Faecal coliform (cfu/100ml)	Total Heterotrophic Bacteria (cfu/1ml)
Raw Water (Intake) Tank	84	0	2304
Slow Sand Filtration Tank	7	0	1408
Clear Water Tank (Chlorinated Tank)	0	0	<1
Mepe Standpipe	0	0	<1
Dedukope Standpipe	0	0	<1
Caesarkope Standpipe	0	0	<1
Nakomkorpe Standpipe	0	0	<1
Sege (Vicco Office tap)	0	0	<1
Dawa Booster Station Reservoir,	0	0	<1
Dawa Standpipe	0	0	<1
Tsokpoli Standpipe	0	0	172
Dawenya	0	0	<1
Ghana Standards	0	0	1000
WHO Guidelines	0	0	-

Table 4: Physico-chemical parameters of water samples from the treatment plant and standpipes (All results are in mg/l except otherwise stated)

Parameter	Raw Water Tank (Intake)	Slow Sand Filtration Tank	Clear Water Tank	Mepe Standpipe	Dedukope Standpipe	Caesarkope Standpipe	Nakomkope Standpipe	Sege (Vicco Office) Tap	Dawa Booster Station Reservoir	Dawa Standpipe	Tsokpoli Standpipe	Dawenya Central Univ. Hydrant	WHO (2006) Guideline Values
Turbidity (NTU)	3.10	1.10	1.10	2.00	1.40	1.10	1.30	1.30	1.30	1.50	1.10	8.70	5.00
Colour (Hz)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	50.0	15.0
pH (pH units)	6.57	6.66	6.98	7.49	7.53	7.07	6.92	6.95	7.16	7.20	7.12	6.55	6.5-8.5
Conductivity (µS/cm)	76.8	79.9	97.6	135	143	80.8	84.9	83.4	93.3	81.6	86.0	90.4	-
TSS	4.00	2.00	2.00	1.00	1.00	1.60	1.00	1.00	2.00	2.00	1.50	8.00	-
TDS	42.2	43.9	53.7	74.3	78.7	44.4	46.7	45.9	51.3	44.9	47.3	49.7	1000
Sodium	5.20	5.80	5.80	4.95	4.96	4.90	4.90	5.10	5.00	4.90	4.80	5.40	200
Potassium	2.80	2.80	3.20	2.90	2.88	2.95	3.10	3.30	3.20	3.10	2.90	3.20	30.0
Calcium	8.02	6.41	8.02	12.0	12.0	8.02	6.41	7.21	6.41	6.41	6.41	7.21	200
Magnesium	0.962	2.42	2.42	2.90	2.90	1.45	2.91	3.88	4.37	4.37	4.85	2.91	150
Iron	0.172	0.068	0.046	0.032	0.082	0.073	0.022	0.013	0.016	<0.010	0.013	0.184	0.3
Chloride	1.00	1.00	5.96	8.93	10.9	3.97	3.97	4.96	3.97	3.97	4.96	2.98	250
Sulphate	1.00	2.00	2.00	1.00	2.00	2.00	1.00	1.00	3.00	2.00	2.00	2.00	250
Phosphate	0.088	0.092	0.084	0.046	0.043	0.066	0.054	0.072	0.083	0.062	0.052	0.098	-
Manganese	0.052	0.044	0.018	0.008	0.006	0.005	0.006	0.018	0.012	0.005	0.012	0.097	0.400
Nitrite-N	0.014	0.010	0.011	0.012	0.014	0.011	0.007	0.005	0.01	0.012	0.008	0.018	1.00
Nitrate-N	0.140	0.130	0.120	0.201	0.150	0.180	0.120	0.133	0.104	0.140	0.150	0.162	10.0
Total Hardness	24.0	26.0	30.0	42.0	42.0	26.0	28.0	34.0	34.0	34.0	36.0	30.0	500
Total Alkalinity	38.0	40.0	44.0	50.0	54.0	40.0	46.0	44.0	46.0	44.0	44.0	50.0	-
Fluoride	<0.005	0.006	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Bicarbonate	46.4	48.8	53.7	61.0	65.9	48.8	56.1	53.7	56.1	53.7	53.7	61	1.50

2.3.5 Limnological Study of Three Coastal Water Supply Reservoirs in Ghana

(Project Staff: Mrs. Joyce Amoako – Research Scientist; Dr. O. D. Ansa-Asare – Principal Research Scientist)

The Inchaban, Brimsu and Weija reservoirs supply water to the Sekondi, Cape Coast and Accra respectively. Adequate and sustainable supply of raw water from these reservoirs for treatment and distribution is changing due to rapid urban population growth and pollution. It was against this background that the study started in 2007 to monitor temporal changes in the water quality of these reservoirs. It is expected to end in 2011.

During the reporting year, water samples were collected hourly in the day at the intake points of the reservoirs during the dry season and analysed using standard methodologies. The study showed that the pH increased considerably in the late mornings and afternoons but decreased when sun was approaching (Figs. 20 – 22). This could be due to changes in temperature of the reservoirs which affected the amount of decomposing organic materials. In addition, the Dissolved Oxygen (DO) increased with increased pH for all the three reservoirs (Figs. 23 – 25) depicting a positive correlation between the parameters.

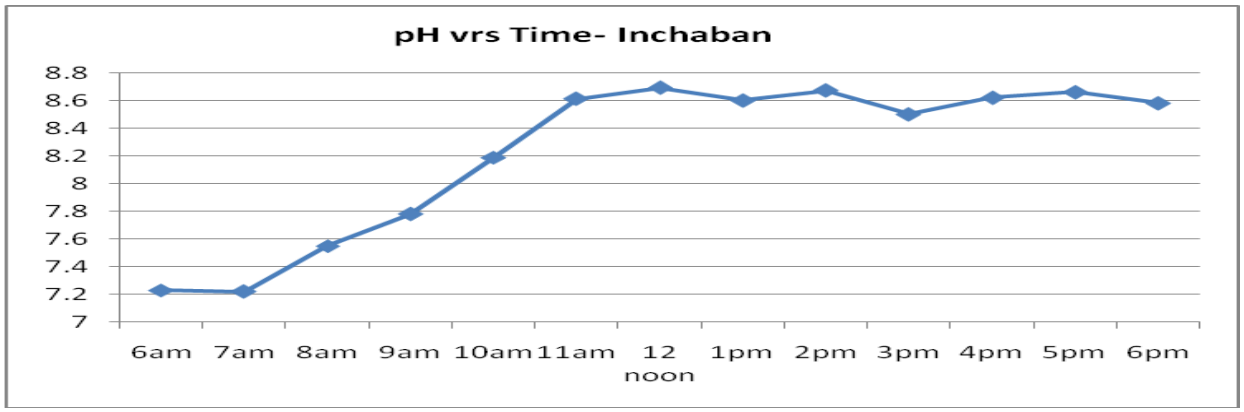


Fig. 20: pH verses time profile for Inchaban reservoir

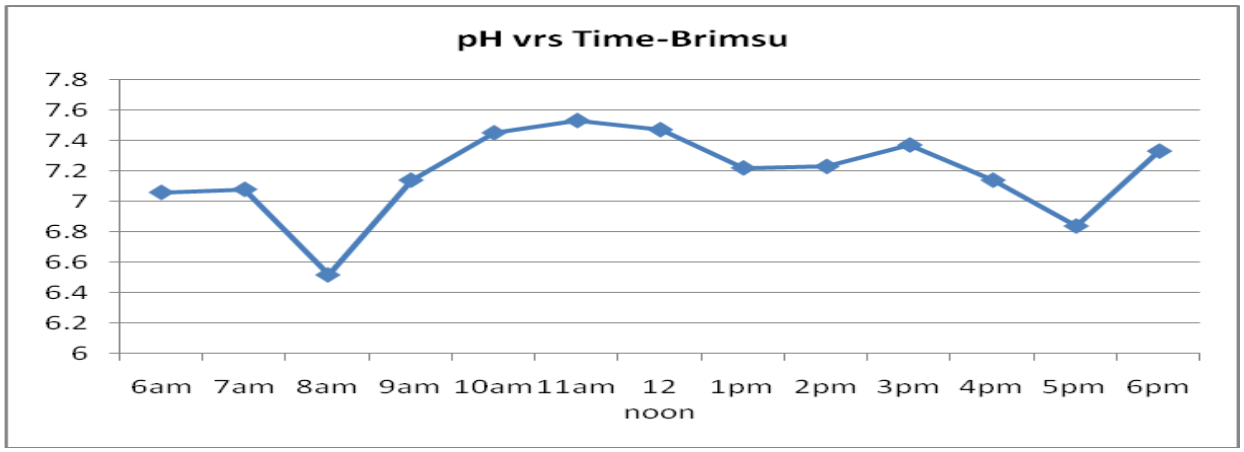


Fig. 21: pH verses time profile for Brimsu reservoir

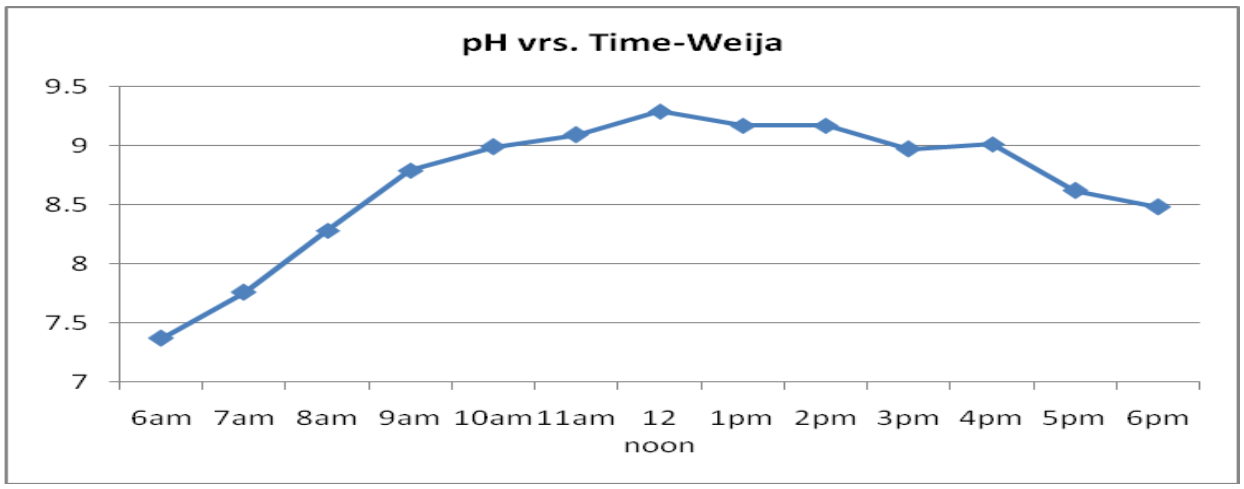


Fig. 22: pH verses time profile for Weija reservoir

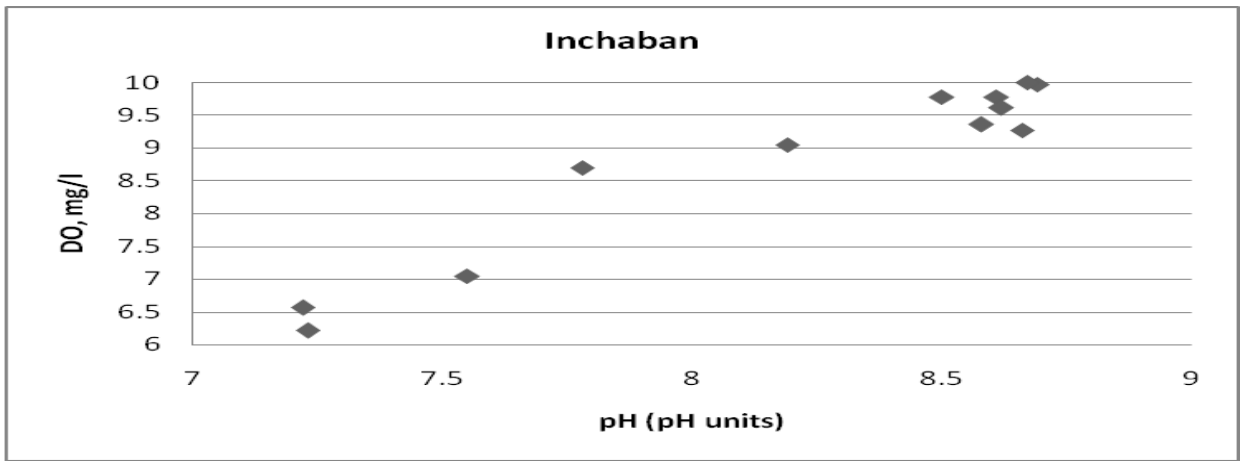


Fig. 23: Correlation between dissolved oxygen (DO) and pH for Inchaban reservoir

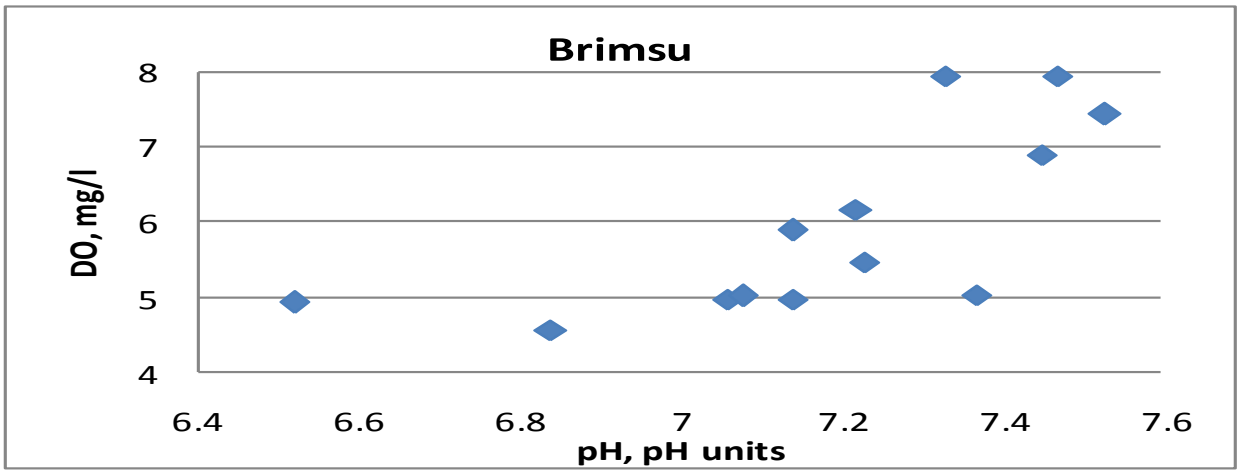


Fig. 24: Correlation between dissolved oxygen (DO) and pH for Brimsu reservoir

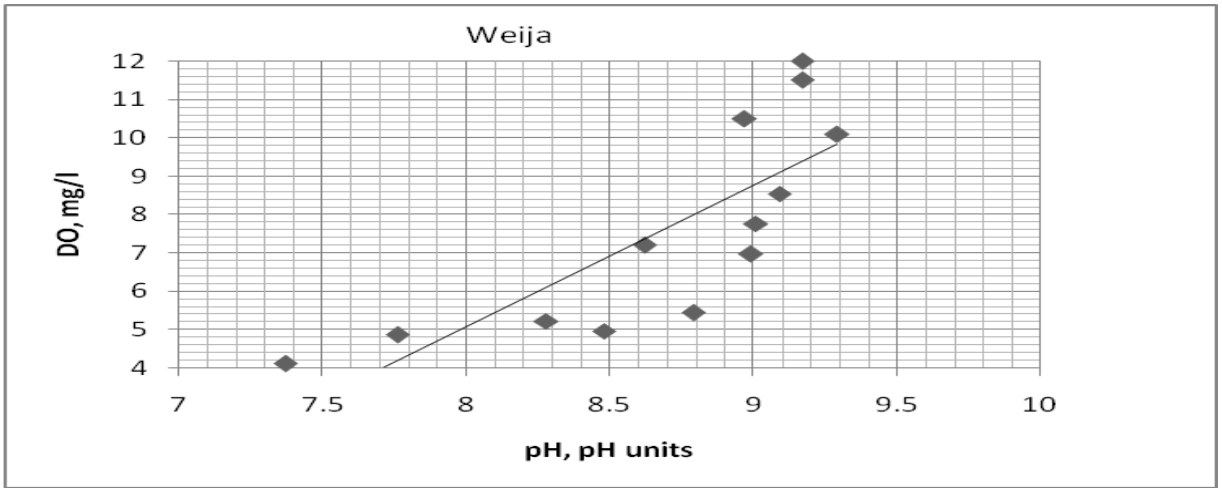


Fig. 25: Correlation between dissolved oxygen (DO) and pH for Weija reservoir

2.3.6 Sustainable Cage Aquaculture Development on the Volta Lake

(Project Staff: Dr (Mrs) Ruby Asmah – Research Scientist; Mr. Anthony Karikari – Senior Research Scientist; Dr. J. K. Ofori – Senior Research Scientist; Mr. L. A. K. Awity - Fisheries Commission)

This collaborative study with the Fisheries Commission started in 2009 to estimate the carrying capacity of the Volta Lake in relation to cage and pen aquaculture development. It was also aimed at assessing the socio-economic impact of cage aquaculture development in the Volta Lake and providing guidelines for sustainable cage aquaculture development in Ghana. It is expected to be completed in 2011.

In the reporting year, water samples for physico-chemical analysis were collected from fifteen (15) locations on the Volta Lake (Fig. 26) with clusters of fish cages or pens including the gorge area, Atimpoku, Akuse and Sogakope. A semi-structured questionnaire was also administered to the fish farmers in the Afram Plains, North Tongu District and parts of the Volta Region (Fig. 27) to determine the sizes of their farms operations and the types of inputs being employed as these influence the environment.

The survey indicated that the sizes of fish farms ranged from 57.1 m^3 to 6500 m^3 and about 60 % of the farmers used extruded feed which is known to have less negative impact on water quality. Fingerlings for stocking were produced from the *Oreochromis niloticus* obtained from the Lake and any incidence of gene pollution in case of fish escape was therefore minimized. The analytical study of the water samples showed that pH values ranged from 6.55 – 7.32 pH units. Mean turbidity (2.94 mg/l), transparency (2.51 m) and dissolved oxygen (5.40 mg/l) were comparable to previously reported works on the Lake, suggesting that the water quality of the lake remains unchanged. The levels of trace metals were generally low and did not present any threat to biota. The observed low ionic content of the Lake is good for aquatic ecosystem use. Nutrient concentrations were generally low in areas with the fish cages except in the lower Volta area. Overall observation from the study was that there were no clear detectable effects of cage aquaculture on water quality in the vicinity of the production sites and this could be attributed to factors such as water currents and the use of floating feed. Although, there were no immediate detectable impacts of fish farming on water quality of the Lake, the study recommended the need

for regular water quality monitoring and the need to estimate the carrying capacity of the Lake to develop good water management practices to ensure sustainable use of the Lake.

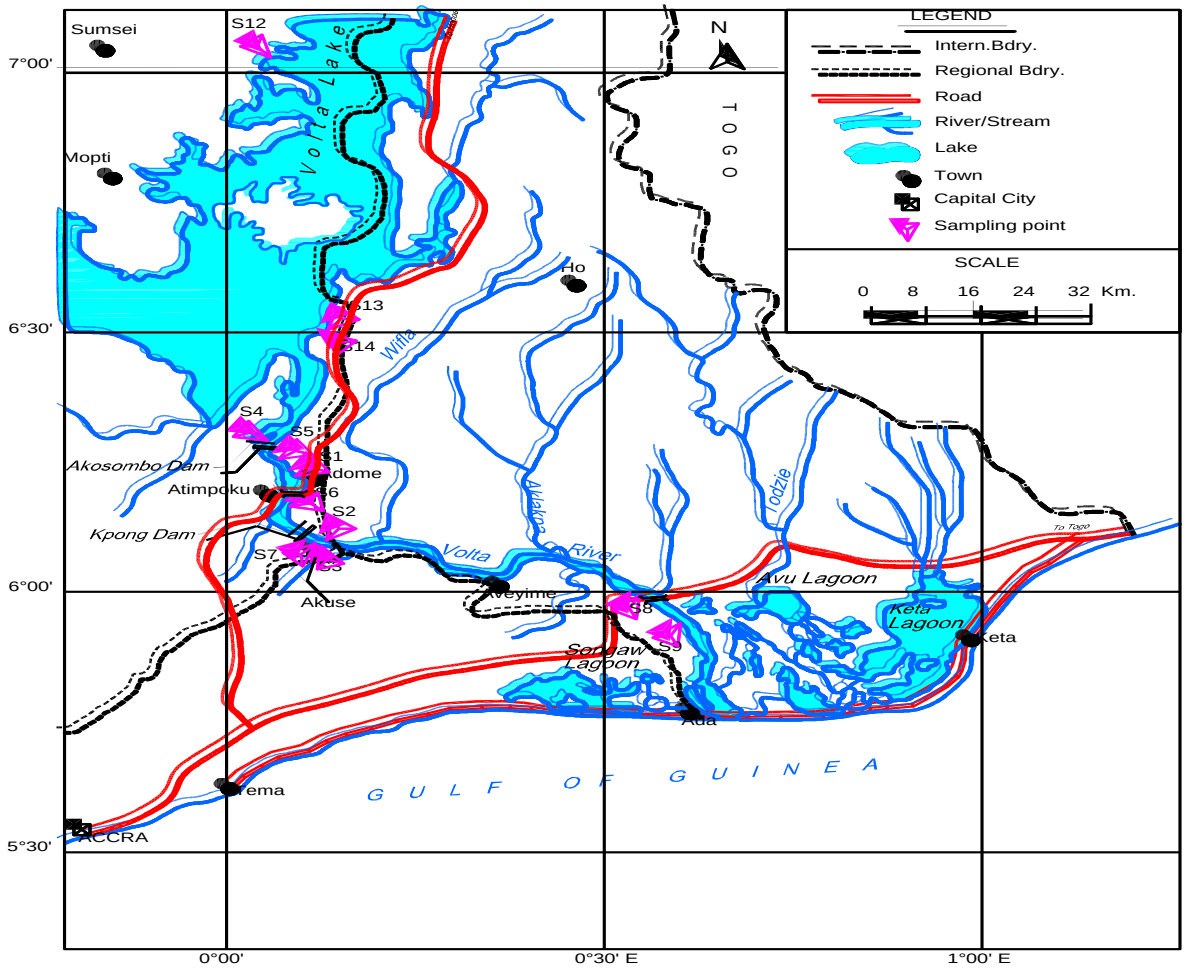


Fig. 26: Location map showing the sampling stations on the Volta Lake

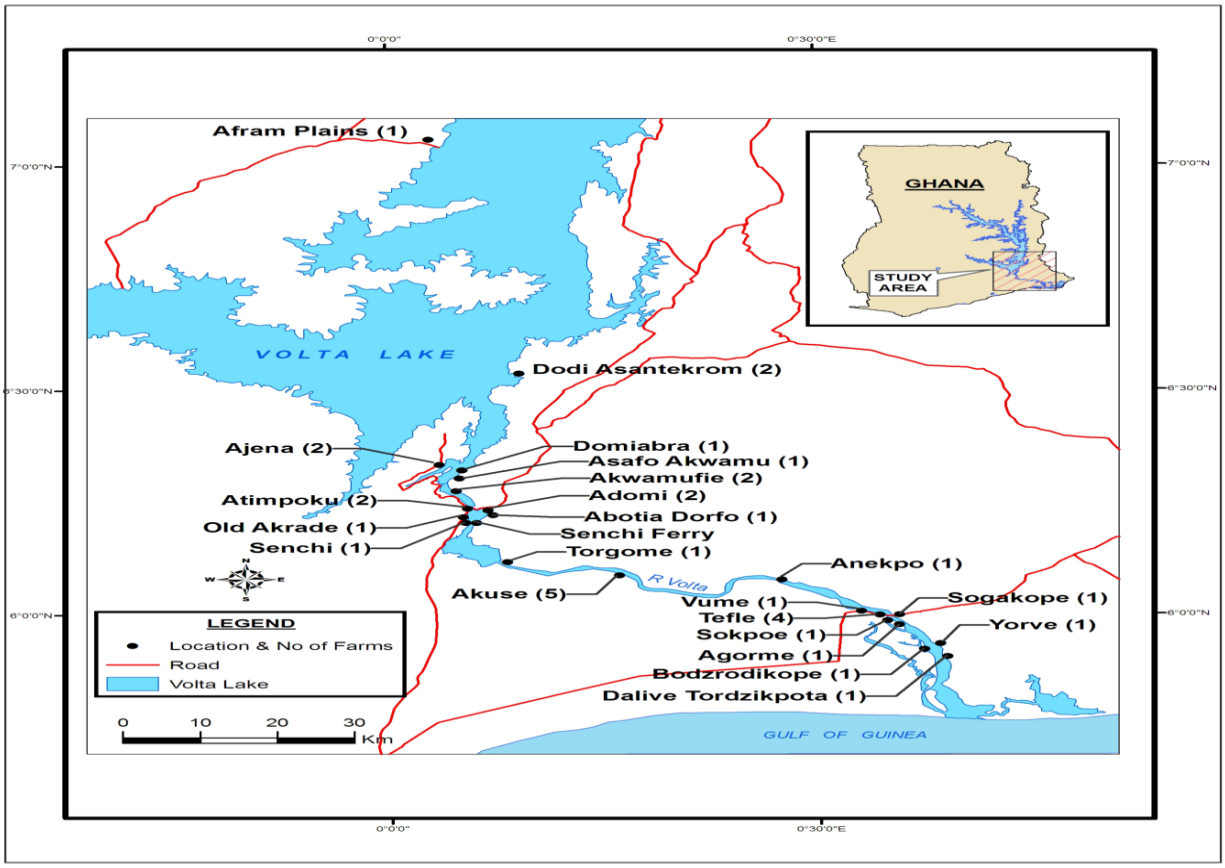


Fig. 27: Location map showing in brackets the number of fish farms visited within each location

2.3.7 Quality of Water Bodies in Mining and Non-Mining Areas within the Ashanti Gold Belt

(Project Staff: Mr. Collins Tay – Research Scientist; Dr. Isaac O. Hodgson – Senior Research Scientist)

Mining activities impact negatively on water bodies through inadequate management of tailings and effluents from processing plants, exposure of mined surfaces leading to acid mine drainage and the use of mercury by the small-scale alluvial workings. It was against this background that the study was initiated in 2008 to:

- assess the hydrochemical processes influencing water bodies; and
- identify and characterise the trace metal levels in water bodies within the Ashanti Gold Belt.

It is expected to end in 2011.

A total of 113 samples were collected from boreholes, wells and streams in Obuasi and some communities within the Ashanti Gold Belt during the dry and wet seasons between 2008 and 2010. The samples were analysed using appropriate certified and acceptable international procedures outlined in the Standard Methods for the Examination of Water and Wastewater. Charge balances were calculated using the equation:

$CB = [(\sum z\ Mc - \sum z\ Ma) / (\sum z\ Mc + \sum z\ Ma)] * 100.$

The pH of boreholes in the mining and non- mining areas ranged from 5.9 – 9.5 pH units and 5.0 – 9.2 pH units in the wet season and 3.6 – 8.0 pH units and 3.7 – 6.8 pH units in the dry season, respectively as compared to the background range of 6.5 – 9.0 pH units. The disparity in pH values between the dry and wet seasons could be due to dilution and nature of deposits over which they flow.

The conductivity in the mining and non-mining areas during the wet season ranged from 47.0 – 450 µS/cm and 489 – 715 µS/cm, respectively while those of the dry season ranged from 22.8 – 473 µS/cm and 23.4 – 473 µS/cm, respectively. The chemical constituents were generally low with relative abundance of cations and anions in the order of $Ca^{+2} > Na^{+} > Mg^{+2} > K^{+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{-2} > NO_3^{-}$, respectively (Fig. 28). The study also showed that, gypsum, anhydrite, calcite and dolomite dissolution were some of the processes influencing the water chemistry of the study area. Two major hydrochemical water types, Ca-Mg-HCO_3 water type with sources comprising either dolomite ($CaMg(CO_3)_2$) or calcite ($CaCO_3$) in the rock matrix and Na-Cl or Na-Cl-HCO_3-Cl water type which have saline characteristics, were delineated (Fig. 29). The Na-Mg-Ca-HCO_3 water type was also delineated. The summaries of the results are shown in Tables 5 and 6. The trace metal level assessment (Table 7) of the water bodies showed that Fe, Mn, Cu, Cd and Pd could be introduced into the water bodies during water-rock interactions. The geochemical and biochemical processes, therefore, influenced the water chemistry of the study area. Generally, there were no significant differences in the water quality parameters between the mining and non-mining areas as the levels were comparable.

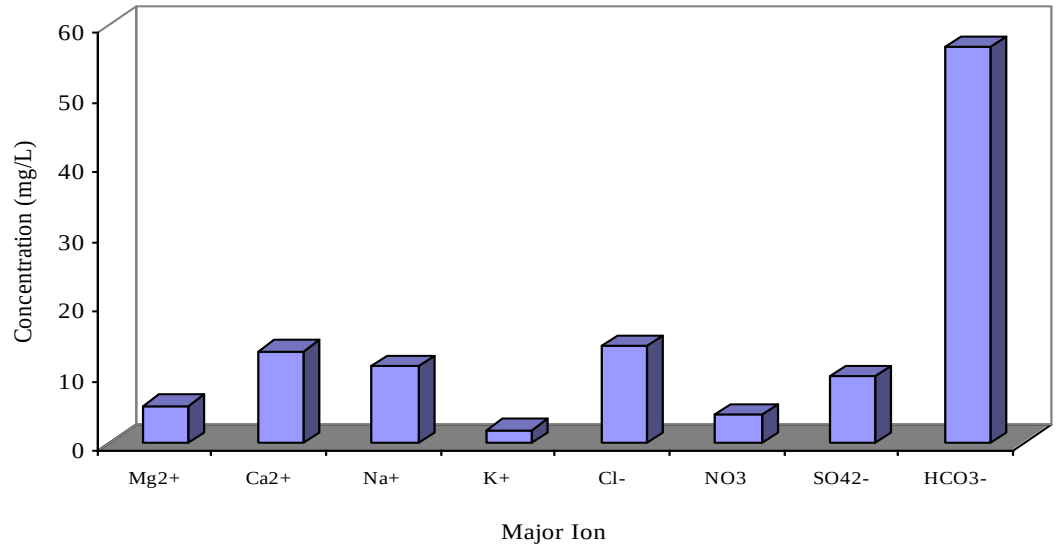


Fig. 28: Mean values of major ion constituents in the water bodies within the Ashanti Gold Belt

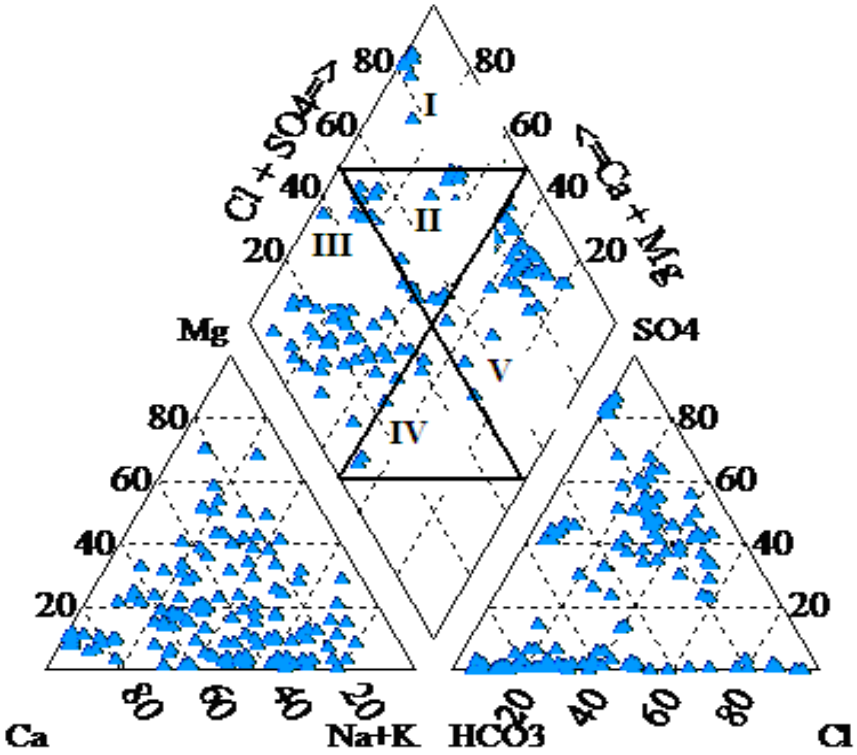


Fig. 29: Piper plot showing the chemical types of groundwater sources within the study area

Table 5: Summary of water quality of boreholes in the Ashanti Gold Belt (wet season)

	Community			
	Mining Area		**Non-mining Area**	
Parameter	**Range**	**Mean**	**Range**	**Mean**
pH (unit)	5.9 – 9.5	7.2	5.0 – 9.2	7.1
Conductivity (uS/cm)	47.0 – 450.0	205	48.5 – 715.2	196.8
PO_4-P (mg/l)	0.3 – 1.4	0.6	0.3 – 2.9	1.2
Total alk. (mg/l $CaCO_3$)	11.0 – 100.0	41.3	9.0 – 140.0	43.6
NO_2-N (mg/l)	0.017 – 0.045	0.033	0.017 – 0.081	0.04
NO_3-N (mg/l)	1.1 – 16.7	5.9	1.2 – 25.7	8.2
HCO_3^- (mg/l)	13.4 – 122	50.4	11.0 – 170.8	53.2
Cl^- (mg/l)	1.8 – 28.8	11.0	4.0 – 37.6	10.3
SO_4^{-2} (mg/l)	0.9 – 98	30.5	2.6 – 64.5	19
Na^+ (mg/l)	4.2 – 28.2	14.8	4.2 – 40.5	14.9
K^+ (mg/l)	0.3 – 10.9	3.3	0.4 – 10.2	2.3
Ca^{+2} (mg/l)	2.4 – 30.9	11.9	2.2 – 60.5	13.0
Mg^{+2} (mg/l)	<0.005 – 19.1	6.39	<0.005 – 11.8	3.9
Tot Hard (mg/l $CaCO_3$)	8.1 – 155	56.2	10 – 200	48.7
TDS (mg/l)	2.0 – 9.0	4.4	26.7 – 399.3	108.2
Ca Hard (mg/l $CaCO_3$)	6.0 – 77	29.8	5.5 – 151.3	32.6
Mg Hard (mg/l $CaCO_3$)	0.1 – 78.8	26.3	1.0 – 48.8	16.1
F^- (mg/l)	<0.005		<0.005	

Table 6: Summary of water quality of boreholes in the Ashanti Gold Belt (dry season)

	Community			
	Mining Area		Non-mining Area	
Parameter	**Range**	**Mean**	**Range**	**Mean**
pH- unit	3.6 – 8.0	6.0	3.7 – 6.8	5.4
Conductivity (uS/cm)	22.8 – 473.0	172.0	23.4 – 473.0	184.0
PO_4-P (mg/l)	0.07 – 3.85	0.91	0.1 – 3.6	0.8
Total alk. (mg/l as $CaCO_3$)	2.0 – 208.0	47.0	2.7 – 218.0	54.6
NO_2-N (mg/l)	0.014 – 18.9	0.77	< 0.001 – 0.3	0.1
NO_3-N (mg/l)	0.01 – 16.1	2.08	<0.001 – 15.4	2.1
HCO_3^- (mg/l)	2.4 – 253	59.1	2.3 – 257.0	66.5
Cl^- (mg/l)	1.0 – 65.5	15.1	1.2 – 63.2	16.4
SO_4^{-2} (mg/l)	0.01 – 15.0	1.31	<0.01 – 2.5	0.9
Na^+ (mg/l)	1.2 – 25.5	9.09	1.6 – 22.2	9.6
K^+ (mg/l)	0.1 – 9.6	1.5	0.1 – 5.4	1.4
Ca^{+2} (mg/l)	0.8 – 62.5	13.4	2.8 – 63.5	13.7
Mg^{+2} (mg/l)	0.5 – 39.8	5.38	0.8 – 28.5	5.2
Tot Hard (mg/l $CaCO_3$)	4.0 – 216.0	56.0	4.3 – 208	62.3
F^- (mg/l)	<0.005		<0.005	

Table 7: Statistical summary of the trace metal levels in the water bodies of the study area

Element	**Borehole water (mg/l)**		**Well water (mg/l)**		**Stream water (mg/l)**		**WHO guideline (2004)**
	Range	**Mean**	**Range**	**Mean**	**Range**	**Mean**	
Fe	<0.01 – 5.1	0.62	<0.01 – 3.7	0.15	<0.01 – 1.58	0.9	0.3
Mn	<0.005 – 1.17	0.2	<0.005 – 0.17	0.05	0.01 – 0.08	0.04	0.3
Cd	<0.002 – 0.009	0.005	<0.002 – 0.006	0.004	<0.002 – 0.007	0.005	0.005
Cu	<0.02 – 0.1	0.04	<0.02 – 0.04	0.03	<0.02		
Pb	<0.005 – 1.58	0.22	<0.005		<0.005		0.05
As	<0.001 – 0.62	0.07	<0.001 – 0.2	0.11	0.003 – 0.005	0.004	
Hg	<0.001 – 0.04	0.04	<0.001		0.002 – 0.006	0.004	0.001

2.4 ENVIRONMENTAL BIOLOGY AND HEALTH DIVISION

The long-term 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. It has multidisciplinary approach to research, consultancy and advisory services, technology transfer, water-related public health and environmental issues. 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 with the aim of their prevention and control. Targeted diseases include malaria, giardiasis, cryptosporidiosis and Neglected Tropical Diseases (NTDs) such as onchocerciasis, schistosomiasis, soil transmitted helminthiasis and leishmaniasis.
- 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.
- Training of scientists, technologists, technicians and students.

Beneficiaries of the Division's activities include the following:

- Ghana Water Company Limited
- Community Water and Sanitation Agency
- Municipal and District Assemblies
- Environmental Protection Agency
- Food and Drug Board
- Industrial and Mining Companies
- Hospitality Industries
- Ministry of Environment, Science and Technology
- Ministry of Health
- Ministry of Food and Agriculture
- Food and Beverage Industries
- Sachet and Bottled Water Producers
- Volta River Authority
- Water Resources Commission
- National Onchocerciasis Secretariat
- Public and Private Universities
- Polytechnics
- Senior High Schools
- Individuals

- Diplomatic Missions
- Borehole Drilling Companies
- Ghana Oil Palm Development Company

2.4.1 The Role of Algae and Macro-Invertebrates in the Removal of Faecal Bacteria from Domestic Wastewater and in Open Waters Using Natural Treatment Systems

(Project Staff: Mr. E. D. O. Ansa – Research Scientist; Dr. J. A. Ampofo – Principal Research Scientist)

The Institute, in collaboration with Environmental Engineering Laboratory, UNESCO-IHE Institute for Water Education, The Netherlands and the Environmental Science Programme, University of Ghana, Legon initiated this study in 2006 to:

- assess the performance and mechanism of faecal bacteria removal from a pilot scale hybrid algal and duckweed domestic wastewater treatment system; and
- assess the ability of some gastropod mollusks of medical importance to withstand some environmental stresses and their contribution to the removal of faecal bacteria from open waters.

It is expected to end in 2011.

During the reporting year, the performance of a pilot-scale hybrid duckweed and algal domestic wastewater treatment plant under tropical conditions was investigated. In addition, the response of the macro-invertebrates, *Biomphalaria pfeifferi* and *Bulinus truncatus* to salinity stress was also investigated under laboratory conditions. Laboratory experiments were also conducted to investigate the role of two most abundantly occurring macro-invertebrates in the removal of faecal bacteria from a polluted river modified for providing drinking water to nearby municipalities. Adults of *Melanoides tuberculata* and *B. truncatus* from this ecosystem were used in freshwater microcosms to investigate their ability to re-suspend faecal bacteria from leaves into the water column and to influence faecal bacteria and algal numbers.

The hybrid pond system (combinations of algal and duckweed ponds) performed well in BOD and faecal coliform removal and is therefore recommended for optimized BOD and faecal coliform removal. Final faecal coliform concentrations of hybrid pond system were similar to that of the algal pond system and final BOD concentrations of the hybrid pond system ($\leq$ 20 mgl^{-1}) were similar to that of the duckweed pond system and met the EPA-Ghana BOD guideline of 50 mgl^{-1}. Removal of BOD, total phosphorus and faecal coliforms were not affected by seasonal changes in all the three pond system types. Faecal coliforms removal was 4.3 log units for the hybrid pond systems in both the wet and dry seasons (Fig. 30). The presence of invertebrate did not result in re-suspension of faecal bacteria in microcosms but rather in the removal of all faecal bacteria located on leaves. Ten times the concentration of faecal bacteria in microcosms were observed on leaves in microcosms with no invertebrate presence. Hence, invertebrates *M. tuberculata* and *B. truncatus* could play a role in the regulation of faecal bacteria numbers in ecosystems with significant leaf litter.

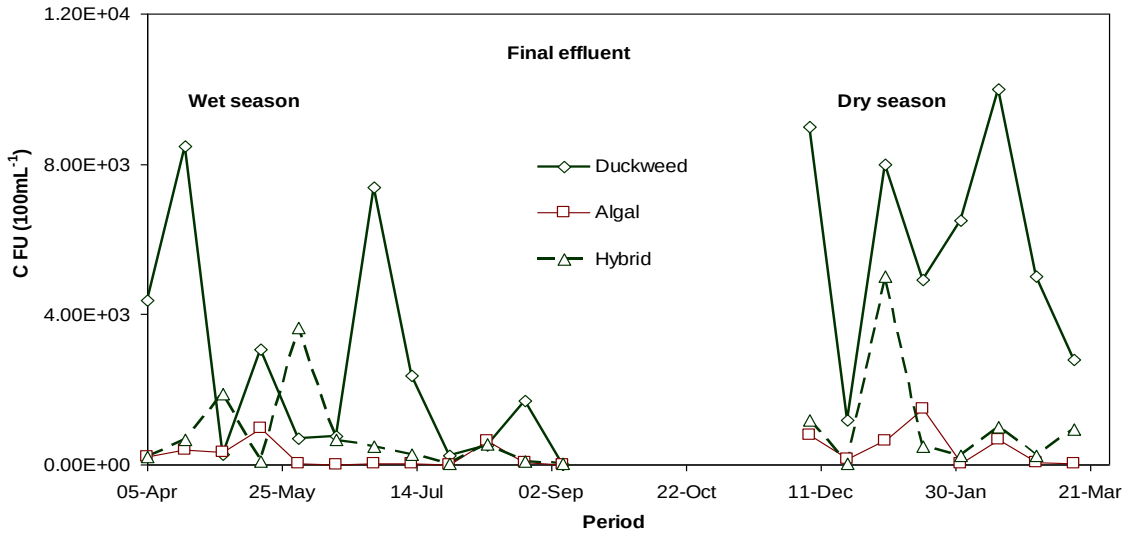


Fig. 30: Faecal coliform concentrations in effluent of duckweed, algal and hybrid ponds

2.4.2 Management of Pulp Mulberry "*Broussonetia papyrifera*" in the River Afram Headwaters Forest Reserve, Ghana

(Project Staff: Dr. A. B. Salifu; Mr. K. A. A. deGraft-Johnson; Mr. Felix J. Akpabey – Research Scientist; Mr. Emmanuel Brakoh; Mrs. Edna Awudi; Mr. Ohene Asa-Offei – VRA)

Pulp mulberry, *Broussonetia papyrifera* (Moraceae) is native to the tropical Americas and was introduced into Ghana in 1969 by Dr. Kadamby, an Indian national. The purpose of its introduction was to supply raw materials to a planned pulp and paper and the sack industries in Ghana. However, in the course of time the experiment was abandoned and *Broussonetia* has since invaded forest edges and canopy gaps disrupting succession processes with a likely long term negative impact on native biodiversity. It was against this background that the study was initiated in 1996 and finalized in the reporting year. The objective was to produce practical means of controlling *Broussonetia* reservoirs in Ghana in order to facilitate forest and biodiversity restoration, improve agricultural efficiency and reduce the rate of spread of the infestation. The study was carried out in collaboration with the United Nations Environment Programme (UNEP), Global Environment Facility of the World Bank (GEF), The World Conservation Union (IUCN), CABI Africa – Nairobi – Kenya, CSIR-Forestry Research Institute of Ghana (FORIG) and the Volta River Authority (VRA).

In the reporting year, three experimental trial plots were demarcated and used for biodiversity restoration studies in the River Afram Headwaters Forest Reserve at Abofour in the Offinso South Municipality of the Ashanti Region. Each plot was one hectare in extent. One of them had a fairly low *B. papyrifera* infestation, the other was moderately invaded while the third plot had a fairly high density of *B. papyrifera* trees. Each plot was then sub-divided into 100 10 x 10 m quadrats and the species present and their abundance recorded. This was to enable the determination of the impact of *B. papyrifera* on established trees and on forest regeneration. Fifty (50) of these quadrats were then randomly selected and various *B. papyrifera* control methodologies implemented – 10 quadrats per treatment and 10 quadrats for the control:

- Treatment 1: Ring-barking at soil surface – band 10 cm wide and 1 cm deep;

- Treatment 2: Ring-barking at soil surface – band 10 cm wide and 1 cm deep plus herbicide A (Spear);
- Treatment 3: Ring-barking at soil surface – band 10 cm wide and 1 cm deep plus herbicide B (Glyphosate or Round-up);
- Treatment 4: Frilling with herbicide A (Spear); and
- Treatment 5: Frilling with herbicide B (Glyphosate or Round-up);

All *B. papyrifera* trees less than 10 cm in diameter were recorded and removed using cut-stump treatment – they were excluded from the trial but monitored nevertheless to determine the efficacy of the treatment. Costs associated with each treatment were also recorded in order to determine the most cost-effective control strategy.

The study showed that the use of Ring-barking without herbicide was largely ineffective. Larger *B. papyrifera* trees with buttresses generally survived because the buttress (root) merely grew over the area where the bark had been removed and the trees continued growing with only some crown die-back. Ring-barking with both herbicides was effective. Although there were some coppicing on trees treated with Glyphosate or Round-up, there was no coppicing on trees treated with Spear. Frilling with the herbicide, Spear appeared to be the most effective control strategy with trees dying relatively soon after application. Frilling with the chemical Glyphosate or Round-up did result in high crown mortality but was not as effective with many of the trees coppicing. The Spear was considerably more expensive than the Round-up.

2.4.3 The Occurrence, Diversity and Ecological Attributes of the Blackfly in the River Densu Basin

(Project Staff: Dr. A. A. Opoku – Senior Research Scientist)

This study was aimed at assessing the status of the blackfly and onchocerciasis in the River Densu Basin. It is expected to end in 2012. In the reporting year, aquatic forms of immature simuliid were sampled from twigs, stems, stones and trailing vegetations in the flowing sections of the River Densu and its tributaries. The samples were examined and identified using Freeman and De Meillon (1968) keys and preserved in 80 % alcohol. Empty pupal cases were also sampled, identified and recorded as a measure of adult emergence. At each sampling site, the pH, DO and flow rates were also determined.

Simulium species identified in the study were *S. unicornutum, S. alcocki, S. damnosum s.l, S. adersi* and *S. cervicornutum* (Table 8). The immature simuliid were invariably found attached to trailing vegetation in the rivers. *S. unicornutum* was the most abundant and widely distributed. The blackfly was predominantly found laying its eggs on vegetation. However, algal growth which is a common phenomenon in the River Densu limited the distribution of the simuliids. The pH and flow rate which are important ecological factors in the distribution of the simuliidae ranged from 6.1 – 7.2 pH units and 0.3 – 2.8ms^{-1}, respectively. The medically important species, *S. damnosum s.I*, occurred at sites with pH range of 6.6 – 6.8 pH units, flow rate range of 1.7 – 2.1ms^{-1} and mean dissolved oxygen levels above 60 % (> 60 %) saturation. Hence, while the other species appeared to be tolerant of varying ecological characteristics of the rivers, the *S. damnosum s.l* appeared to exhibit some sensitivity. The sympatric occurrence of two or more species at a site was an indication of their adaptability to varying conditions.

Table 8: Simulium species identified at the various sampling locations

No.	Location (River/flow)	Mean flow rate (ms^{-1})	Mean pH	Species Identified
1	Bayera/Tafo	0.12	6.1	*S. unicornutum, S. alcocki*
2	Bonwoana/Nsawam	0.23	7.0	*S. unicornutum*
3	Kvia/Asuboi	0.31	6.4	*S. alcocki, S. unicornutum*
4	Doboro/Pokuase	0.4	6.1	*S. unicornutum*
5	Densu/Akwadum	1.7	6.6	*S. damnosum s.l*
6	Asuoyaa/Asuoyaa	2.1	6.8	*S. damnosum s.l, S. adersi*
7	Boribea/Adawso	0.22	7.1	*S. unicornutum, S. cervicornutum*
8	Abomina/Tafo	0.15	7.2	*S. unicornutum*
9	Densu/Amangoase	0.2	6.9	*S. alcocki, S. unicornutum*
10	Suhyien/koforidua	0.3	6.8	*S. unicornutum*
11	Yensi/Adawso	0.24	7.3	*S. unicornutum*
12	Adaisi/Adaisi	0.21	6.7	*S. unicornutum*

2.4.4 The Impact of Collection and Disposal of Solid Wastes on the Environment and on Health: The Case of Accra Metropolitan Area

(Project Staff: Dr. J. A. Ampofo – Principal Research Scientist)

This study ended in the reporting year. The Institute, in collaboration with the Environmental Science Programme, University of Ghana - Legon and the Accra Metropolitan Assembly (AMA), initiated it in 2009 in the Accra metropolis to investigate the impacts of solid wastes collection and disposal on the environment and on human health. It was also aimed at examining the effectiveness of the various solid wastes management systems put in place. The specific objectives were to:

- enumerate the quantity of different helminths eggs in the soil, water and leachate samples collected at the various disposal sites within the Accra metropolis;
- determine the levels of microbial indicators (total heterotrophic bacteria, total and faecal coliforms) in the surface water and leachate samples collected at the various disposal or landfill sites; and
- undertake a social survey for contribution towards sustainable wastes management in general and particularly through resource recovery in Accra.

Water, leachate and soil samples were collected from six sampling sites (Fig. 31) over a period of six months. The water samples were analyzed for coliform bacteria and helminths. The leachate samples were analyzed for coliform bacteria and helminth eggs, while the soil samples were analyzed for only helminth eggs. The Membrane Filtration Method was used for the determination of the total and faecal coliforms while the Schwartzbrod Method was used in the determination of helminth ova. One litre of water and 20 g (wet weight) of soil samples were used for the analysis of helminth egg count. The helminth ova were quantified on the Rafter Sheet. The identities of the specific helminth eggs were established using the WHO bench aid for the diagnosis of intestinal parasite.

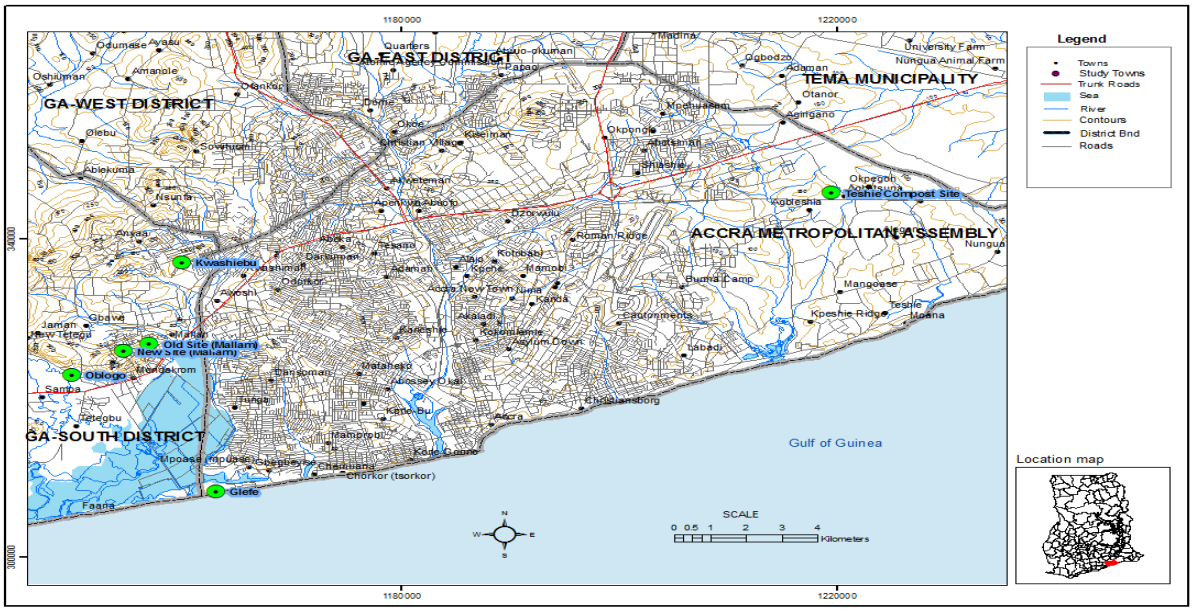


Fig. 31: Map of the Accra metropolitan area showing sampling locations

The total and faecal coliforms concentrations in the water samples ranged from 1.0 – 232.0 x 10^4 cfu/100 ml and 0.2 – 22.4 x 10^4 cfu/100 ml, respectively (Fig. 32) while those registered in the leachate samples ranged from 52.0 – 720 x 10^4 cfu/100 ml and 1.0 – 186.0 x 10^4 cfu/100 ml, respectively (Fig. 33). The Population of helminth eggs in the water, leachate and soil samples is shown in Fig. 34. The level of concentration of coliform bacteria could pose a major risk to human health and the environment. The water bodies within the metropolis are likely to experience eutrophication due to the elevated levels of BOD, turbidity, suspended solids, phosphate and nitrate recorded in the water samples.

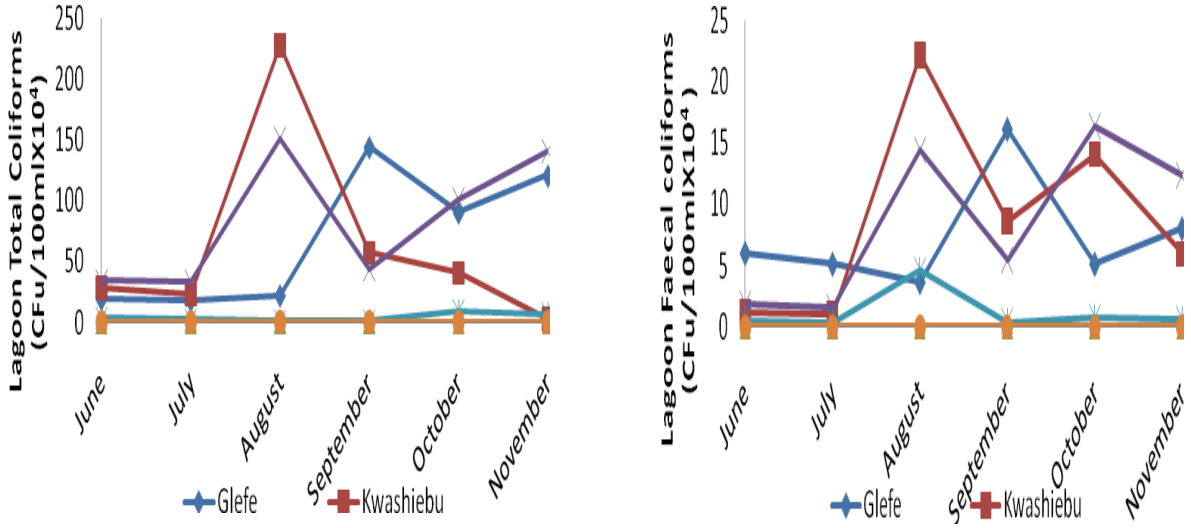


Fig. 32: Mean total coliform and faecal coliform population of the water samples

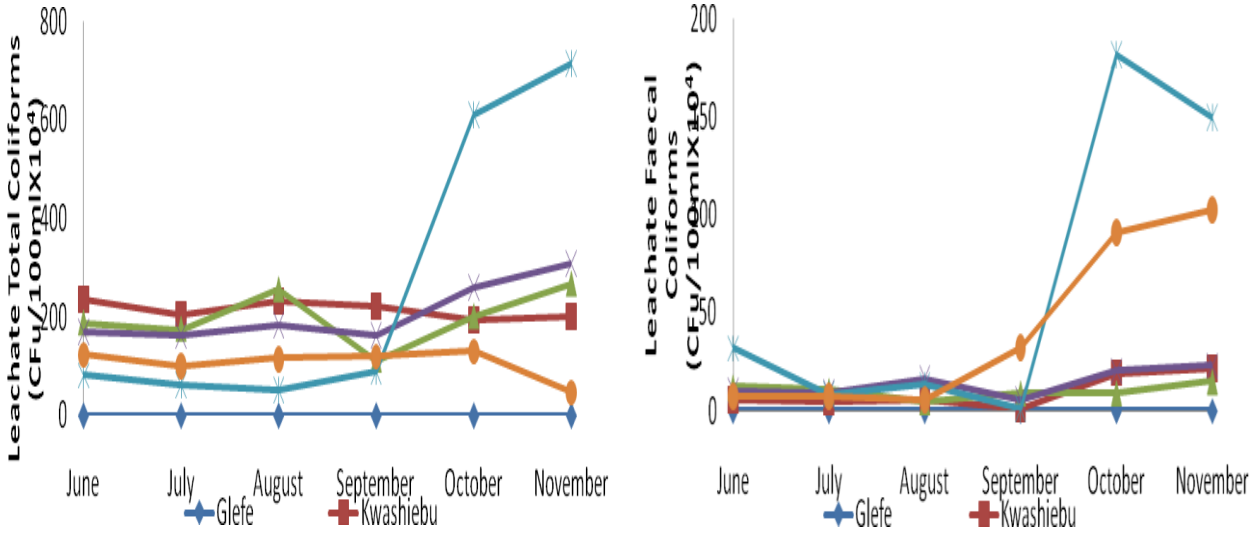


Fig. 33: Mean total coliform and faecal coliform population in the leachate samples

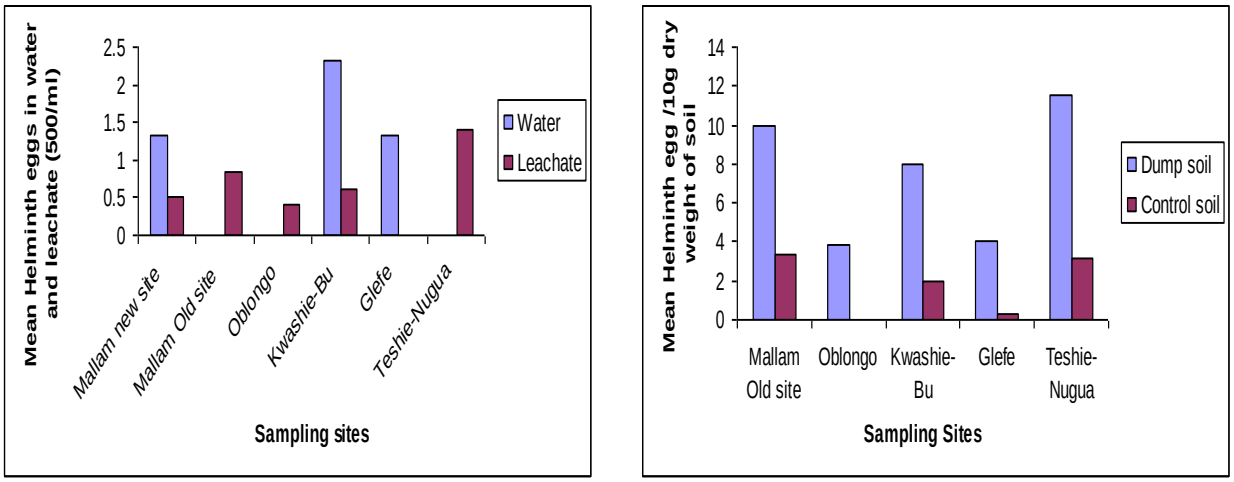


Fig. 34: Population of helminth eggs in water, leachate and soil samples

Social survey revealed that the increasing solid wastes generation in the Accra metropolis has not been accompanied with adequate sanitation facilities and management programmes. Some key problems identified included indiscriminate dumping and difficulties in the acquisition of suitable disposal sites; landfills not engineered and located in ecologically and hydrologically sensitive areas (Plate 1); inadequate logistics and difficulties in applying service charges (Fig. 35); difficulties with conveyance of solid waste by road due to worsening traffic problems and the lack of alternative transport options; and weak demand for composting and recycling as options for waste treatment and disposal. Scavengers and recyclers recovered most hard plastics and metal scraps but majority of the people did not practice any safe method of waste disposal. The Ghanaian experience showed that within the existing socio-economic context, manual systems were appropriate. The challenge, however, was to develop and promote disposal systems

that require minimum mechanical equipment. The long term measures require the exploitation of other options like landfilling which must be engineered to prevent leachate containing potentially dangerous chemicals and biological agents from polluting the environment.

Plate 1: Disposal of refuse into the Gbegbe Lagoon at Glefe (left) and leachate emanating from the Oblogo landfill site (right)

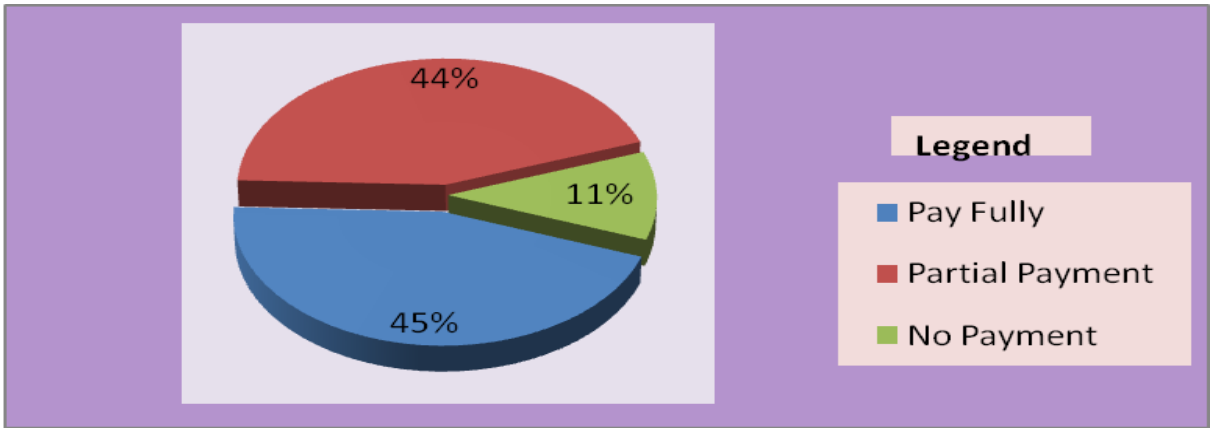


Fig. 35: Willingness to pay for waste management services

To ensure effective and efficient solid wastes management in the Accra metropolis, it was recommended that:

- The Environmental Health Directorate of the AMA should draw up a health education plan every year to educate the people on safe methods of wastes disposal.
- Policies on private participation in solid wastes management must be redesigned and implemented to address the solid wastes management issues.
- The AMA should provide assistance to individuals to purchase standard refuse bins for the storage of household refuse.
- The metropolitan authorities must monitor constantly to check consumers responses on the services rendered to them by the private wastes contractors.

- There is the need for more communal containers which are emptied regularly and timely in the communities in order to prevent solid wastes spillage resulting in indiscriminate dumping of wastes.
- People should be encouraged to practice composting of organic wastes and enlightened on wastes re-use/recycling.
- Landfill siting, construction and operation must be done with the assistance of experts to prevent risk to the environment and to the health of the people it is supposed to serve. In this regard, the government, technocrats and stakeholders must be involved in all the aspects of the designing process.
- Bye-laws on solid wastes management must be vigorously enforced and people who contravene these laws must be punished.
- Stakeholders like churches, NGOs, opinion leaders and others should inculcate the need for proper disposal of wastes in their programmes in order to enlighten more people.

2.4.5 Water Supply and Sanitation and their Effects on the Health Status of the People of Chorkor in the Ablekuma Sub-Metro of the Accra Metropolitan Assembly

(Project Staff: Dr. J. A. Ampofo – Principal Research Scientist)

This study was carried out in collaboration with the Environmental Science Programme, University of Ghana, Legon and the Ablekuma Sub-Metro, Accra Metropolitan Assembly (AMA). It started in 2009 and ended in the reporting year. The aim was to identify the present water supply and sanitation situation and their effects on the health status of the people of Chorkor. The specific objectives were to:

- examine sources of domestic water supply for households in the study area;
- review the present sanitary conditions in the area;
- conduct bacteriological and chemical analyses by taking samples from the various sources of water to ensure that quality guidelines are not compromised;
- evaluate the role of Government and Non-governmental Organizations in the provision of potable water towards ensuring that there is proper sanitation in the study area; and
- make appropriate suggestions and recommendations to stakeholders on how to mitigate the problems.

In the reporting year, water samples were collected at vantage points (Fig. 36) from the distribution pipelines and analyzed. Social survey was also undertaken to assess the sanitary condition of the study area.

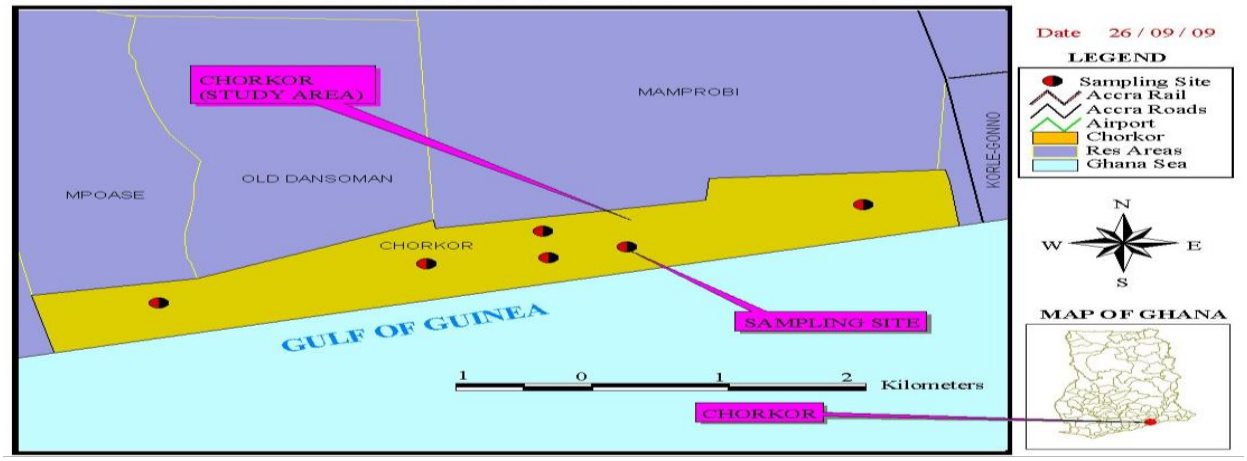


Fig. 36: Map of Chorkor showing sampling points

The analyses revealed that the physical and chemical parameters of most of the water sources in the community were within the WHO and Ghana standards with few sources having values that were quite high. However, the microbiological parameters of the water sources extremely exceeded the WHO and Ghana standards for permissible limits of Total Coliform, Faecal Coliform and Total Heterotrophic Bacteria for potable water. Poor sanitary conditions, burst and leaked pipelines, illegal connections and distribution pipelines laid through wastewater channels were observed in the study area (Fig. 37; Plates 2 and 3). These practices were responsible for the presence of *Vibrio cholera*, *Salmonella typhii*, diarrhoea and dysentery and malaria within the area and its catchments.

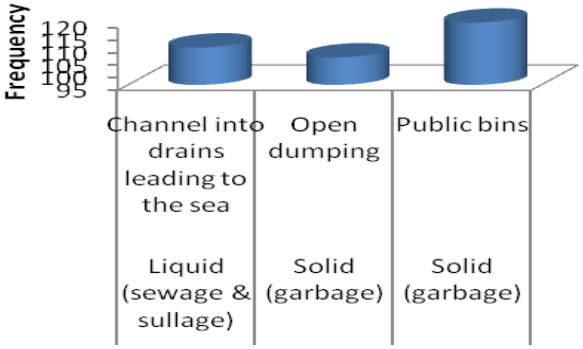


Fig. 37: Methods of disposing solid and liquid waste in Chorkor

Plate 2: Sanitary condition (left) and illegal connections through wastewater channels (right) at Chorkor

Plate 3: Illegal connections, leaked and burst pipelines at Chorkor

Some recommendations made were:

- There should be public education on attitudinal change towards sanitation and hygiene practices.
- There should be regular sanitary inspection by the sub-metropolitan authorities to keep Chorkor clean.
- Thorough microbiological examination of water from homes and water vendors should be conducted.
- There should be routine monitoring of distribution pipelines by Ghana Water Company Limited and its operating agencies to check on illegal connections, burst and leaking pipes.

- Aged distribution pipes should be changed.
- Provision of more public bins at designated locations and regular disposal to ensure adequate sanitation.
- The Accra Metropolitan Assembly should build modern public places of convenience for the community to avoid open defecation.
- Indiscriminate refuse disposal should attract spot fine to serve as deterrent to others.
- The assembly should embark on "Keep Chorkor clean" campaign.

2.4.6 Cattle-Grazing on Playing Fields: Source of Environmental Contamination to School Children in the Greater Accra Region

(Project Staff: Dr. J. A. Ampofo – Principal Research Scientist; Mrs. Regina Banu – Research Scientist)

In collaboration with the Environmental Science Programme, University of Ghana, Legon and the Ablekuma Sub-Metro, Accra Metropolitan Assembly (AMA), the Institute started this study in 2009 and ended in the reporting year. The aim was to investigate the presence of pathogenic organisms in cattle dung and grass from playing fields used for cattle grazing. The specific objectives were to: swab palms of randomly selected school children after playing on the field; culture dung, grass and swab samples; isolate coliforms and other pathogens; and determine by direct microscopy the presence of other parasites and helminths eggs.

Two playing fields used for cattle grazing (Plate 4) and one other playing field not used for cattle grazing (control sample) (Plate 5) were selected. Cattle dung and grass samples from the fields and finger/hand swab samples from children who played on the fields were collected on monthly basis in the dry and wet seasons for six (6) months. A total of 288 samples were collected and examined bacteriologically and for helminth. The Membrane Filtration technique was used for the bacteriological analysis whilst the Sludge Method was applied in the helminth eggs analysis.

Plate 4: School playing fields used for cattle grazing within the Greater Accra Region

Plate 5: Playing field of Bishop Bowers school, Accra (control sample)

The study indicated that there were pathogens in cattle dung from playing fields which are zoonotic. The presence of *Salmonella, E. coli, Ascaris, Strongyloides* and Hookworm in the cattle dung was indication that other pathogens such as *Clostridia, Shigella, Giardia* and other helminths could be present in the dung. These were transferred onto the grass and were subsequently picked on the fingers/hands of the children who played on the fields. For instance, *Ascaris* specific mean of 0.63 for the dung, 0.259 for the grass and 0.093 for the swap were recorded with p-value of 0.0020 (at 5 % significance level). In addition, the grand mean for *E.coli* was 257.00 with specific mean of 381.00 for Ashaiman, 378.00 for Kawukudi and 13.00 for Bishop Bowers parks. Cattle grazing on playing fields could therefore contribute immensely to the endemicity of diarrhoeal, typhoid fever, helminthic and other communicable infections across the Greater Accra Region and beyond.

Recommendations made included:

- Educating the cattle owners/farmers, schools and community leaders who have allowed their premises to be used for cattle grazing and the general public on the health hazards of their activities to the society;
- Laws against cattle grazing in cities/towns should be revisited and enforced;
- The crusade for hand washing with soap after playing, visiting the toilet, handling wastes and similar activities should be inculcated in the school children in order to curtail the infection and spread of faeco-oral infections.
- There should be further research to identify the other species of the pathogens present in the cattle dung.

2.4.7 The Impact of Doxycycline Treatment on Transmission of *Onchocerca volvulus* in Communities Showing Sub-Optimal Response to Ivermectin Treatment

(Project Staff: Mike Osei-Atweneboana – Research Scientist; Mr. Samuel Armoo – Research Scientist)

Onchocerciasis, commonly known as 'river blindness', is a parasitic disease caused by the filarial nematode, *Onchocerca volvulus* and transmitted by the infective bite of *Simulium species*. In Ghana, onchocerciasis is endemic in nine (9) of its ten (10) regions and a population of about 3,400,000 persons living in 3,204 communities is at risk. Ivermectin (IVM) has been used for the control of onchocerciasis since 1987 and it still remains the only available drug for the control of the disease worldwide. IVM treatment in Ghana has been ongoing for more than two decades in some communities leading to drastic reduction in onchocerciasis morbidity, prevalence and transmission. However, some hot spots where parasite burden is high, transmission persists and sub-optimal responses to IVM treatment have been documented still remain. If this situation persists, onchocerciasis elimination may be jeopardized and recrudescence infections could occur in areas where the disease is no longer a public health problem. It was against this background that this study was initiated in 2007 and finalized in the reporting year in collaboration with the Noguchi Memorial Institute for Medical Research (NMIMR) – Accra, Kumasi Centre for Collaborative Research (KCCR), McGill University Research Foundation and the European Union. The aim was to determine whether the treatment of IVM sub-optimal responders with doxycycline would significantly impact on onchocerciasis transmission. The specific objectives were to:

- assess vector abundance, densities and the man biting rate of *S. damnosum* in the study areas;
- determine the vector infection rates and transmission potential following treatment of sub-optimal responders with doxycycline; and
- assess the reduction in transmission of onchocerciasis following doxycycline treatment and determine whether possible disease recrudescence can be prevented using doxycycline.

Thirteen onchocerciasis endemic communities showing sub-optimal response to IVM treatment were selected from Yeji, Kintampo and Tain districts of the Brong-Ahafo Region. The communities were Bolga Nkwanta, Tigamgam, Abua, Bita Nkwanta, Prang, Adjaraja, Beposo and Mantukwa in the Yeji district; New Longoro and Ayorya in the Kintampo district; and Tainso, Fawoman and Nyire in the Tain district. Blackflies were caught for five consecutive days per month for eight months. A total of 3,790 and 14,555 blackflies were collected during the dry and wet seasons post trials respectively. The flies collected were identified and dissected on the same day to determine the fly parity and presence of the parasite larvae of *O. volvulus*. The regular community mass IVM treatments were also assessed.

Analyses of the three sets of entomological data collected before and after the doxycycline trial showed that the interventions with doxycycline had significant impact on onchocerciasis transmission in communities showing sub-optimal responses to IVM treatment. The fly densities in the dry season was significantly lower ($p < 0.001$) than both the fly densities in the wet season post-trial and at pre-trial. The most significant impact of the doxy trial was observed in the Yeji district where 75 % of the communities showed significant reduction ($p < 0.02$) in seasonal transmission potential up to zero level following the post-doxycycline treatment (Fig. 38). The reduction in transmission potential up to zero levels observed especially in the Yeji district

suggest that the anti-Walbachia drug, doxycycline, can be used to augment Ivermectin for clearing possible resistant parasites in communities responding sub-optimally to IVM treatment. The vector abundance and densities, man biting rate, parity rate, infection and infective rates and transmission potential of the study are shown in Table 9.

It was recommended that in endemic communities where onchocerciasis transmission is still moderate high, individuals responding sub-optimally to IVM treatment should be identified and treated with doxycycline. This will help eliminate all possible resistant parasites and prevent possible recrudescence of the disease.

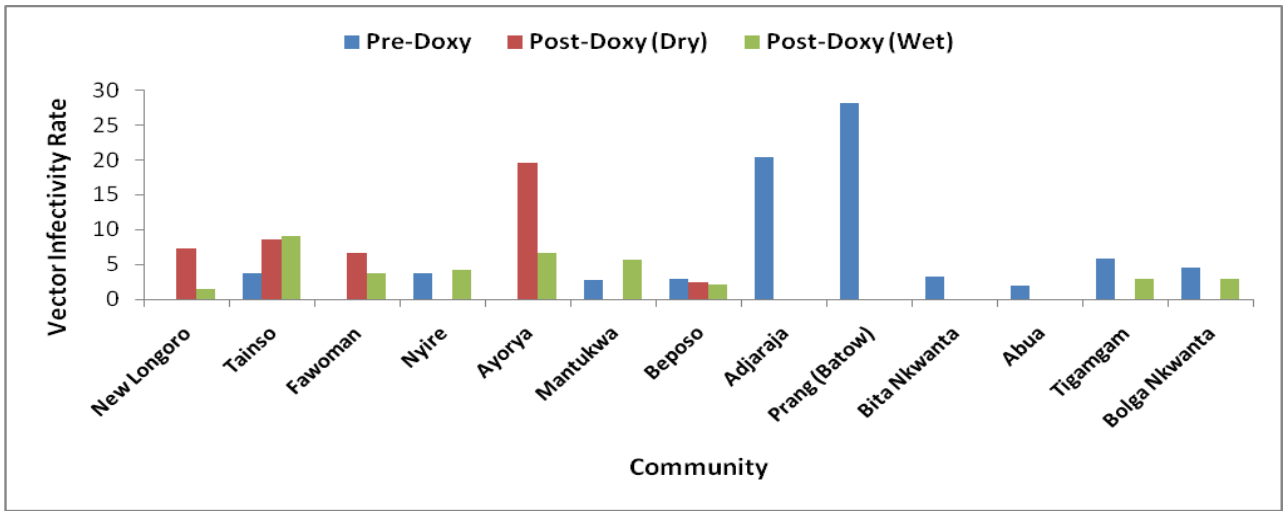


Fig. 38: Comparison of seasonal transmission potentials of pre and post Doxycycline treatment periods

Table 9: MBR-monthly biting rate, MTP-monthly transmission potential, SBR-seasonal biting rate, STP-seasonal transmission potential

Sub district	Communities	Pre-Treatment Entomological Parameters					Post-Treatment Entomological Parameters (Dry season)					Post-Treatment Entomological Parameters (Wet Season)				
		MONTHS	**MBR**	**MTP**	**SBR**	**STP**	**MONTHS**	**MBR**	**MTP**	**SBR**	**STP**	**MONTHS**	**MBR**	**MTP**	**SBR**	**STP**
PRANG AREA	Bolga-Nkwanta	NOV	834	6	2166	7.57	JAN	12.4	0	78	0	AUG	1016.8	6.2	4416	6.35
		DEC	223.2	0			FEB	682	0			SEP	2466	0		
		FEB	1041.6	0			DEC	0	0			OCT	998.2	0		
	Tigamgam	NOV	5148	55.96	8850	35.94	JAN	0	0	96	0	AUG	2089.4	6.2	4458	6.17
		DEC	1153.2	0			FEB	93	0			SEP	1704	0		
		FEB	2413.6	0			DEC	6.2	0			OCT	756.4	0		
	Abua	NOV	4050	23.82	14808	15.11	JAN	254.2	0	504	0	AUG	1525.2	0	3066	0
		DEC	3193	6.25			FEB	235.6	0			SEP	1002	0		
		FEB	7156.8	0			DEC	31	0			OCT	607.6	0		
	Bita - Nkwanta	NOV	1536	6	5088	6	JAN	161.2	0	318	0	AUG	892.8	0	1974	0
		DEC	706.8	0			FEB	93	0			SEP	372	0		
		FEB	2676.8	0			DEC	74.4	0			OCT	762.6	0		
	Prang (Battor)	NOV	834	24	1740	24	JAN	248	0	516	0	AUG	837	0	2238	0
		DEC	179.8	0			FEB	279	0			SEP	816	0		
		FEB	683.2	0			DEC	6.2	0			OCT	632.4	0		
	Adjaraja	NOV	5046	46.44	5358	42.52	JAN	74.4	0	786	0	AUG	1643	0	6318	0
		DEC	6.2	0			FEB	675.8	0			SEP	2370	0		
		FEB	285.6	0			DEC	62	0			OCT	2436.6	0		
	Beposo	NOV	2388	6	7938	6	JAN	3391.4	0	5538	0	AUG	5840.4	0	12042	12.84
		DEC	111.6	0			FEB	1965.4	0			SEP	3360	0		
		FEB	5079.2	0			DEC	365.8	0			OCT	3131	0		
	Mantukwa	NOV	1746	12	6450	12	JAN	1382.6	0	2712	0	AUG	3707.6	0	8454	25.93
		DEC	1271	0			FEB	1252.4	0			SEP	3894	7.16		
		FEB	3242.4	0			DEC	167.4	0			OCT	1004.4	0		

Table 9 continue

KINTAMPO AND TAIN AREA	New-Longoro	NOV	4674	0	12672	0	JAN	768.8	0	3804	12.21	AUG	5307.2	12.4	11592	12
		DEC	6733.2	0			FEB	37.2	0			SEP	2262	0		
		FEB	1383.2	0			DEC	3124.8	12.68			OCT	4333.8	0		
	Ayorya	NOV	858	0	2028	0	JAN	204.6	0	576	6.06	AUG	1847.6	12.4	2952	12
		DEC	1159.4	0			FEB	80.6	6.2			SEP	366	0		
		FEB	44.8	0			DEC	387.5	0			OCT	824.6	0		
	Tainso	NOV	2286	6	7326	6	JAN	1519	12.66	4536	18.87	AUG	2839.6	0	7068	42.65
		DEC	3558.8	0			FEB	936.2	0			SEP	1464	0		
		FEB	1489.6	0			DEC	2232	6.76			OCT	2951.2	38.66		
	Fawoman	NOV	3438	0	4914	0	JAN	589	0	2202	6.26	AUG	3906	6.23	11088	24.22
		DEC	1357.8	0			FEB	12.4	0			SEP	2964	18		
		FEB	151.2	0			DEC	1674	6.49			OCT	4488.8	0		
	Nyire	NOV	1758	6	3078	6.14	JAN	130.2	0	1080	0	AUG	3453.4	6.21	11664	30.02
		DEC	1351.6	0			FEB	0	0			SEP	3420	18		
		FEB	11.2	0			DEC	985.8	0			OCT	5065.4	6.2		

2.5 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, and fisheries enhancement and culture-based fisheries.

Beneficiaries of the Division's research activities include:

- Government policy-makers
- Development partners
- Ministry of Food and Agriculture
- Ministry of Health
- Ghana Wildlife Division of the Forestry Commission
- Water Resources Commission
- Fisheries Commission
- Universities and Polytechnics
- Fishers, farmers
- Individuals

2.5.1 Population Characteristics of *Chrysichthys nigrodigitatus* in the Weija Reservoir in Ghana

(Project Staff: Mr. Theodore Quarcoopome – Research Scientist)

The Weija Reservoir was impounded in 1977 mainly to satisfy the need for potable water supply by Ghana Water Company Limited (GWCL). Currently the reservoir provides treated water to western parts of Accra and supports irrigation and fisheries. *Chrysichthys nigrodigitatus* (Lacepede) (Commonly known as silver catfish) is one of the most important with highly food value, supports thriving commercial fisheries in many West African countries and with high potential for culture in Ghana. It was against this background that this study was undertaken to provide information on the population characteristics of *C. nigrodigitatus* which would be helpful in the conservation and sustainable management of the species for food security and socio-economic development.

During the reporting year, monthly fish sampling was undertaken from March to December at three (3) existing and easily accessible sampling stations in the Weija Reservoir namely: Dam Intake, Machigani and Galilea, with two (2) sets each of eight (8) multifilament and monofilament gill nets of laterally stretched meshes. All fishes sampled were identified and standard length and weight measured for the computation of length frequency, length weight relationships and condition factor. Catches in each mesh-sized net were counted and weighed for the computation of Catch Per Unit of Effort in terms of number and weight. Sexes of individual fishes were determined for sex ratio computation.

Out of a total number of 549 specimen of *C. nigrodigitatus* examined, 39.89 % were males, 55.19 % were females while 4.92 % were undetermined. Of the 522 individuals whose sexes could be determined, 219 (41.95 %) were males while 303 (58.05 %) were females. The largest male specimen measured 33.5 cm and weighed 1000 g while the largest female measured 30.5 cm and weighed 800.0 g. The smallest male specimen measured 9.7 cm and weighed 18.3 g while the smallest female specimen measured 8.4 cm and weighed 11.7 g. The most frequently recorded length class size (modal SL class) for both male and female *C. nigrodigitatus* was 14.95 – 17.95 cm while the most frequently measured standard length (modal SL) was 17.5 cm (Table 10).

Table 10: Descriptive statistics of *Chrysichthys nigrodigitatus* in Weija Reservoir (March – December 2010)

Parameter	Male (n = 219)	Female (n = 303)	Pooled (n= 549)
Minimum standard length (cm)	9.70	8.40	6.50
Maximum standard length (cm)	33.50	30.50	33.50
Mean standard length (cm)	18.753 ±3.975	17.871 ±3.610	17.952 ±3.988
Minimum weight (g)	18.3	11.7	4.8
Maximum weight (g)	1000.0	800.0	1000.0
Mean weight (g)	149.7 ±11.369	130.67 ±9.290	134.15 ±10.232
Total weight (g)	32,784.2	39,594.0	73,650.3
Standard length modal class (cm)	14.95 – 17.95	14.95 – 17.95	14.95 – 17.95
Standard length mode (cm)	17.5	17.5	17.5
Mean condition factor	1.9648 ± 0.0588	2.0253 ± 0.1101	1.9963 ± 0.0392
Relative Abundance	38.59%	55.19%	100%*

**Individuals with undetermined sex represented 4.92%*

The least dominant length class for males was 32.95 – 35.95 cm while that for females was 5.95 – 8.95 cm (Fig. 39). It is noteworthy that while no male was recorded for the 5.95 – 8.95 cm length class, no female was recorded for the 32.95 – 35.95 cm length class. Fig. 40 shows the length frequency histogram.

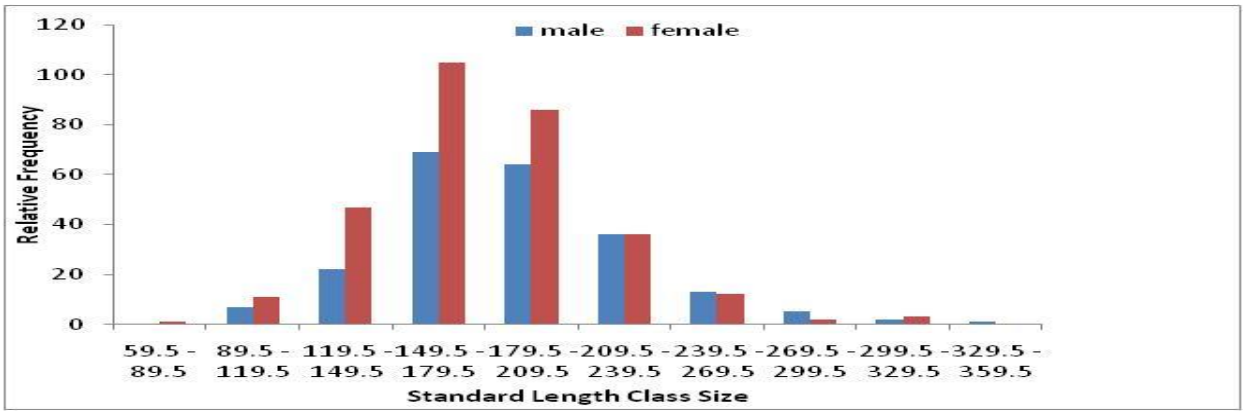


Fig. 39: Length frequency distribution of male and female *C. nigrodigitatus* from Weija Reservoir based on standard length class (March – December 2010)

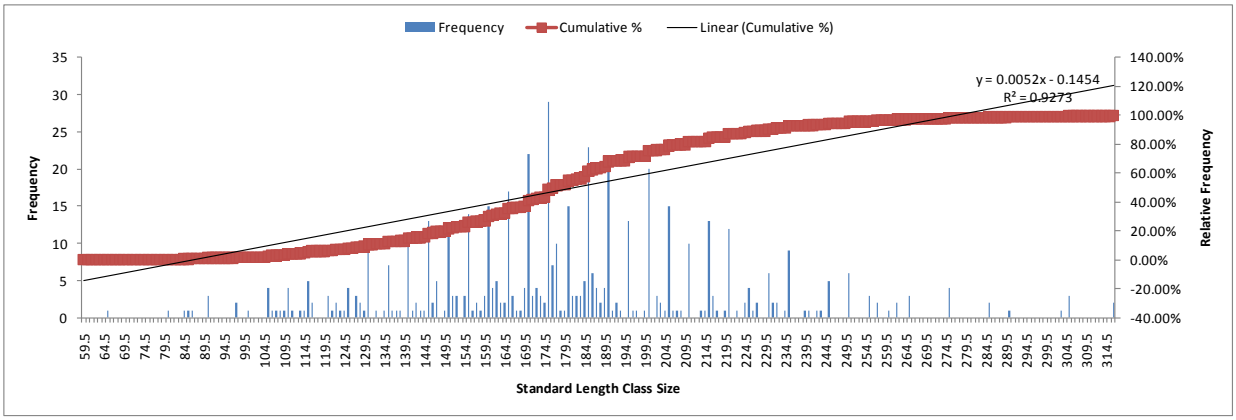


Fig. 40: Histogram of male and female *C. nigrodigitatus* in Weija Reservoir based on length frequency (March – December 2010)

The length weight parameters for males, females and mixed populations of *C. nigrodigitatus* (Table 11) are not significant at 95 % CI (Tables 12 and 13).

Table 11: Length weight relationships based on sex for *C. nigrodigitatus* in the Weija Reservoir (March – December 2010)

Species	N	Length range (cm)	a	b	r
Males	219	9.7 - 33.5	-4.793	3.04	0.991
Females	303	8.4 - 30.5	-4.794	3.04	0.992
Mixed data	549	6.5 - 33.5	-4.790	3.04	0.993

Table 12: Analysis of variance (ANOVA) of length weight relationships for male *C. nigrodigitatus* in Weija Reservoir at 95 % CI (March – December 2010)

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	*3.5361*	*1*	*3.5361*	*79.754*	*1E-17*	*3.8629*
Within Groups	*19.331*	*436*	*0.0443*			
Total	*22.867*	*437*				

Table 13: Analysis of variance (ANOVA) of length weight relationships for female *C. nigrodigitatus* in Weija Reservoir at 95 % CI (March – December 2010)

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	*6.718273*	*1*	*6.7182731*	*166.8917*	*6.95E-34*	*3.8569*
Within Groups	*24.31419*	*604*	*0.0402553*			
Total	*31.03247*	*605*				

The mean monthly condition factor for male, female and mixed populations ranged from 1.847 – 2.069, 1.927 – 2.308 and 1.950 – 2.078, respectively. Almost 50 % of males and 44 % of females had condition factor values above the respective mean values.

The lowest mean Catch Per Unit of Effort (CPUE) in terms of both number and weight was recorded in May 2010 whilst the highest mean CPUE in terms of both number and weight was recorded in September 2010 (Fig. 41).

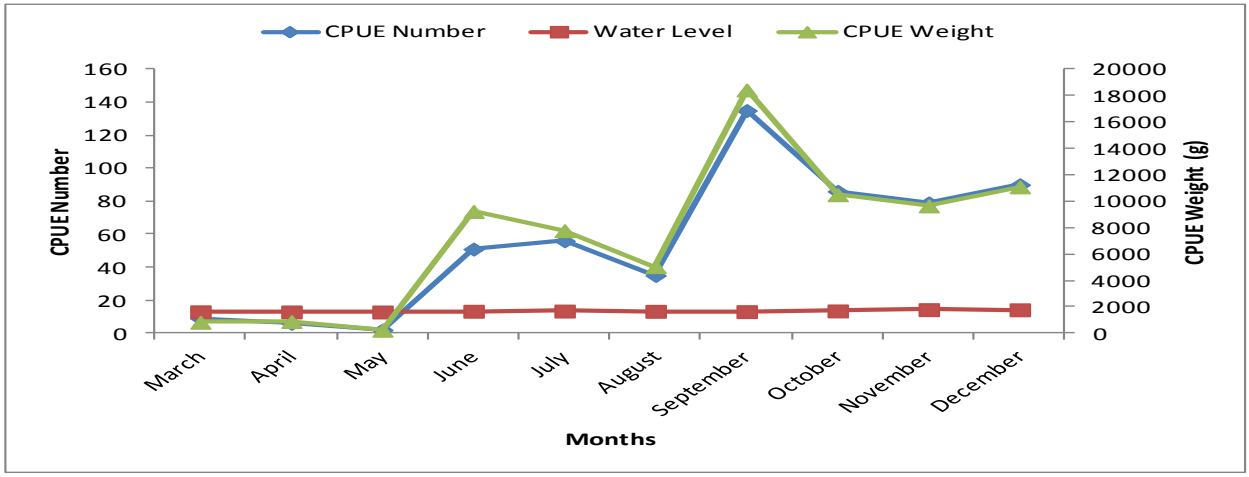


Fig. 41: Monthly changes in CPUE numbers and CPUE weight of *C. nigrodigitatus* with water level in Weija Reservoir (March – December 2010)

It was concluded among others that *C. nigrodigitatus* females were of better condition and were better suited to the Weija environment than males as indicated by the mean condition factor of 1.9648 and 2.0253 for males and females, respectively.

2.5.2 Production Parameters and Economics of Small-Scale Tilapia Cage Culture with Micro-Credit Support in Two Communities of Asuogyaman District - Ghana

(Project Staff: Dr. Joseph K. Ofori – Senior Research Scientist; Mr. Francis Anani – Research Scientist; Mr. Emmanuel Tetteh Mensah – Research Scientist)

Aquaculture, including cage farming of tilapia, is a means for decreasing fish supply gap as well as generating jobs among resources poor farmers. Hence, in collaboration with Planet Finance - France based NGO, and Asuogyaman Rural Bank, this study started in 2009 to establish production pattern and profitability of small-scale tilapia cage farming when micro-credit and technical knowledge is provided to small-scale farmers. The specific objectives were to:

- study a public private partnership scheme of assisting resource poor farmers with financial (micro-credit) and technical support to farm fish in small cages;
- introduce and train selected members of two communities in small-scale cage culture of tilapia through use of high density low volume (HDLV) cages on the Kpong reservoir; and
- assess the potential fish yield characteristics and production economics of the introduced HDLV cages for tilapia culture in the two communities.

It is expected to end in 2012.

Activities carried out during the reporting year included selection of members of the two communities at Tusker and South Senchi, in the Asuogyaman District in the Eastern Region, conducting interviews, training qualified and selected members in cage fish farming and small-scale business management and planning in preparation for the granting of micro-credit loan managed by the Asuogyaman Rural Bank for the purpose of farming fish in cages. Members in a group were assigned a 14 m^3 cage, stocked with 2000 fishes and fed with floating pelleted feed at a declining feeding rate of 5 – 1.5 % total body weight five times daily. Fifty fish was sampled at three weeks intervals for measurement of standard length (SL), total length (TL) and

individual weight (Wt g). Data obtained was used to determine growth and yield characteristics such as mean size (weight and length), gross and net yield, survival/recovery at harvest. Economic assessments and scenarios were also made for improvements of yields and revenues.

Fish harvested after 6 months culture in cages for New Powmu and South Senchi ranged from 247.97 – 248.29 g and 216.37 – 239.82 g, respectively, Survival averaged 81.6 % and 75.1 %, FCR averaged 2.17 and 2.5, Net yield averaged 347.46 kg/cage/group and 280.84 kg/cage/group, respectively. Growth was curvilinear and mean sampling weight (g) was related to sampling event by the equation $Y = 3.6238\ X^{1.9246}$ ($R^2 = 0.9968$) (Fig. 42). Economic assessment of the small-scale tilapia production showed that most farmers did not make profit (Table 14) and this could be attributed to non-conformity by farmers to use recommended feed due to their insistence to use a supposedly high performing feed that was more costly than what was intended for the trial. Additionally, some farmers over applied feed. Others recorded lower than expected recovery due to stocking, sampling mortalities or fish escape.

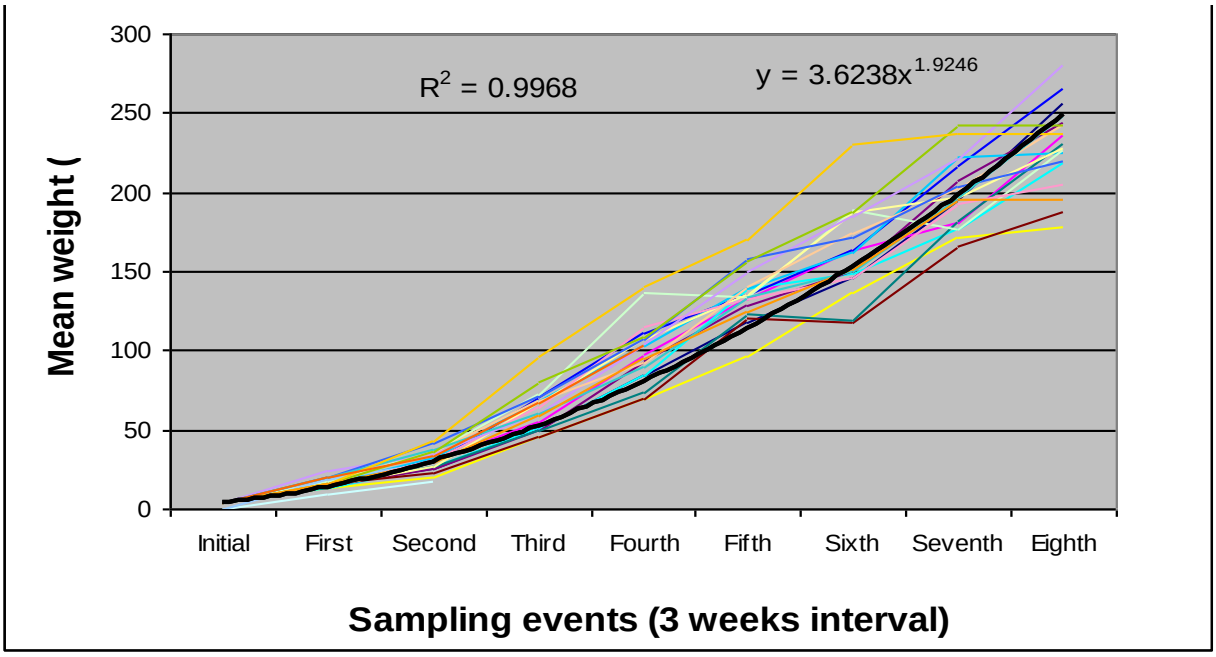


Fig. 42: Trend of mean weight at sampling for Tilapia cultured in small cages (14 m^3 cages)

Table 14: Economic assessment of cage cultured Tilapia operated for six months in the Kpong Reservoir in Ghana at New Powmu and South Senchi

	New Powmu		South Senchi			
	G1	**G2**	**G1**	**G2**	**G3**	**G4**
Average fixed cost	133.75	133.75	133.75	133.75	133.75	133.75
Average variable cost	1984.00	1904.00	1964.00	1745.00	1811.00	1745.00
Total cost	2117.75	2037.75	2097.75	1878.75	1944.75	1878.75
Revenue	1679.45	1498.00	1430.00	1255.53	1084.45	953.53
Net revenue	-438.30	-539.75	-667.75	-623.22	-860.30	-925.22

Profitability projections showed that small-scale cage culture could make a profit (GH¢ 325.00) when feed cost could be reduced by 25 % and FCR to less than 1.5. Ninety percent (90 %) fish survival/recovery could further improve profit to GH¢ 650.00. Fish farmers could make appreciable yield and profits if they adhere to the use of good technical information and instructions provided them in the choice of feed and its application to feeding fish. Furthermore, micro credit support properly packaged and extended could get poorly resourced farmers to undertake farming and improve their economic status.

2.5.3 Assessment of the Ecological and Public Health Status of a Water Storage Facility

(Project Staff: Dr. H. R. Dankwa – Senior Research Scientist; Mr. Francis Amevenku – Research Scientist)

Newmont Ghana Ltd., a gold mining company operating in the Brong Ahafo region of Ghana, has created a Water Storage Facility (WSF) to provide water for its operations and for community use. The WSF had been stocked earlier with the Nile tilapia (*Oreochromis niloticus*). After some years of existence, the company was desirous of developing the WSF to provide fish for the community on sustainable bases. It was against this background that the Institute, in collaboration with Newmont Ghana Ltd., initiated and finalized this study in the reporting year to assess its biological and environmental status with the view of enhancing its fish production.

Activities carried out included fish sampling and identification, and measurement of fish length and weight. Five fish species caught during the study period and their corresponding numbers and weight and percentage representation in the total catch are shown in Table 15.

Table 15: Fish species caught in the WSF and their percentage representation in total catch

Species	No caught	Weight (g)	% Number	% Weight
Oreochromis niloticus	784	56,093	93.2	71.2
Clarias anguillaris	24.0	14,132	2.90	17.9
Clarias gariepinus	1.00	584	0.120	0.700
Parachanna obscura	31.0	7,674	3.70	9.70
Brycinus nurse	1.00	349	0.120	0.44

The Nile tilapia, *O. niloticus,* was the predominant species in the WSF and constituted 93.2 % and 71.2 % by number and weight, respectively of the total catch. This tilapia was followed by the catfish, *Clarias anguillaris,* and the snake head, *Parachanna obscura,* which constituted 17.9 % and 9.7 %, respectively of the total catch. The dominance of *O. niloticus* in the system could be explained by the stocking of the reservoir with *O. niloticus* after its formation.

The distribution of length frequency of *O. niloticus* from the reservoir is presented in Fig. 43. The distribution of *O. niloticus* in the reservoir indicates that the dominant size group was between 110 – 120 mm (SL). It is likely that much bigger fish could have been caught if bigger net mesh sizes were deployed. This is anticipated because fishing was not allowed in the reservoir.

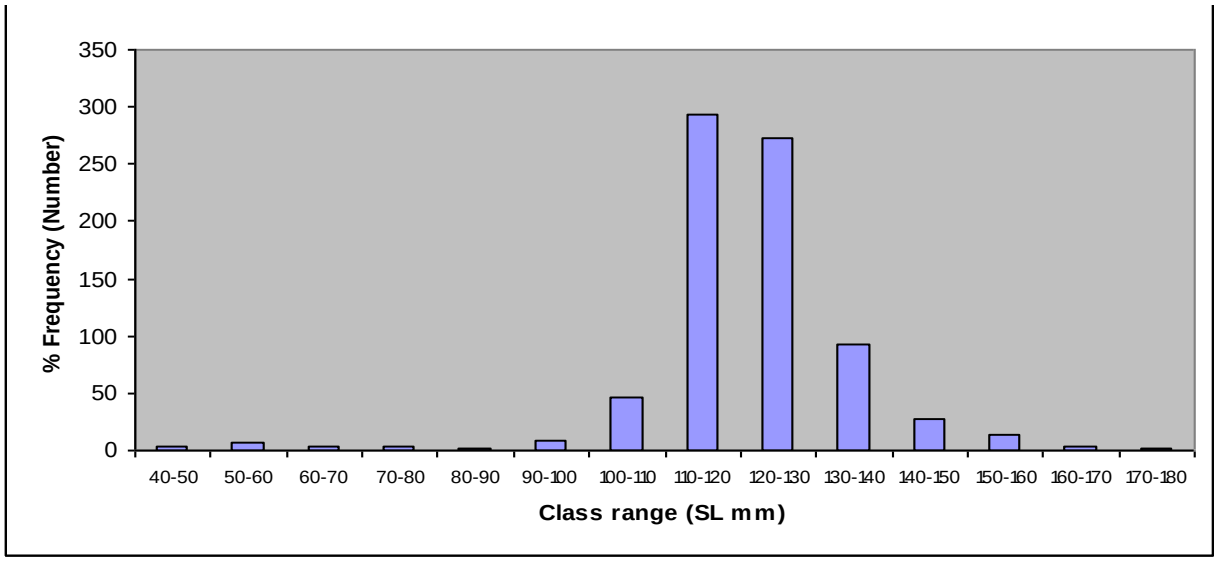


Fig. 43: Length frequency distribution of *O. niloticus* in the WSF

The diversity (H') and evenness indices (Ds) of 0.1323 of 0.1289, respectively were low indicating poor diversity and distribution of species. The Forage Carnivore ratio (F/C ratio) was 13.75 (for number) and 0.40 (for weight). These values respectively fall outside the recommended range of 1.4 – 10.0 indicating that the fish community in the reservoir is ecologically unbalanced. The population was skewed towards forage species.

Recommendations given included:

- The water quality of the reservoir should be improved by frequently diluting the water with fresh one while allowing some of the resident water out.
- Once the water quality is improved other species e.g, the Nile perch, *Lates niloticus* (carnivore), *Chrysichthys* spp and the bony tongue, *Heterotis niloticus*, could be introduced to ensure a more diversified and balanced fish community.

2.5.4 The Threat of Pesticide Residues to Fisheries of Bontanga Reservoir in Ghana

(Project Staff: Dr. K. Kwarfo-Apegyah – Research Scientist)

This study was undertaken to determine the impact of pesticide residues concentration on the condition factor of major fish species, namely, *Auchenoglanis occidentalis, Brycinus nurse, Clarias gariepinus, Hemichromis fasciatus, Marcusenius senegalensis, Oreochromis niloticus, Sarotherodon galilaeus and Tilapia zillii* of Bontanga reservoir during the dry and wet seasons.

In the year under review, pesticide residues in fish were analyzed using Gas Chromatography and Solid Phase Extraction (SPE) via Turbo Vap II. Sixteen (16) organochlorine (OC) pesticide residues were identified in the reservoir (Figs. 44 and 45).

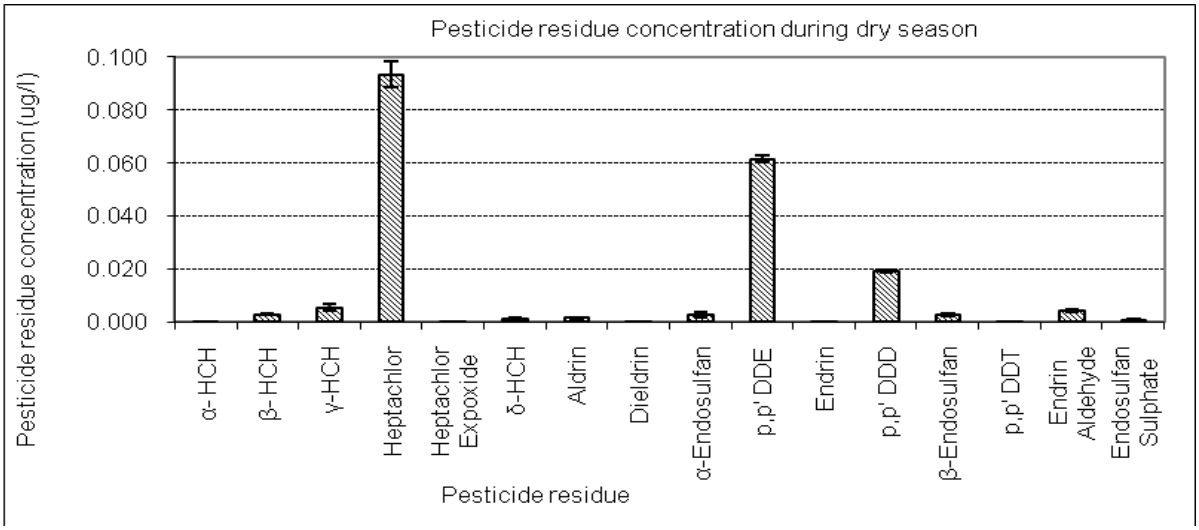


Fig. 44: Organo-chlorine pesticides concentrations in Bontanga Reservoir during the dry season

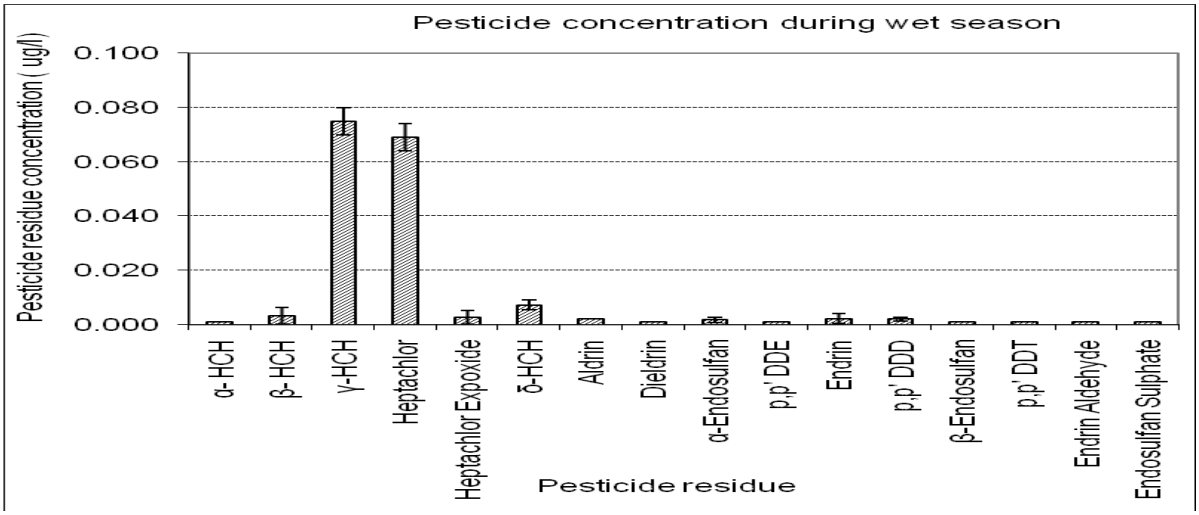


Fig. 45: Organo-chlorine pesticides concentrations in Bontanga reservoir during the wet season

During the dry season, heptachlor, p,p'DDE and p,p'DDD recorded concentrations of 0.094 µg/l, 0.061 µg/l and 0.019 µg/l, respectively. In the wet season, concentrations of γ-HCH and heptachlor were 0.075 µg/l and 0.069 µg/l, respectively. The condition factor (K) of the major fish species did not fluctuate significantly ($P < 0.05$) around the mean K of the individual species during the wet and dry seasons. Therefore, the minor variations observed in fish condition factor during the seasons could be attributed to changes in reservoir's environmental factors notably the hydrology and internal factors of the species such as maturity stage and stomach contents of the fishes. The calculated acute risk ratio (ARR) (Fig. 46) of the pesticide residues was less than 1.0 indicating that the concentrations were below toxic level to the fishes. This ARR value, however, is a cause for concern considering the bio-accumulative nature of organo-chlorine compounds.

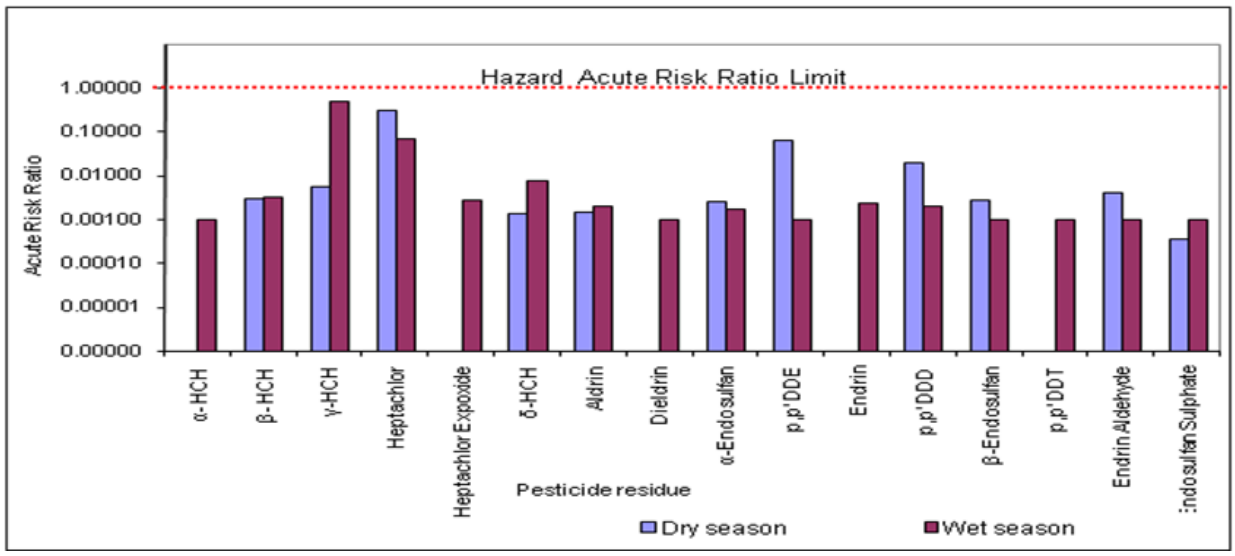


Fig. 46: Calculated Acute Risk Ratio (ARR) of the pesticide residues

The pesticide residues in the reservoir water were found to have originated from pesticides used by farmers on the farms around the reservoir. For conservation of the fisheries and biodiversity, farmers were advised instead to use biological control methods and organic pesticides on farms around the reservoir were recommended.

2.5.5 Evaluation of Selected Commercial Fish Feeds

(Project Staff: Dr. Felix Attipoe – Research Scientist; Mr. Francis K. Y. Amevenku – Research Scientist; Mr. Seth Agyakwa – Research Scientist)

In collaboration with Ghana Aquaculture Association (GAA) and Food and Agriculture Organization (FAO), the Institute initiated and finalized this study in the reporting year. The objective was to determine the most cost effective feed, compare the different feeds currently available on the market to producers and suggest interventions that will lead to increased fish productivity and better the livelihood prospects of fish farmers. The types of commercial fish feeds used in this study included Ranaan feed, Indonesia Tilapia feed, Inter Aqua feed, Nicolluzi feed, Ghana Protein feed and China Tilapia feed.

During the reporting year, experimental, technical and administrative data on the study were obtained and analysed. Depreciation was computed using the straight-line method based on the estimated economic life of the capital items. Cost of repairs and maintenance was computed at 5.0 % of the capital asset value at GH¢10,480.00. Similarly, marketing expense was estimated at 2.0 % of total revenue from sale of fish obtained from a given feed type. Costs and returns analysis was used to determine the return on investment (ROI) as a comparative indicator. The undiscounted ROI was calculated by dividing income by the total investment. Break-even analysis was used to determine the level at which the gains and losses are equal. Break even quantity of fish was calculated by dividing the total fixed cost by the contribution per unit weight of fish. Break-even unit price was obtained by equating total cost to total revenue using the relation: $F + Vx = Sx$ where F is Fixed cost, V is variable cost per unit, S is selling price per unit and x is the break-even quantity of fish.

The capital outlay was valued at GH¢10,480.00. Food conversion ratios (FCR) of the feeds employed were estimated to range between 1.69 and 2.46. Crude protein varied from 30 – 36 % (Table 16). The respective unit prices ranged between GH¢1.35 and GH¢1.80. In terms of usage, the quantities follow the order: B > D > C > E > A > F. With respect to their cost however, the order was D > B > C > E > F > A. Table 17 shows the comparative costs and returns computation of the different feed types employed. Feed was the major component of cost, averaging 61 % of the total variable costs. Comparatively, the estimated ROI was highest at -0.4 and lowest at -18.3 and followed the order F > C > B > A > D > E. At these levels of profitability, the various feeds could not be considered as alternatives. Table 18 reveals that at the prevailing assumptions, the average price of GH¢3.80 per kg received from fish sales should be increased by about 60 % to enable the usage of the respective feed break even. Therefore, at the given level of production and sales prices, prospective farmers are likely to lose using any of the feeds evaluated at the corresponding input prices.

Table 16: Characteristics of the feed types and usage during the experiment (1.0 US$ = 1.45 GH¢)

Type of Feed	Feed Conversion Ration (FCR)	Crude Protein (%)	Unit Price (GH¢/kg)	Quantity of Feed employed (kg)	Total Cost of Feed employed (GH¢/kg)
A	1.78	30	1.6	782.63	1,252.21
B	2.46	30	1.35	1,081.61	1,460.18
C	1.89	33	1.75	831.00	1,454.24
D	2.12	30	1.8	932.12	1,677.82
E	1.87	30	1.75	822.20	1,438.85
F	1.69	36	1.8	743.06	1,337.51

Table 17: Break even quantities and prices of fish (1.0 US$ = 1.45 GH¢)

Type of Feed	Quantity of fish required to break even (kg)	Break even Unit Price (GH¢/kg)
A	440.0	7.02
B	560.0	5.90
C	606.5	5.45
D	451.0	7.79
E	603.0	5.50
F	709.0	4.52

Table 18: Cost and returns for the cages stocked and fed with the seven (7) types of feed (1.0 US$ = 1.45 GH¢)

Item	Feed Type A		Feed Type B		Feed Type C		Feed Type D		Feed Type E		Feed Type F		Feed Type G	
	Qty. (kg)	Total Value (GH¢)	Qty. (kg)	Total Value (GH¢)	Qty. (kg)	Total Value (GH¢)	Qty. (kg)	Total Value (GH¢)	Qty. (kg)	Total Value (GH¢)	Qty. (kg)	Total Value (GH¢)	Qty. (kg)	Total Value (GH¢)
Revenue	439.7	1,586.40	559.9	2,181.00	473	1,685.50	603.4	2,522.00	452.1	1,625.90	604.7	2,509.30	708.9	3,160.60
Variable costs		324		324		324		324		324		324		324
Fingerlings		394		394		394		394		394		394		394
Labour														
Feed		1,252.21		1,460.18				1,454.24		1,677.82		1,438.85		1,337.51
Vehicle running (Fuel, engine oil etc.)		143		143		143		143		143		143		143
Marketing expenses (2%)		32		43.6		33.7		50		32.6		50.2		63
Sub total		2,145.21		2,364.78		894.70		2,365.24		2,571.42		2,350.05		2,261.51
Fixed costs		524		524		524		524		524		524		524
Repairs and maintenance (5 %)		417.2		417.2		417.2		417.2		417.2		417.2		417.2
Depreciation		941.2		941.2		941.2		941.2		941.2		941.2		941.2
Sub total		3,086.41		3,305.98		1,835.90		3,306.44		3,512.62		3,291.25		3,202.71
Total costs														
Return on investment (ROI)		-14.3		-10.7				-7.5		-18.0		-18.3		-0.4

2.5.6 Catch Assessment and Reproductive Seasonality of Major Commercial Catfishes in Strata II and III of the Volta Lake

(Project Staff: Mr. Seth Koranteng Agyakwah – Research Scientist)

In collaboration with the Challenge Program for Water and Food Project 34 (CPWF: PN 34) of CGIAR's WorldFish Center, Egypt, this study began in 2006 to assess the exploitation patterns of catfishes of the genera *Bagrus, Chrysichthys, Clarias* and *Synodontis* in the Volta Lake for sustainable management strategy development. During the year under review, catch assessment was conducted by determining the composition of fish species by weight per major gear of commercial fishers, changes in relative abundance of fish species, length-frequency distribution, condition factor (K), catch per unit of effort (CPUE), seasonality of spawns, size at first maturity and relationship of catches and spawning activities with physico-chemical parameters of the lake. Fish species diversity and similarity between Dzemeni (Stratum II) and Kpando (Stratum III) study sites were conducted.

The clarotid catfishes of the genus *Chrysichthys* (i.e. *C. auratus, C. nigrodigitatus and C. walkeri*) dominated all catches by all gears with the exception of hook-and-line fishery in both Dzemeni and Kpando study areas (Fig. 47).

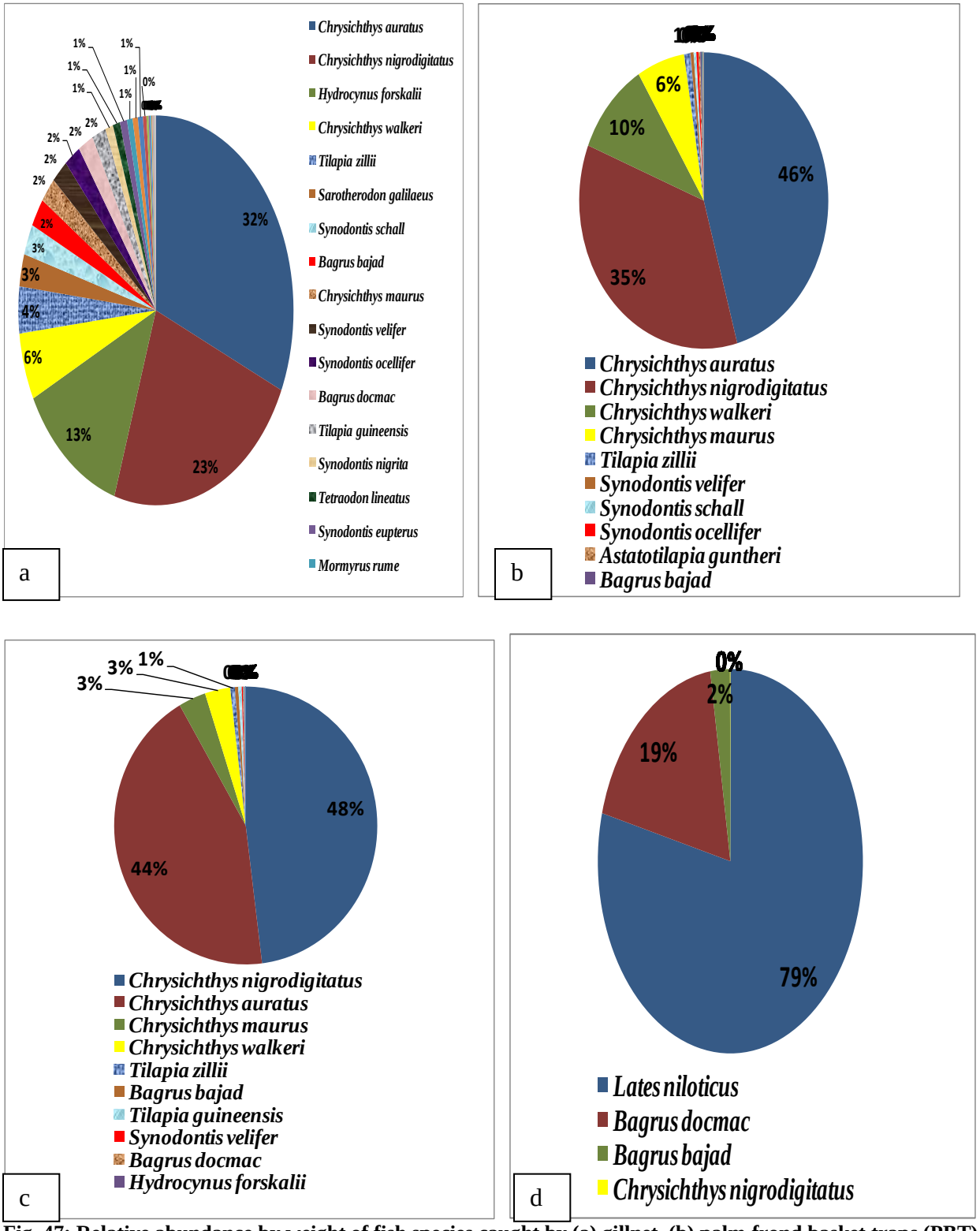


Fig. 47: Relative abundance by weight of fish species caught by (a) gillnet, (b) palm-frond basket traps (PBT), (c) multifilament net traps (MNT) and (d) hook-and-line in the lacustrine section (Strata II and III) of the Volta Lake

Distributions of length – frequencies by major gear types, viz: gillnets (GN), multifilament net trap (MNT) and palmfrond basket trap (PBT) of the two most exploited catfishes (*Chrysichthys auratus and C. nigrodigitatus*) at Dzemeni and Kpando-Torkor were similar by location for same gear, but different by species for same gear. More than 50 % of claroteids were caught at sizes below 13.5 cm SL for *C. auratus* and below 17.5 cm SL for *C. nigrodigitatus* which suggested growth overfishing. All three gears captured more than one size class of the claroteid catfishes. At both study sites, only gillnet catches of *C. auratus* showed bi-modal length class distributions, whereas MNT and PBT gears showed three or more distinctive modal length classes (Figs. 48 and 49).

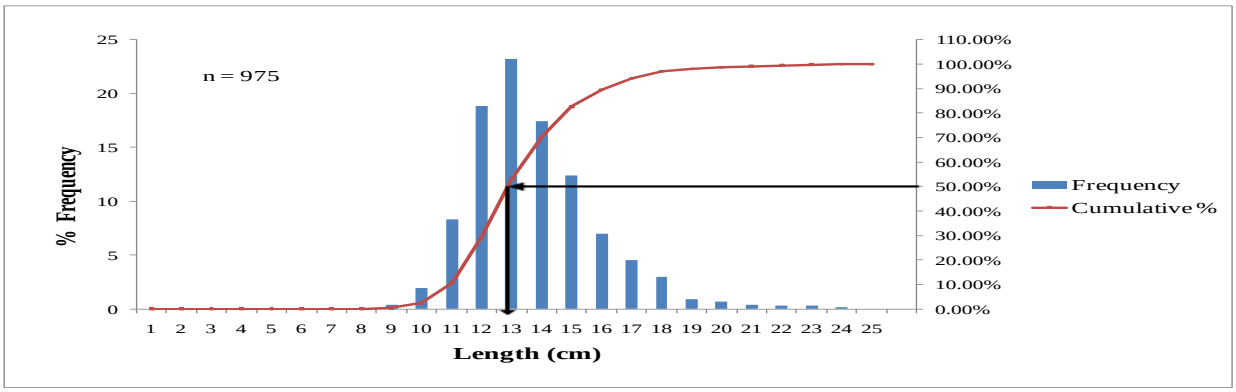


Fig. 48: Length – frequency distribution of *Chrysichthys auratus* caught by gillnets of various mesh sizes at Dzemeni in Stratum II of the Volta Lake

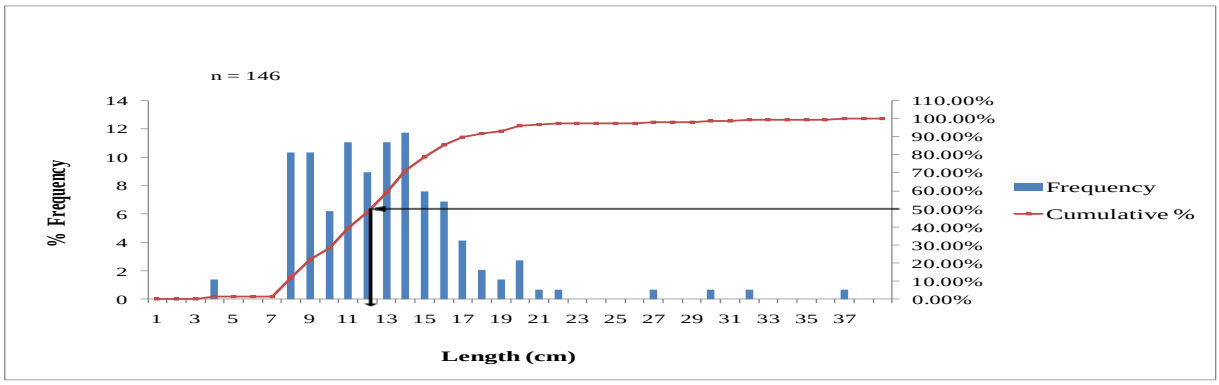


Fig. 49: Length –frequency distribution of *Chrysichthys nigrodigitatus* caught by palm-frond basket traps (PBT) at Kpando in Stratum III of the Volta Lake

Relative fecundity among the claroteids was comparable between same species in the different study locations, except *C. nigrodigitatus* and *C. walkeri* in Stratum III at Kpando that produced relatively higher number of eggs per female body weight in grams compared to their counterpart species in Stratum II at Dzemeni. The mochokids produced relatively higher numbers of eggs per female, ranging from 383 – 21,452 eggs. *S. schall* at Kpando (Stratum III) produced the least number of eggs among the mochokids as well as the highest number of eggs in the same Stratum (Tables 19 and 20).

Table 19: Mean relative fecundity, numbers and sizes of ripe eggs per female catfishes at Dzemeni study area in Stratum II of the Volta Lake

	Egg size (mm)				No. of ripe eggs / female				Relative fecundity (/g)			
Species	**Mean (±s.e.)**	**Min.**	**Max.**	**n**	**Mean (±s.e.)**	**Min.**	**Max.**	**n**	**Mean (±s.e.)**	**Min.**	**Max.**	**n**
*B. bajad**	--	--	--	--	--	--	--	--	--	--	--	--
*B. docmak**	--	--	--	--	--	--	--	--	--	--	--	--
C. auratus	1.6 (0.05)	1.0	2.5	46	988.9 (203.69)	88	10125	49	17.6 (3.77)	2.7	185.8	49
C. maurus	1.9 (0.1)	1.8	2.0	2	925 (470.0)	455	1395	2	13.3 (7.72)	5.6	21.0	2
C.nigrodigitatus	1.9 (0.07)	1.5	2.5	16	1645.2 (166.36)	901	3000	16	12.5 (2.18)	4.4	39.7	16
C. walkeri	1.9 (0.07)	1.5	2.0	9	1009 (180.3)	367	1874	9	11.5 (1.34)	2.3	16.3	9
S. eupterus	1.0 (N/A)	1.0	1.0	1	6000 (N/A)	6000	6000	1	41.1 (N/A)	41.1	41.1	1
S. ocellifer	1.25(0.25)	1.0	1.5	2	1747.5 (225.5)	1522	1973	2	13.4 (0.28)	13.1	13.7	2
S. schall	1.3(0.14)	1.0	1.8	6	8853.3 (2189.9)	538	16253	6	38.3 (9.16)	1.6	64.3	6
S. velifer	1.2(0.17)	1.0	1.5	3	6078.0 (1557.4)	3754	9036	3	38.9 (8.66)	30.1	56.3	3

* Information not provided because no ripe eggs were encountered, s.e. = Standard error, N/A = undefined standard error for only one sample observation, Min. = minimum value, Max. = maximum value.

Table 20: Mean relative fecundity, numbers and sizes of ripe eggs per female catfishes at Kpando study area in Stratum III of the Volta Lake

	Egg size (mm)				No. of ripe eggs / female				Relative fecundity (/g)			
Species	**Mean (±s.e.)**	**Min.**	**Max.**	**n**	**Mean (±s.e.)**	**Min.**	**Max.**	**n**	**Mean (±s.e.)**	**Min.**	**Max.**	**n**
*B. bajad**	--	--	--	--	--	--	--	--	--	--	--	--
*B. docmak**	--	--	--	--	--	--	--	--	--	--	--	--
C. auratus	1.6 (0.05)	1.0	2.0	26	1023.0 (153.15)	192	4000	26	17.2 (2.08)	4.1	49.6	26
C. maurus	1.8 (0.44)	1.0	2.5	3	1412.3 (66.68)	1297	1528	3	14.9 (1.99)	11.0	17.4	3
C.nigrodigitatus	1.8 (0.08)	1.0	2.6	25	1949.6 (405.61)	354	9967	25	20.7 (7.45)	2.9	194.9	25
C. walkeri	1.8 (0.11)	1.0	2.6	17	1564.3 (490.14)	241	8000	18	22.5 (6.31)	3.1	121.4	18
S. eupterus	1.5 (0.00)	1.5	1.5	2	2102.5 (757.5)	1345	2860	2	25.1 (10.66)	14.4	35.7	2
S. ocellifer	1.6 (0.22)	1.0	2.0	4	1626.8 (912.63)	438	4329	4	10.4 (7.06)	2.0	31.5	4
S. schall	1.3 (0.09)	1.0	1.8	9	6475.9 (2284.2)	383	21452	9	40.8 (12.36)	2.3	101.2	9
S. velifer	1.1 (0.1)	1.0	1.2	2	12260 (8600.5)	3659	20860	2	48.6 (33.24)	15.4	81.8	2

* Information not provided because no ripe eggs were encountered, s.e. = Standard error, Min. = minimum value, Max. = maximum value.

Diversity of fish species in commercial catches of artisanal fishers at Kpando-Torkor was significantly higher than at Dzemeni ($P < 0.05$). Fish species occurrence in commercial catches of fishers at Dzemeni was however very similar to that of Kpando-Torkor as depicted by a high Jaccard similarity index (S_j') of 0.811 (Table 21).

Table 21: Indices of species diversity and similarity of commercial fish catches at Dzemeni and Kpando during June 2006 and March 2008

	Indices of Diversity and Similarity*					Probability (5 %)	
Location	S_j'	H'	D_s'	**Variance**	**df**	**t-calculated**	**t-inverse**
Dzemeni	0.811	1.097[a]	0.505[a†]	0.003	65	14.474	1.997
Kpando		1.19[b]	0.564[b]	0.028			

* S_j' = Jaccard similarity index, H' = Shannon-Weiner diversity index, D_s' = Simpson diversity index

† Values with different letters in a column show significant difference at $P < 0.05$.

Total annual catfish production at Dzemeni was 806 tonnes, which was almost double the quantity produced at Kpando-Torkor (444 tonnes) over the same study period. At Dzemeni and Kpando-Torkor study sites, catfishes contributed 92.2 % and 90.6 % of total fish production respectively. Generally, the catch per unit of effort (CPUE) of PBT or MNT was significantly higher than that of gillnet.

It was concluded that unapproved gillnet mesh sizes of less than 2 inches (51 mm) contributed to about 45 % of gillnet catfish landings of immature or first time spawning populations. Hence, Fishers should be identified by the gears they use, be registered in their respective fishing communities and be monitored regularly to facilitate effective management of the fishery resources. It was recommended that there should be regular monitoring of commercial catfish catches by way of catch assessment to control and sustain the catfish production in the Volta Lake. Further studies should also be conducted on the reproductive activities and food habits of the less abundant, yet highly valued commercial catfishes (e.g. *Synodontis* spp and *Bagrus* spp) in the Volta Lake for improvement of their productivity and sustainable management.

2.6 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.

2.6.1 Cartographic Section

During the year, the Cartographic Section supported Research and Consultancy services through the provision of elaborate drawings in the form of maps and borehole profiles. Some old maps and graphs were also updated in addition to miscellaneous services. As the year ended, a total of 32 drawings were prepared for five (5) research divisions and the Estate Section as shown in Table 22 and Fig 50 below:

Table 22: Cartographic drawings prepared during the year 2010

Divisions	No. of Drawings
Groundwater	12
Surface Water	6
Environmental Chemistry	9
Environmental Biology & Health	2
Fishery	2
Estate	1

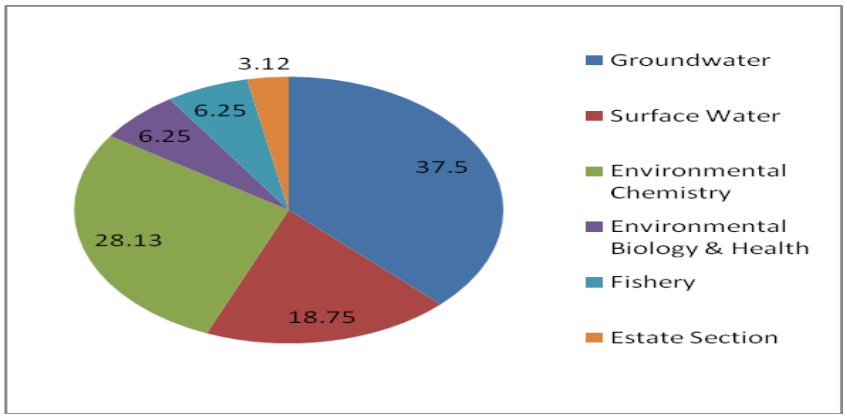


Fig. 50: Percentage composition of cartographic drawings prepared during the year 2010

The Cartographic Section still has coloured Hydrogeological Maps of Greater Accra, Volta, Eastern, Ashanti, Western and Central regions for sale to Groundwater Consultants, Institutions as well as Individuals.

2.6.2 Development of Research Library and Water Resources Documentation System

The main objective of the library is to acquire, catalogue, classify, organize and preserve all available information to support research and development activities of the Institute. In the reporting year, a total number of 194 books were received, processed and added to the existing stock at the library. Gazzettes, Acts and other government publications were purchased during the year. The number of users of the library increased by about 12.5 % over the previous year as detailed in Table 23 and Fig. 51. Data entry of all technical reports, theses, books and journals was resumed and newspaper publications for the year 2009 were bounded into volumes for reference purposes. In support of research activities, the Library acquired a scanner through its partnership with FAO's Aquatic Sciences and Fisheries Abstract (ASFA) Project.

Table 23: Number of users of the Library for the period 2006 – 2010

Year	No. of users
2010	3,044
2009	2,707
2008	2546
2007	2532
2006	1723

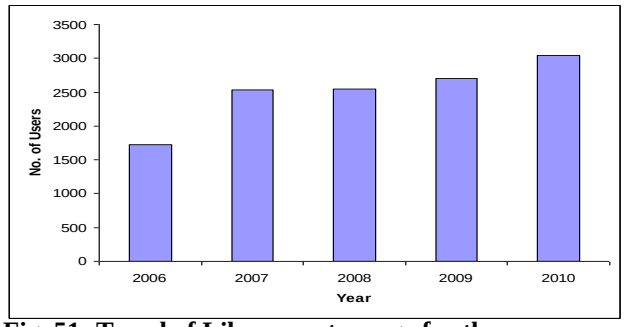


Fig. 51: Trend of Library patronage for the period 2006 – 2010

2.6.3 Internal Seminars

Eight presentations on various research topics being addressed by the Institute were made. Scientists from allied institutions and the media attended. The seminars were to provide fora for participants to discuss and also bring into the public domain current research activities of the Institute. The details are presented in Table 24.

Table 24: Internal seminars during the year 2010

Month	Presenters/Speakers	Topics
June	Mr. Humphrey F. Darko Dr. O. D. Ansa-Asare	Trace metal concentrations in major rivers from the southwestern and coastal river systems of Ghana
	Mr. Anthony Yaw Karikari Mr. Felix Akpabey	Assessment of water quality and primary productivity characteristics of the Volta Lake
	Mr. Francis K. Y. Amevenku Dr. Emmanuel Obuobie	Water resources management: cultural and human factors and their impact on the environment
July	Dr. Emmanuel Obuobie	Climate change effects on hydrology and water resources and adaptation strategies in Ghana
	Mr. Samuel Sasu (Ph.D. student, University of Stuttgart, Germany)	Assessment of pharmaceutical waste management situation in Ghana
October	Mr. Francis Assogba Anani	Growth performance of the Nile Tilapia (*Oreochromis niloticus*) fry on three different diets with different soyabean levels
	Mr. Seth K. Agyakwah	Catch assessment reproductive seasonality of major commercial catfishes in Lake Volta (Strata II and III)
November	Mrs. Marian Amu-Mensah	Policy support on HIV/AIDS in CSIR

2.6.4 Exhibitions

The Institute took part in many exhibitions organised during the year to showcase some of the major research activities and findings of the Institute. These included:

- 26th National Farmers Day;
- 4th International Conference on Appropriate Technology for Water and Sanitation: Solution for a Thirsty Pollutted Planet;
- Alliance for Green Revolution in Africa Forum; and
- Day of Scientific Renaissance of Africa – Themed: "Science and Technology for Post Harvest Loss Reduction – the Key to Food Security".

The stand of the Institute during the exhibitions was patronised by people from all walks of life. Some of these came for consultation and collaborative research work after the exhibitions.

2.6.5 Educational Visits

Educational visits were organized for a number of organisations and institutions during the year. Among them were students from:

- Presbyterian Boys' Secondary School, Legon;
- Archbishop Porter Girls' Secondary School, Takoradi;
- Department of Geography and Resource Development, University of Ghana-Legon;
- Polytechnic Association of Science Laboratory Technologists and Technicians, Accra Polytechnic; and
- Ghana Association of Science Teachers (GAST).

2.7 CONSULTANCY AND OTHER SERVICES

2.7.1 Consultancy and Advisory Services

A number of 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:

- Update on flood phenomenon in Ghana (Client: UNESCO)
- Managing water as a shared responsibility across geographical and social boundaries by promoting IWRM in the cluster countries: The case of Tano and Keta basins (Client: UNESCO)
- Assessment of innovative institutional arrangement and technical interventions in irrigation farming in northern Ghana (Client: IWMI)
- Impact of climate change on water resources of Ghana (Client: UNESCO)
- Water resources modelling with MIKE BASIN under the Sustainable Development of Research Capacity (SDRC) programme (Client: Glowa Volta Project)
- Geophysical survey, analyses and interpretion of data to select suitable drilling locations to supply underground water at a proposed Warehouse site at Apowa-Kadjebril near Takoradi (Client: COCOBOD)
- Geophysical survey at Nankese to drill additional borehole to supplement the existing supply source (Client: CSIR Mineral Water Co. Ltd.)
- Baseline environmental studies at Obuasi Anglogold Tailing Dump Sites by carrying out pumping test and data analyses of nine (9) monitoring boreholes(Client: Anglogold Ashanti Ghana Ltd.)
- Assessment of the ecological and public health status of a Water Storage Facility (Client: Newmont Ghana Gold Ltd.)
- Assessment of pond water quality and trace metal levels in fish (Client: Newmont Ghana Gold Ltd)
- Trace metal levels in fish and water quality assessment (Client: AngloGold Ashanti Ghana Ltd.)
- Assessment of ground and surface water quality (Client: Tarkwa Goldfield Company Ltd.)
- Physico-chemical and biological assessment of the quality of the Subri River and its tributaries (Client: MEST)
- Physico-chemical and bacteriological assessment of raw and treated water(Client: Vicco Ventures Limited)
- Water quality assessment of rainwater harvesting systems in Mfantsiman, Abura Asebu Kwamangkese and Ajumako Enyan Essiam districts (Client: Plan Ghana Limited)
- Assessment of effluent quality (Client: PhytoRiker pharmaceuticals Limited)
- Assessment of effluent quality (Client: Pioneer Food Cannery Limited)
- Assessment of potable water quality (Client: Pioneer Food Cannery Limited)
- Physico-chemical and bacteriological tests on potable and swimming pool waters (Client: Golden Tulip Hotel)
- Final effluent quality monitoring (Client: Golden Hotel Limited)
- Assessment of the quality of swimming pool water (Client: Tesano Sports Club)

2.7.2 Training Services

The Institute, through the Technical Divisions, 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 of graduate students at the Graduate School of Nuclear and Allied Sciences (SNAS)
- Review of M.Sc. thesis entitled "Accumulation of Selected Pollutants in Clymene Dolphins (*Stenella clymene*), caught from Ghanaian Coastal Waters" from the University of Ghana, Legon
- Training of Laboratory Staff from AngloGold Ashanti
- Laboratory assistance to HND Laboratory technology students from Accra Polytechnic and students from the Environmental Science Programme and the Department of Botany, University of Ghana, Legon
- Part-time lectureship of undergraduate students at the Department of Botany, post-graduate students of the Environmental Science Programme and the Department of Botany, all of the University of Ghana, Legon
- Co-supervision of M. Phil. Students from the Department of Zoology and the Department of Environmental Science Programme, all of the University of Ghana, Legon
- External examination of thesis of students from the Environmental Science Program and the African Regional Programme for Insect Science, all of the University of Ghana, Legon

3.0 ADMINISTRATION

3.1 Management

The Institute was managed by a 8-member Management Board chaired by Prof. C. Dorm-Adzobu, Dean of the Faculty of Arts and Social Sciences, Central University College, and a 20-member Internal Management Committee (IMC) chaired by the Director. Membership of the Board and IMC are given in Appendices I and II, respectively.

3.2 Staff Strength

At the end of the reporting year, staff strength stood at 225. It was made up of 52 Senior Members, 76 Senior Staff and 97 Junior Staff. The distribution of staff and list of senior members and senior staff are shown in Appendices III and IV, respectively. Table 25 shows the number of promotions, retirements, vacation of post, temporary appointments, contracts and deaths during the year.

Table 25: Promotions, retirements, temporary appointment, contracts and deaths during 2010

		Senior Members	Senior Staff	Junior Staff	Total
1.	**Promotions**	4	13	7	**24**
2.	**Retirements**	1	6	1	**8**
3.	**Temporary Appointments**	2	5	2	**9**
4.	**Contracts**	-	-	1	**1**
5.	**Death(s)**	-	1	-	**1**

3.3 Human Resources Development

In the reporting year, 5 members of staff were pursuing various programmes at various levels both locally and abroad. A total of four (4) other members of staff who successfully completed their respective programmes during the year returned to post. The details are given in Table 26.

Table 26: Human resources development

No.	Programmes	No. Pursuing Programmes Abroad	No. Pursuing Programmes Locally	No. Completing Programmes in 2010	Total No. Still Pursuing Programmes
1	**PhD**	2	3	3	**2**
2	**BSc**	-	1	1	**0**
3	**HND/Univ. Dip**	-	3	-	**3**
	Total No.	**2**	**7**	**4**	**5**

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

- WEAP Training Workshop for Key Partners of Riparian States of Volta Basin Authority, Bamako, 28 February – 4 March 2010
- Achieving Organisational Performance at the CSIR: Some Ideas, Accra, 10 March 2010
- Pesticide Residues in Local and Imported Fruits and Vegetables in Ghana, Accra, 2 September 2010
- Training Course on Marine Nutrient Chemistry and Monitoring, Tunis, September 2010
- Training Course on Sanitation in Sub-Sahara African Countries: The fundamental role of education, Politechnico Di Torino, Italy, November 2010
- Training Course on Water Management, Treatment and Salinity Control, Egypt, 5 – 25 December 2010
- Hydroaid Distance Learning Programme on Sanitation - Urban Waste Recycling, Turin, 2010
- GLOWA Volta Project MIKE BASIN Training Workshop, Cape Coast, 27 – 28 September 2010
- Workshop on Water allocation optimization using GAMS and M^3 Water, Accra, 6 – 8 July 2010
- Workshop on Modeling of the onset of the rainy season in West Africa and potential implications for Agriculture, Cape Coast, 8 – 12 February 2010

3.4 Participation in Scientific Meetings

A number of research and technical staff participated in the following workshops, seminars and conferences held at the national, regional and international levels:

- Removing Barriers to Invasive Plant Management in Africa, UNEP/GEF Project Termination Workshop, Addis Ababa, 27 – 30 September 2010
- National Workshop for Interaction on the West Africa Water Resources Policy, Accra, 21 December 2010
- Research Design Workshop for ESPA call for full proposal, Nairobi, 8 – 11 November 2010
- 9th International workshop on Climate and Environmental Change: Challenges for Developing Countries, Beijing, 17 – 20 November 2010
- 2nd GLOWA GeoPortal and Database Management Workshop, Cape Coast, 28 – 29 October 2010
- 2nd Ghana Water Forum, Accra, 19 – 21 October 2010
- Environmental Management Plan of the Volta Dam at Akosombo, Accra, 19 October 2010
- Ghana-Iran Joint Commission for Co-operation and Development, Accra, 10 – 11 August 2010
- Regional Stakeholders' Meeting on Consortium Research Program 5, Ouagadougou, 3 August 2010
- Evaluation Workshop - Activities of Global Water Partnership-Nigeria in Integrated Water Resources Management, GWP-WA, Abuja, 28 June – 2 July 2010
- Regional Workshop on the Contribution of Big Water Infrastructures to the Sustainable Development of Countries for Journalists in West Africa, Global Water Partnership-West Africa/Country Water Partnership-Ghana, Accra, 17 – 21 May 2010
- Rethinking Storage Project Partners Progress Meeting, Addis Ababa, April 2010

- Toolkits for the Sustainable Management of Ghana's Riverine Biodiversity, Accra, 11 January 2010
- Review workshop on Draft Master's Programme in Integrated Environmental, Economic and Social Development in Rural Africa (ProIRD). Under the UNU project – Education for Sustainable Development in Africa, Accra, 28 January 2010
- Workshop on the Preparation of Environmental Management Plan for the Akosombo and Kpong Generation Stations, Accra, 10 February 2010
- Consultative meeting on the Guidelines for Environmental Assessment and Management in the Offshore Oil and Gas Development, Accra, 5 August 2010
- First ODINAFRICA National Co-ordination Meeting, Tema, 12 August 2010
- Biodiversity 2010: A Renewing Commitment to the Biodiversity Convention – Stakeholders Consultation Workshop, Koforidua, 13 August 2010
- Stakeholder Engagement Workshop on Implementation of the Rio Conventions, Akosombo, 10 May 2010
- Workshop to Facilitate a Fair Trade Label for Aquaculture Fish Products and Exports in Africa, Nairobi, 22 – 23 November 2010
- Training Workshop on Developing a Training Manual for the Certification and Exports of Fair Trade Fish Products, Nairobi, 24 – 25 November 2010
- Workshop on Aquaculture Site Selection and Carrying Capacity Estimates for Inland and Coastal Water Bodies, Stirling, 6 – 8 December 2010
- National Forum on Wetlands: Celebrating World Wetlands day, Accra, 2 February 2010
- Workshop on Advanced Solutions for Wastewater Treatment and reuse in Africa, Accra, 9 – 10 February 2010
- Intergovernmental Oceanographic Commission Sixth Session of the IOC Regional Committee for the Central Eastern Atlantic (IOCEA-VI), Accra, 28 – 30 March 2010
- National Workshop for the Development of Ghana's National Action Plan (NAP), Accra, 27 April 2010
- National Workshop on Institutional Collaboration towards Shoreline Management for Ghana, Accra, 28 April 2010
- National Workshop for the Validation of Ghana's National Action Plan (NAP), Accra, 20 December 2010
- Technical Roundtable on Flood Mitigation Strategy for the SADA Area, Tamale, 7 – 11 December 2010
- National Transboundary Diagnostic Analysis (TDA) Validation Workshop, Accra, 11 – 12 March 2010
- National Forum on Science, Technology and Innovation policy, Accra, 17 March 2010
- Ghana Taxonomic Needs Assessment, Accra, 12 – 15 April 2010
- 12th Biennial Workshop on Minimizing post harvest losses as an Effective Poverty reduction Strategy: The Role of Science and Technology, Tamale, 4 August 2010
- National Transboundary Diagnostic Analysis (TDA) Validation Workshop, Accra, 7 November 2010
- 4th International Conference on Appropritae Technology for Water and Sanitation: Solutions for a Thirsty, Polluted planet, Accra, 24 – 27 November 2010
- Mentoring Workshop on Female Scientists: Bridging the Gap between research and Development, Accra, 6 – 8 December 2010

3.5 Membership of Committees and Boards

Staff continued to serve on various committees and boards including the under-mentioned:

- Advisory Committee of the Ghana Environmental Conventions Coordinating Authority, MEST
- CSIR WRI-BRRI Rainwater Harvesting Development Committee
- Darwin Initiative – Ghana
- GCLME Project Steering Committee-Ghana
- Ghana Chemical Society
- Ghana Institute of Biology.
- Ghana-Iran Joint Commission for Co-operation and Development
- Ghana National Commission for UNESCO
- Ghana National Committee for International Hydrological Programme (IHP)
- Ghana Science Association
- Ghana Science Congress Planning Committee
- Governing Board of the Ghana Meteorological Agency
- Governing Board of the Ghana Irrigation Development Authority
- Governing Commissioners, Water Resources Commission
- MEST Technical Committee on Marine Algal bloom in the Central and Western Regions
- National Coordinating Committee of the Ghana Dams Dialogue
- National Filariasis Task Force
- National Malaria Task Force
- Natural Sciences Committee
- ODINAFRICA-Ghana Atlas Team
- Steering Committee for Integrated Management of Invasive Aquatic Weeds Project
- Steering Committee of Technical Co-operation Africa Project RAF/7/008-9002
- World Water Day Celebration Committee

3.6 Staff Publications

Several administrative reports, technical reports, conference papers, consultancy reports, journal papers and newsletter articles were produced by staff. Most of the technical papers and thesis have been shelved at the Institute's library as reference material. The details are given as Appendix V.

3.7 National Service and Industrial Attachment

Twenty (20) graduates from tertiary institutions and 8 others from polytechnics did their national service at the Institute. Five (5) others also had their industrial attachment at the Institute. The details are given in Table 27.

Table 27: National Service/Industrial Attachment

National Service	No.	Industrial Attachment	No.
University of Cape Coast	5	University of Development Studies	1
Kwame Nkrumah Univ. of Science and Tech.	7	Sight and Sound Secretarial	2
University of Ghana	3	Amison Secondary School	1
University of Development Studies	2	Francklyds Professional Training Inst.	1
Pentecost University College	1		-
Accra Polytechnic	5		-
Ho Polytechnic	1		
Koforidua Polytechnic	1		
Ohawu Agric College	1		
Russia University	1		
Delhi University	1		
Total	**28**	**Total**	**5**

4.0 FINANCE

The total receipts for the year was GH¢4,583,664.02. Out of this amount, 77.37 % represented government subvention, 14.54 % represented internally generated funds and 8.09 % represented donor assistance to the Institute.

4.1 Recurrent and Development Budget in 2010

Receipt for recurrent and development expenditure was GH¢3,546,442.81 based on an approved budget of GH¢3,536,577.00. This constituted 77.37 % of total receipt for the year. The details are given in Table 28.

Table 28: Receipts and Expenditure of Government Funds in 2010

		2009 Budget GH¢	
	Type of Expenditure	**Approved**	**Released**
1.	Personnel Emoluments	3,316,895.00	3,345,067.68
2.	Administrative Activities	219,682.00	201,375.13
	Total	**3,536,577.00**	**3,546,442.81**

4.2 Internally Generated Funds (IGF) in 2010

An amount of GH¢666,613.82 was generated from consultancy services out of which an expenditure of GH¢517,221.80 was made (Table 29). The IGF constituted 14.54 % of total receipts for the year.

Table 29: Receipts and Expenditure of IGF in 2010

Receipts (GH¢)	Expenditure (GH¢)	2011 Projected Receipts (GH¢)
666,613.82	517,221.80	610,841.77

4.3 Donor Assistance in 2010

Receipt for donor assistance was GH¢370,607.39 during the year. However, an expenditure of GH¢270,744.62 was made (Table 30). Donor assistance receipts represented 8.09 % of total receipts for the year.

Table 30: Receipts and Expenditure of Donor Assistance in 2010

Total Receipts (GH¢)	Total Expenditure (GH¢)
370,607.39	270,744.62

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. R.K.D. Van-Ess Member	- Director, Community Water and Sanitation Agency
6.	Mr. Eugene Atiemo Member	- Director, CSIR Building and Road Research Institute
7.	Dr. Y. Opoku-Ankomah Member	- Director, CSIR Water Research Institute
8.	Mr. A. Tagoe Acting Secretary	- Head of Administration, CSIR Water Research Institute

APPENDIX II: Membership of the Internal Management Committee

1.	Dr. Yaw Opoku-Ankomah	-	Director (Chairman)
2.	Dr. S. Dapaah-Siakwan	-	Deputy Director & Head, Groundwater Division
3.	Dr. K. Kankam-Yeboah	-	Head, Surface Water Division
4.	Dr. Joseph A. Ampofo	-	Head, Environmental Biology and Health Division
5.	Dr. Osmund D. Ansa-Asare	-	Head, Environmental Chemistry Division
6.	Dr. J. K. Ofori	-	Head, Fishery Division
7.	Marian A. Jiagge (Mrs.)	-	Head, Commercialization and Information Division
8.	M. Azara Sedziafa (Mrs.)	-	Head, Administration Division
9.	Mr. Paul Fabalona	-	Head, Finance Division
10.	Dr. Felix Y. Attipoe	-	Officer-In-Charge, ARDEC
11.	Dr. K. Kwafo-Apegya	-	Officer-In-Charge, WRI Tamale
12.	Mr. Samuel A. Tagoe	-	Acting Head, Personnel Section
13.	Mr. Simon Anane	-	Acting Head, Estate Section
14.	Mr. Samuel Teivi	-	Head, Transport Section
15.	Mr. Rex Sapah	-	Head, Cartographic Drawing Section
16.	Mr. S.O. Ankrah	-	Acting Head, Security Section
17.	Mr. Anthony Karikari	-	Representative, Research Staff Association
18.	Mr. James Owusu	-	Representative, Senior Staff Association
19.	Mr. M.T. Sappor	-	Representative, Local Union
20.	Mrs. M. Amu-Mensah	-	Head, Scientific Secretariat Section

APPENDIX III: Staff Distribution among the Divisions and Sections

Division/ Section	Senior Members	Senior Staff	Junior Staff	Total
Directorate	2	-	-	**2**
Surface Water Division	7	4	-	**11**
Ground Water Division	5	3	2	**10**
Environmental Chemistry Division	9	11	1	**21**
Environmental Biology & Health Division	10	6	1	**17**
Fishery Division	10	5	5	**20**
Commercialization and Information Division				
▪ Scientific Secretariat	3	1	-	**4**
▪ Library	2	1	-	**3**
▪ Printing Section	-	1	1	**2**
▪ Cartographic Drawing Office	-	3	-	**3**
▪ Computer Centre	-	1	1	**2**
Finance Division	1	11	5	**17**
Administration Division				
▪ Personnel	1	8	12	**21**
▪ Transport/Mechanical Workshop	-	13	13	**26**
▪ Estate	-	1	25	**26**
▪ Security	-	2	28	**30**
Temporary Appointment	2	5	2	**9**
Contracts	-	-	1	**1**
Total	**52**	**76**	**97**	**225**

APPENDIX IV: List of Senior Members and Senior Staff

DIRECTORATE

S. Dapaah-Siakwan
B.Sc. (Hons) Physics, (UST)
M.Sc. G/Water Hydrol. (VUB Belgium)
Ph.D. Tsukuba Univ. Japan
Principal Research Scientist
Acting Director

P. Gyau-Boakye
B.Sc. (Hons) Civil Eng. (UST)
M.Sc. Water & Waste Eng. (L'borough)
Ph.D. (Hydrology) Bochum
Principal Research Scientist

SURFACE WATER DIVISION

K. Kankam-Yeboah
BSc. Agric. & Dip. Ed. (UCC)
MSc. Tropical Agric. (CUL, LLN, Belgium)
MSc. Irrig. Eng. (KULeuven, Belgium)
PhD. Earth Science & Env. Eng. (Okaya., Japan)
Principal Research Scientist
Head of Division

S.A. Akrasi
B.Sc. (Hons) Maths/Stats (Legon)
MSc. Soil Conservation & Land Reclamation Eng. (Southampton)
Senior Research Scientist

F.K. Amu-Mensah
BSc. Agric Eng. (UST)
MSc. Soil & Water Eng. (Wageningen)
PhD. Bioenv. Science (Tottori, Japan)
Senior Research Scientist

B. A. Amisigo
BSc.(Hons) Agricultural Eng. (UST)
MSc. Water Res. Eng. (Guelph)
PhD. Hydrology/Water Res. Eng. (Delft)
Senior Research Scientist

E.O. Bekoe
BSc. Agric. Eng. (UST)
MSc. Soil & Water Eng. (Wageningen, Neth.)
PhD. Water & Environment (Cranfield, UK)
Research Scientist

Fredrick Yaw Logah
BSc. Agric. Eng. (KNUST)
MSc. Water Res. Eng. (KULeuven, Belgium)
Research Scientist

E. Obuobie
BSc. Agric Eng. (UST)
MSc. Soil & Water Eng. (Wageningen, Neth.)
PhD. Natural Science (Univ. Bonn, Germany)
Research Scientist

S. Baah
Chief Technical Officer

Albert A. Agyapong
Principal Technical Officer

Collins K. Asante-Sasu
Principal Technical Officer

Gabriel Appiah
Technical Officer

GROUNDWATER DIVISION

B.K. Kortatsi
B.Sc. (Hons) Physics/Maths, (Legon)
M.Sc. Hydrogeol. (Univ. of B'ham)
Ph.D Geology (Univ. of Ghana)
Principal Research Scientist

A.A. Duah
B.Sc. (Hons) Geol. Eng (UST)
M.Sc. Groundwater Survey, GIS (ITC)
Research Scientist

W.A. Agyekum
B.Sc. Geol. Eng. (UST)
M.Eng. Groundwater Hydrology (Delft)
Research Scientist

Patrick A. Mainoo
B.Sc. Physics (KNUST)
MSc Physics (KNUST)
Research Scientist

Collins Okra
BSc (Physics) & Dip. Ed. (UCC)
MSc Geophysics (KNUST)
Research Scientist

James Owusu
Principal Technical Officer

Emmauel A. Ayizemi
Technical Officer

Eric Yaw Darko
Technical Officer

ENVIRONMENTAL CHEMISTRY DIVISION

O. D. Ansa-Asare
B.Sc. (Hons) Chem.Dip.Ed. (UCC)
P.G. Dip. Water Quality Mgt. (Delft)
PhD. Env. Chem. (Aberdeen)
Principal Research Scientist
Head of Division

I. O. A. Hodgson
B.Sc. (Hons) Chem.Eng. (UST),
MSc. Chem. Eng. (UBC, Canada)
PhD Chem. Eng. (LU, UK)
Senior Research Scientist

A. Y. Karikari
B.Sc. (Hons) UST
MSc. Chem. (Univ. of Ryukyus, Japan)
Senior Research Scientist

Asmah Ruby (Mrs)
B.Sc. (Hons) Chem. (UST)
M.Sc. Ecol. Marine Mgt. (Belgium)
Ph.D Aquaculture (Uni. of Sterling, UK)
Research Scientist

Collins Tay
B.Sc. Chem. (KNUST)
M.Sc. Env. Res. Mgt. (KNUST)
Research Scientist

K. A. Asante
B.Sc. (Hons) Chem.(UST)
Cert. Protection & Utilization
of Oceans (Hamburg)
M.Sc. Env. Chemistry and Exotoxicology
Research Scientist

Joyce Amoako (Mrs.)
BSc Chem. (UST)
MSc Env. Sanitation (Belgium)
Research Scientist

Humphrey F. Darko
B.Sc. Chem. (UCC)
MSc Ecological Marine Mgt. (VUB)
Research Scientist

Samuel Obiri
BED Chemistry/Integrated Science
MPhil Inorganic/Analytical Chemistry
Research Scientist

Patience Atsakpo (Mrs)
Principal Technologist

Grace Dartey (Ms)
Senior Technologist

Michael Dorleku
Senior Technologist

Irene D. Adu-Poku
Principal Technical Officer

William E. Arko
Principal Technical Officer

Martha D. Agyemang
Principal Technical Officer

Zita Naangmenyele
Principal Technical Officer

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Accountant

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Chief Stores Supt.

Godwin N. Dohertso
Chief Accounting Asst.

Kwame Osei-Mensah
Chief Accounting Asst

Charles K. Dzokoto
Principal Accounting Asst.

J. H. Baffoe
Principal Accounting Asst.

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Joyce Osibo
Senior Admin. Asst

Agnes Darko
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Rebecca Yankson
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Admin. Asst (Sect)

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Johnson K. Adonkor
Snr. Works Supt. (Auto)

Robert Azongo
Snr. Works Supt. (Machine)

Kenneth K. Opare
Snr. Works Supt. (Auto)

Samuel O. Agyei
Asst. Transport Officer

John K. Kpamah
Asst. Transport Officer

Alex A. Yeboah
Asst. Transport Officer

Samuel Annang
Asst. Transport Officer

Edem K. Ayegbe
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Matthew Kwara
Asst. Transport Officer

Samuel K. Nikoi
Asst. Transport Officer

Benjamin K. Kodjo
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Samuel K. Osafo
Works Superintendent

Security Section

Samuel O. Ankrah
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Anthony Arko
Security Officer

Estate

Simon K. Anane
Estate Assistant

APPENDIX V: List of Staff Publications

Administrative Reports

Agyekum, W. A. and Dapaah-Siakwan, S. (2010) Borehole sites selection at CSIR Mineral Water Co. Ltd. Factory Premises, Nankese, CSIR WRI, Accra.

Amoako, J. (2010) Sustainability of final effluent quality for irrigational purposes, CSIR WRI, Accra.

Asmah, R. (2010) Preliminary Environmental Report for the Aquaculture Research and Development Centre (WRI/ARDEC), CSIR WRI, Accra.

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Kortatsi, B. K., Amevenku, F. K. Y., Kankam-Yeboah, K., Hodgson, I. O. A., Tay, C. and Mainoo, P. A. (2010) Report on Water Resources Inventory and source identification for water supply to rural communities in Upper Manya Krobo District (WSSP Phase II), CSIR WRI, Accra.

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Amoako, J. (2010) Potable Water Quality Studies. Report prepared for Pioneer Food Cannery Limited Tema, CSIR WRI, Accra.

Amoako, J., Karikari, A. Y., Hodgson, I. O. A., Ampofo, J. A., Amevenku, F. and Banu, R. (2010) Water Quality Assessment of Rainwater Harvesting systems in Mfanstiman, Abura Asebu Kwamangkese and Ajumako Enyan Essiam Districts. Report prepared for Plan Ghana, CSIR WRI, Accra.

Ansa-Asare, O. D. (2010) Baseline Environmental Studies: Water Quality assessment of surface and groundwater at Anglogold Ashanti concessions in Obuasi, CSIR WRI, Accra.

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Okrah, C., Dapaah-Siakwan, S., Agyekum, W. A., and Mainoo, P. A. (2010) Borehole site selection at the premises of Tema main branch of Ecobank Ghana Limited, CSIR WRI, Accra.

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Agyekum, W. A. and Kankam-Yeboah, K. (2010) Characteristics of a Crystalline Granitic Aquifer in North-Western Ghana. *Ghana Journal of Science*, Vol. 50.

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Akpabey, F. J. and Ocran, M. (2010) An assessment of microbial formulations of *Bacillus thuringiensis* and *Bacillus sphaericus* for the management of mosquito larvae causing malaria and filariasis. *Journal of Entomology and Nematology* Vol. 2(2), pp. 18-24.

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Biney, C. A. and Asmah, R. (2010) The effects of physico-chemical parameters on speciation of trace metals in sediments from inland and coastal waters of Ghana. *African Journal of Aquatic Sciences*, 35(3)

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Kankam-Yeboah, K., Obuobie, E. and Amisigo, B. (2010) Climate Change Impacts on Water Resources in Ghana, *Ghana and UNESCO Annual Magazine*, 2nd Ed. 2009/2010, Ghana National Commission for UNESCO, Ministry of Education, Accra, pp 65-69. http://unescoghana.org/natural.php

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Addico, G. N. D. (2010) Microcystin –RR like toxin in the cyanobacterium anabaena flos – Aquae strain CCAP 1403/13B, CSIR WRI, Accra.

Agyekum, W. A. (2010) Application of Geophysical Borehole Logging for Hydrogeological Studies in Northern Ghana, CSIR WRI, Accra.

Agyekum, W. A. and Dapaah-Siakwan, S. (2010) Geophysical exploration for siting borehole at COCOBOD' proposed warehouse site at Apowa-Kajebril near Takoradi, CSIR WRI, Accra.

Agyekum, A. W. and Dapaah-Siakwan, S. (2010) Hydrological assessment project in the three Northern Regions of Ghana: Groundwater monitoring of HAP/WUB boreholes, CSIR WRI, Accra.

Dapaah-Siakwan, S. and Agyekum, W. A. (2010) Hydrological Assessment Project of Northern Ghana (Phase II) Geologging and Diver installation of 15 newly drilled monitoring boreholes, CSIR WRI, Accra.

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Gyau-Boakye, P., Kankam-Yeboah, K., Darko, P. K. and Dapaah-Siakwan, S. (2010) Applied Groundwater Studies in Africa, CSIR WRI, Accra.

Joyce, A., Ansa-Asare, O. D., Karikari, A. Y. and Grace, D. (2010) Levels of Polycyclic Aromatic Hydrocarbons (PAHs) in the Densu River Basin of Ghana, CSIR WRI, Accra.

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Longe, E. O., Oyebande, L. and Kankam-Yeboah, K. (2010) Assessment of Country Water Partnership-Nigeria in Integrated Water Resources Management, Global Water Partnership-West Africa, CSIR WRI, Accra.

Mainoo, P. A. (2010) Geophysical studies to locate suitable sites to drill high yielding borehole at Dormaa Akwamu in the Brong Ahafo Region, CSIR WRI, Accra.

Mainoo, P. A. (2010) Report on geophysical investigations to select suitable sites for borehole drilling at Ogbojo in Accra, CSIR WRI, Accra.

Mainoo, P. A. and Dapaah-Siakwan S. (2010) Report on Geophysical Investigation to select suitable sites for borehole drilling for Judicial Services of Ghana - Accra, CSIR WRI, Accra.

Mainoo, P. A. and Dapaah-Siakwan, S. (2010) Report on Geophysical investigations to select suitable sites for drilling mechanized boreholes in six small towns in Nkoranza North District, Sene District and Nkoranza Municipal in Brong Ahafo Region of Ghana, CSIR WRI, Accra.

Mainoo, P. A., Dapaah-Siakwan, S. and Okrah, C. (2010) Report on groundwater exploration using electromagnetic (EM) and Continuous Vertical Electrical Sounding (CVES) geophysical in Upper Voltaian Formation: A case study around Mampong in Ashanti Region of Ghana, CSIR WRI, Accra.

Obuobie E. (2010) Estimation of Groundwater recharge in the White Volta River Basin, West Africa, CSIR WRI, Accra.

Obuobie, E., Barry, B. (2010) Ghana country status on groundwater. Report prepared as part of IWMI led project on Groundwater in sub-Saharan Africa: Implications for food security and livelihoods, CSIR WRI, Accra.

Okrah, C. and Dapaah-Siakwan, S. (2010) Report on borehole drilling at Kwabenya, Accra, CSIR WRI, Accra.

Okrah, C., Dapaah-Siakwan, S. and Agyekum, W. A. and Amankwah Mainoo, P. (2010) Geophysical investigations for borehole drilling siting in the Acidic Dahomeyan formation at a new settlement in Ashaley-Botwe, Greater Accra Region, CSIR WRI, Accra.

Quarcoopome, T. (2010) Population Characteristics of *Chrysichthys nigrodigitatus* in the Weija Reservoir in Ghana, CSIR-WRI, Accra.

Tay, C. (2010) Assesment of the physio-chemical characteristics of wastewater and trace metal levels in sediments from ponds used in Urban Agriculture at Dworwulu and Roman Ridge vegetable irrigation sites, CSIR WRI, Accra.

Theses

Agyekum, W. A. (2010) Geophysical Borehole logging for Hydro-geological Studies in Northern Ghana, University of Ghana, Accra. PhD Thesis

Akpabey, F. J. (2010) Quantification of the cross-sectoral impacts of waterweeds and their control in Ghana, Rhodes University, PhD Thesis

Location map of CSIR Water Research Institute, Accra