CSIR
WATER RESEARCH INSTITUTE

2022 ANNUAL REPORT

CSIR-WATER RESEARCH INSTITUTE (CSIR-WRI)

Annual Report 2022

ACCRA, GHANA

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QUALITY WATER RESEARCH

FOR SUSTAINABLE NATIONAL DEVELOPMENT

CSIR-WATER RESEARCH INSTITUTE

ACCRA, GHANA

ACRONYMS

AAS	-	Atomic Absorption Spectrophotometer
ARDEC	-	Aquaculture Research and Development Centre
AgriEWS	-	Agriculture Early Warning System
BOD	-	Biological Oxygen Demand
CC	-	Climate Change
COD	-	Chemical Oxygen Demand
CSIR	-	Council for Scientific and Industrial Research
CWSA	-	Community Water and Sanitation
DANIDA	-	Danish International Development Agency
CSIR	-	Council for Scientific and Industrial Research
DO	-	Dissolved Oxygen
ECOWAS	-	Economic Community of West African States
EPA	-	Environmental Protection Agency
FAO	-	Food and Agricultural Organization
GIDA	-	Ghana Irrigation Development Authority
GIS	-	Geographic Information System
GNPC	-	Ghana National Petroleum Commission
GSA	-	Ghana Standard Board
GHS	-	Ghana Health Service
GWCL	-	Ghana Water Company Limited
MESTI	-	Ministry of Environment, Science, Technology and Innovation
PURC	-	Public Utilities Regulatory Commission
WHO	-	World Health Organization
IWMI	-	International Water Management Institute
MMDAs	-	Metropolitan, Municipal and District Assemblies
MoFA	-	Ministry of Food and Agriculture
NADMO	-	National Disaster Management Organization
NGRL	-	Newmont Golden Ridge Limited
NTDs	-	Neglected Tropical Diseases
RSA	-	Research Staff Association
SSA	-	Senior Staff Association
UNECA	-	United Nations Economic Commission for Africa
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UNICEF	-	United Nations International Children's Emergency Fund
VALCO	-	Volta Aluminium Company
VRA	-	Volta River Authority
WRC	-	Water Resources Commission

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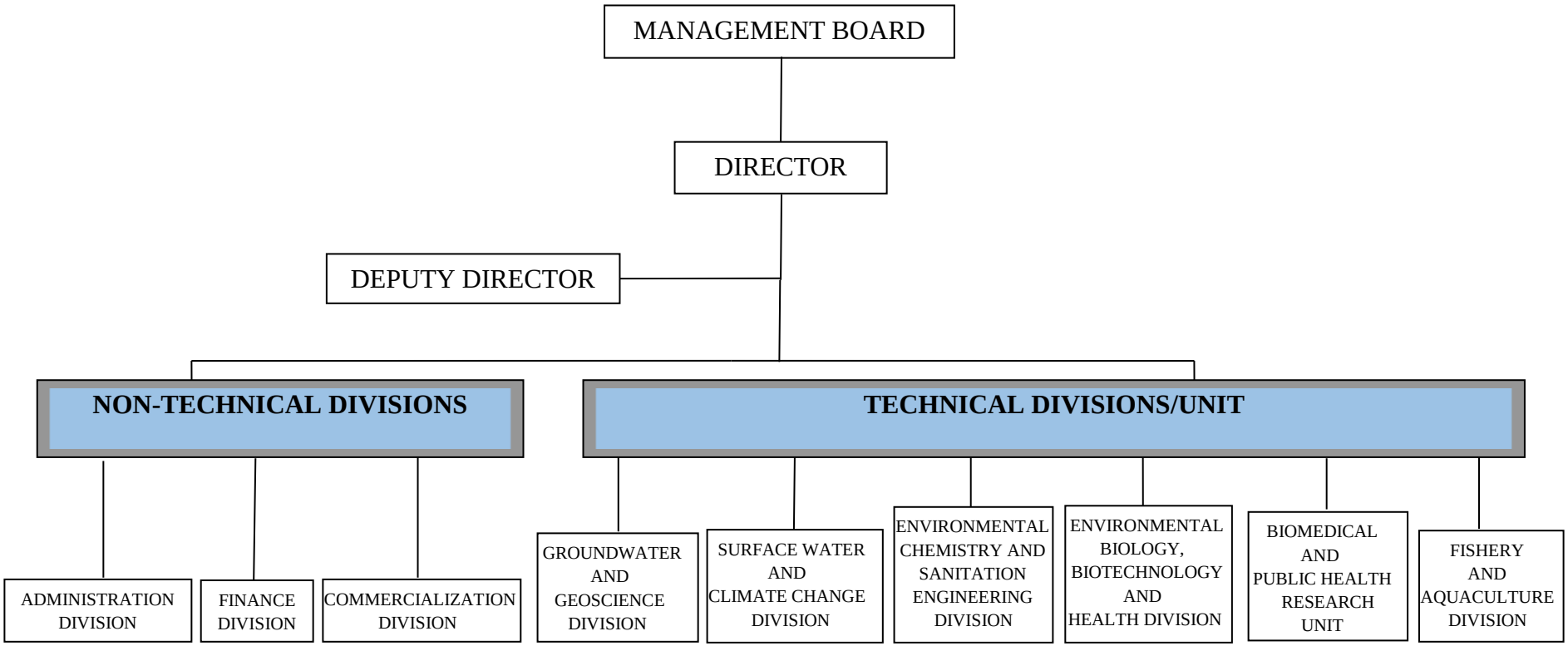
ORGANOGRAM


MANAGEMENT BOARD
DIRECTOR
DEPUTY DIRECTOR
NON-TECHNICAL DIVISIONS
TECHNICAL DIVISIONS/UNIT
ADMINISTRATION DIVISION
FINANCE DIVISION
COMMERCIALIZATION DIVISION
GROUNDWATER AND GEOSCIENCE DIVISION
SURFACE WATER AND CLIMATE CHANGE DIVISION
ENVIRONMENTAL CHEMISTRY AND SANITATION ENGINEERING DIVISION
ENVIRONMENTAL BIOLOGY, BIOTECHNOLOGY AND HEALTH DIVISION
BIOMEDICAL AND PUBLIC HEALTH RESEARCH UNIT
FISHERY AND AQUACULTURE DIVISION

FOREWORD BY THE DIRECTOR

Prof. Mike Yaw Osei-Atweneboana

It is with great pleasure that we present to you an overview of the Institute's Activities for 2022. The Council for Scientific and Industrial Research – Water Research Institute (CSIR-WRI) is mandated to conduct research into all aspects of water resources (both living and non-living) to provide scientific and technological information and services as well as strategies for the sustainable development, utilization, and management of such resources for the socio-economic advancement of the country.

The year 2022, brought into being the long-awaited Management Board. On 30th August 2022, the 6th Management Board of the Institute was inaugurated and sworn in. The Board had its maiden meeting, which was the 47th Management Board Meeting of the CSIR-WRI on the 6th and 7th of September 2022.

For the year under review, the Institute intensified its contribution towards socioeconomic development of the nation through the generation of demand-driven technologies and the provision of scientific and technological information and services in the areas of water and related resources. Most of our research and other activities were in the following thematic areas: Food Security and Poverty Reduction; Climate change; Environmental Management and Green Technology; and Biomedical and Public Health. Under these thematic areas, all research activities were directed toward achieving the key strategic thrusts of the Institute's strategic plan as well as the Sustainable Development Goals (SDGs), especially the SDG 6.

The year 2022, continued to be challenging amid the economic crises. We are grateful to Almighty God for helping us achieve our core mandate. Our strategic direction and operational plans during the year, have brought value to our research and development and innovative technology for our stakeholders and for national development. Our major achievements for the year included: improving productivity, profitability and sustainability of cage and pond tilapia farming in Ghana, with particular focus on women and youth small-scale farmers; exploring the potential of the NUF500 filtration device to filter viral pathogens of public health importance in surface and ground water sources; and driving eco-innovation through capacity building for a safe circular water economy.

All staff comprising Senior Members, Senior and Junior staff continued to support the Institute to achieve its mandate and goals with excellent values, professionalism and quality delivery of all our products and services all year round. The cooperation resulted in a peaceful conducive environment in the Institute; adherence to policies, procedures and statutory requirements; ensuring internal control system and good cooperate governance to achieve growth and development of the Institute.

In all, we realized that we would not have come this far without the support of our donors, development partners, sponsors and collaborators. We also appreciate all those who have in diverse ways contributed to our success.

We are grateful to the Management Board members who accepted to be part of our Team, the Internal Management Team, and the entire staff for their hard work and dedication. Together we have made great strides in 2022 and we are taking steps toward the realization of our vision of becoming a centre of excellence in the provision of scientific research into water and related resources as well as public health.

We hope to continue to work even harder and seize every opportunity presented to us to secure our successes.

EXECUTIVE SUMMARY

This report outlines research and development activities undertaken by the CSIR-Water Research Institute of the Council for Scientific and Industrial Research during the year 2022. The CSIR-Water Research Institute (CSIR-WRI) is one of the 13 institutes of the Council for Scientific and Industrial Research (CSIR). The core mandate of the Institute is to conduct research into all aspects of water resources (both living and non-living) in order to provide scientific and technical information and services as well as strategies for the sustainable development, utilization and management of such resources for the socio-economic advancement of the country.

The 2022 Annual Report comprises three (3) chapters, namely: Introduction, Administration, and Research and Development Activities. The Research and Development activities were compiled from research projects undertaken by the Institute and commercialization of research and development activities through consultancy and advisory services. The administrative report encompasses staff strength, appointments, promotion/upgrading, new recruitment, death as well as national service recruitment during the year 2022.

The Institute, in partnership with local and international collaborators, implemented a total of twenty-six (26) research projects during the year. These had been reported under the following thematic areas:

i. Food Security and Poverty Reduction (8 projects)
ii. Climate Change and Environmental Management (14 projects)
iii. Biomedical and Public Health (4 projects)

A total of forty-eight (48) journal papers, six (6) book chapters, nine (9) conference papers, and a number of technical reports, consultancy reports, policy brief and mass media publications were authored by scientists in collaboration with scholars worldwide. A number of media features were also undertaken during the year.

1.0 INTRODUCTION

1.1 Establishment

The Council for Scientific and Industrial Research – Water Research Institute (CSIR-WRI) is one of the thirteen (13) research institutes of the CSIR. It is a public institution established in 1996 from the merger of the former Institute of Aquatic Biology (IAB) and the Water Resources Research Institute (WRRI) which were established in 1965 and 1982, respectively.

1.2 Vision

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

1.3 Mission

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

1.4 Values

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

1.5 Key Objectives

The key objectives of the Institute are to:

i. generate, develop, and transfer appropriate technologies, information, and services for sustainable development, utilization, and management of surface water resources;
ii. 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;
iii. generate, process and disseminate water and wastewater quality information to end users;
iv. enhance public health status through sound environmental management and water pollution control strategies;
v. increase local fish production through participatory research and technology transfer in aquaculture and sustainable management strategies in inland and coastal waters of Ghana;
vi. develop technologies and strategies that significantly increase knowledge towards the control and elimination of communicable and non-communicable diseases

1.6 Divisions

The mandate of the Institute is realized through the research and development activities of five (5) Technical Divisions, one (1) Technical Unit and three (3) Non-technical Divisions. The Technical Divisions and Unit are:

- Environmental Biology, Biotechnology and Health
- Environmental Chemistry and Sanitation Engineering
- Fishery and Aquaculture
- Groundwater and Geoscience
- Surface Water and Climate Change
- Biomedical and Public Health Research Unit

The Non-Technical Divisions are:

- Administration
- Commercialization and Information
- Finance

1.6.1 Environmental Biology, Biotechnology and Health Division (EBBHD)

The main objective of the Environmental Biology, Biotechnology and Health Division is to enhance public health status of Ghanaians through sound environmental management, water pollution control strategies, and preventive and control strategies for water-borne and other infectious diseases. The Division makes use of unicellular organisms and their products to control diseases and produce environmentally friendly by-products for socio-economic advancement of the country. The Division has expertise in the areas of Microbiology, Parasitology, Entomology, Aquatic flora and fauna, Molecular Biology and Public Health.

Activities of the Division include:

- Water quality monitoring through microbial, algal, and macro-invertebrate analyses;
- Microbiological analyses of drinking water, wastewater, and other samples;
- Identification and management of invasive plants in Ghana;
- Isolation and production of entomopathogenic bacteria used in biological control of disease vectors;
- Environmental impact assessment and watershed management;
- Research into water-related/borne parasitic diseases and other infectious diseases;
- Research into water-related vectors of diseases of public health importance to develop innovative strategies for control and prevention;
- Molecular epidemiological studies of parasites and other related diseases;
- Understanding the mechanism and genetics of drug resistance and the development of DNA-based diagnostic tools;
- Isolation, cultivation, and commercialization of Ghanaian microalgae species;
- Large-scale cultivation of microalgae cultures for industrial applications;
- Sale of microalgae growth media;
- Pilot-scale trial of seaweed cultivation for technology transfer;
- Public and environmental health education;
- Consultancy in the establishment of science and medical laboratories; and
- Training of scientists, technologists and technicians.

1.6.2 Environmental Chemistry and Sanitation Engineering Division (ECSED)

The long-term objective of the Environmental Chemistry and Sanitation Engineering 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 environmental impact and health risks;
- Collect, process and disseminate comprehensive high quality and reliable environmental data on surface and groundwater with regard to their chemical constituents, and their human and ecological health risks; and
- Monitor pollution in coastal waters and lagoons in Ghana.

Currently, the major research programs of the Division are:

- Monitoring of water quality and their associated health risks;
- Domestic and industrial wastewater studies;
- Environmental impact assessment studies; and
- Development of strategies for water pollution control.

1.6.3 Fishery and Aquaculture Division (FAD)

The mandate of the Fishery and Aquaculture Division is to generate scientific information to potentially 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 the development of sustainable aquaculture and culture-based fisheries practices.

Currently, the Division's major Research and Development programmes are in the areas of Aquaculture Development, Environmental Impact Assessment and monitoring of fish populations in relation to socio-economic development activities, fisheries enhancement and cultured fisheries.

1.6.4 Groundwater and Geoscience Division (GWGD)

The Groundwater and Geoscience Division (GWGD) generates, processes and disseminates information on groundwater availability, sustainability and its suitability to meet the demand for consumptive and non-consumptive use today and in the future; promotes integrated groundwater resources management; and undertakes geotechnical applications for socio-economic development.

The Division primarily conducts research on Ghana's and Sub-Saharan Africa's groundwater resources for government, non-governmental organizations and the general public, focusing on the following, among other things:

- Hydrogeological and geophysical investigations
- Groundwater monitoring and technical services
- Groundwater flow and contaminant transport modeling
- Hydrochemical modelling

1.6.5 Surface Water and Climate Change Division (SWCCD)

The mandate of the Surface Water and Climate Change 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 scope of work of the Division includes:

- Design, installation and monitoring of climate and river/stream discharges for research and decision support;
- Development of climate products, information and scenarios for assessment of surface water resources;
- Mapping and assessment of land-cover dynamics of the country;
- Assessment of surface water resources of the country, including impacts of climate and land-cover changes on the resources;
- Assessment of sediment transport by streams/rivers and discharges into reservoirs and other surface water bodies;
- Mapping and assessment of water-related ecosystem services;
- Development and adaptation of appropriate technologies and water conservation techniques for water supply to households, communities, farms and industries; and

- Assessment and development of climate change adaptation and mitigation strategies.

1.6.6 Biomedical and Public Health Research Unit (BPHRU)

The main objective of the Biomedical and Public Health Research Unit is to conduct bio-medical research into communicable and non-communicable diseases and to develop technologies and strategies towards the control and elimination of various diseases. Core diseases of interest include:

- Onchocerciasis
- Schistosomiasis
- Soil Transmitted Helminthes
- Elephantiasis
- Malaria
- Fish diseases
- Covid 19

Upcoming diseases of interest include:

- Cancer
- Buruli ulcer
- Diabetes
- Hypertension

1.7 Branches and Contacts

- Main office is in Accra, in the Greater Accra Region;
- Branch office in Tamale, in the Northern Region; and
- Aquaculture Research and Development Centre (ARDEC), at Akosombo in the Eastern Region.

The locations of the branches of CSIR-Water Research Institute at different parts of the country are shown in Fig 1.1.

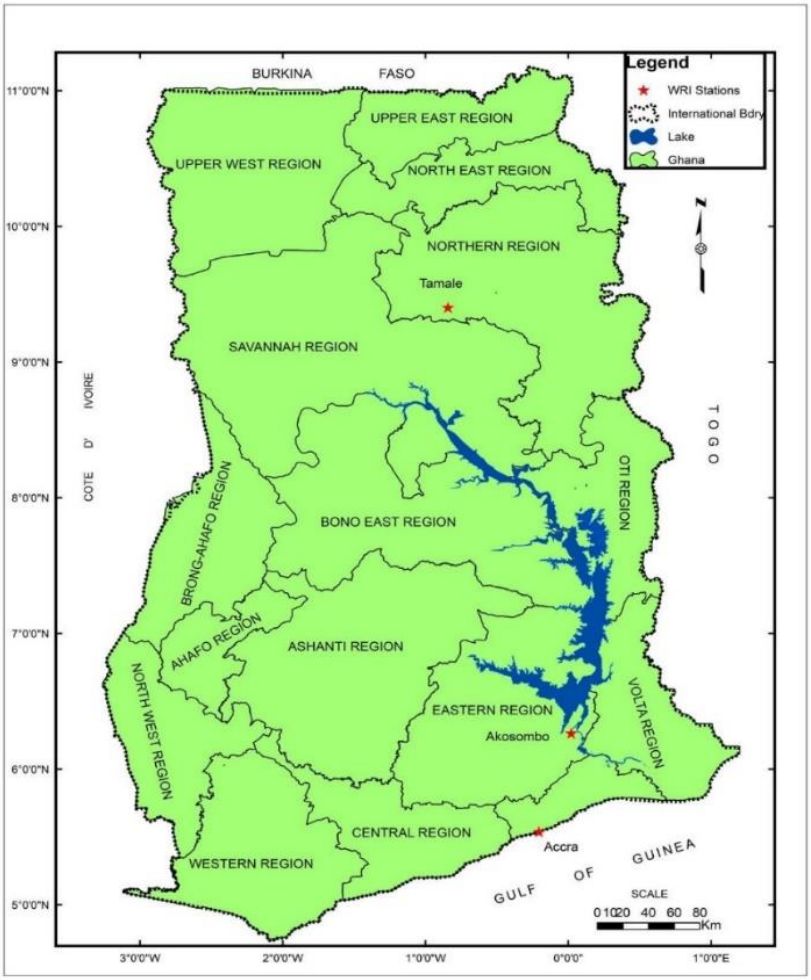


Fig. 1.1: Map of Ghana showing locations of the branches of CSIR-Water Research Institute

We shall be grateful to receive comments and suggestions on any aspects of our activities or report. The contact addresses are:

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Website	**:**	**www.wri.csir.org.gh**
GPS Address	**:**	**GA -018-9651**

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Achimota-Ghana

or

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

2.0 ADMINISTRATION

2.1 Management

On Wednesday 31st August, 2022 in the Institute's Staff Conference Room, a newly constituted 47th Management Board was inaugurated to see to the affairs of the Institute. The Board Chairman was Mr. Anthony Boateng. Other members were Professor Mike Yaw Osei-Atweneboana, Dr. Worlanyo Kwadjo Siabi, Mr. Magnus Nunoo, Mrs. Genevieve Nyameke-Mano Yankey and Mr. Samuel Kwadjo Agyapong Appenteng (Fig 2.1). The Board, assisted by the Internal Management Committee (IMC), ensured that policies, regulations and rules of the council were implemented at the Institute. Some decisions to ensure smooth running of the Institute were also taken at IMC meetings. Membership of the IMC is shown in Appendix I.

Fig 2.1: CSIR-WRI Management Board members (from the left are Mr. Magnus Nunoo, Professor Mike Yaw Osei-Atweneboana, Mrs. Genevieve Nyameke-Mano Yankey, Mr. Anthony Boateng, Mr. Worlanyo Kwadjo Siabi, Mr. Samuel Appenteng and Dr. Daniel Asenso-Gyambibi)

2.2 Staff Strength

Staff strength at the end of the year 2022 stood at 251. This was made up of 102 Senior Members, 102 Senior Staff and 47 Junior Staff. The list of Senior Members and Senior Staff and staff distribution are presented in Appendix II.

2.3 Statistics on Human Resource Activities

The number of appointments, promotions/upgrading, transfer, compulsory retirement, resignation and death are shown in Appendix III.

2.4 Human Resources Development

In conformity with the policy of CSIR to provide relevant staff training, members of staff were given the opportunity to acquire the necessary skills and knowledge through local and international training for the enhancement of their performance in the Institute. The details are presented in Appendix IV.

Members of staff also participated in short-term training programmes such as the following:

- Hands-On Training of 378 farmers on small-scale Nile Tilapia pond/cage farming in six regions of Ghana (Eastern, Volta, Ashanti, Bono, Bono East, and Ahafo)
- Online Certificate course, Part 1, on 'Introduction to Ecosystem Restoration' organized by 'Learning for Nature'
- USSEC's Cage Aquaculture Production Practices - SEC Training Program in Cooperation with WorldFish - Egypt Wednesday, July 20th, 2022
- USSEC's Shrimp Production and Management - SEC Training Program in Cooperation with WorldFish - Egypt Wednesday, September 14th, 2022
- AquaTrans virtual training series on success stories in Southern African aquaculture, 15th Nov. – 1st December 2022

2.5 Participation in National and International Scientific Meetings

During the year, several Research and Technical staff participated in workshops, seminars and conferences held at regional, national and international levels. These offered staff the opportunities to acquire the necessary skills and knowledge through local and international training to enhance their performance. The workshops, seminars and conferences included the following:

- EMPOWER Project workshop 1 & 2: 'Mapping Threats and interventions to Climate Change in the Lower Volta Basin', 12 January & 9th February 2022, Sogakope, Volta Region; organized by the EMPOWER project.
- Workshop on "FutureDAMS Knowledge Exchange Workshop - Benefit Sharing in Dam Development: Principles, Experience & Lessons", organized by the CSIR-WRI, on 8 February 2022 at the Golden Tulip Hotel, Accra.
- National Technical Workshop on Nature Based Solutions Capacity Building and Development on National and Basin-Wide Projects, organized by the Water Resources Commission, between 15 - 17 February 2022 at Coconut Groove Regency Hotel, Accra.
- Final meeting for the RECIRCULATE Project (Driving eco-innovation in Africa: Capacity Building for a Safe Circular Water Economy). LANCASTER UNIVERSITY (UK) Marriott Hotel, Airport, Accra. 16th -17th March 2022.
- Workshop on Developing a Business Model for Water–Smart Solutions under the Wider Uptake project, CSIR – STEPRI. 22nd March 2022
- Training on Whole Genome Sequencing and Surveillance of Antimicrobial Resistance in Bacteria. Noguchi Memorial Institute for Medical Research. 6-10th June 2022
- A 2-day Effective Herbal product formulations and standardization Workshop organized by CSIR-WRI together with Herbal Training Institute from 17th to 18th June 2022 at CSIR-WRI conference room, Accra.
- 'National launch of Ghana's 2022 voluntary national review (VNR) report' held at the Accra International Conference Centre on Friday 15th August 2022.
- Antimicrobial resistance (AMR) crisis in Ghana- Experience from the WHO Global Tricycle Survey in Ghana: What are the avenues for policy action. A Tricycle Policy Brief Launch. AH Hotel and Conferencing, East Legon, Accra 15th November 2022.
- Financing Climate Resilient Infrastructure in Ghana – Ministerial Dialogue and Report Launch, 24th March 2022, at Accra City Hotel
- FutureDAMS Project Wrap-up Meeting for Ghana/Volta River Basin Case Study, organized by CSIR-WRI on 24 March 2022 at the Golden Tulip Hotel, Accra.

- Aquaculture Health Program and Vertinary Molecular Diagnostics and Vaccine Program at CSIR-WRI, 11th March, 2022.
- First Training of National Stakeholder under the Special Programme Project to Strengthen Institutional Capacity for the Sound Management of Chemicals and Waste in Ghana, on 10th March 2022 at the Alisa Hotel, Accra.
- Dissemination workshop on fluoride contamination of groundwater resources in Ghana, Organized by CSIR-Water Research Institute in Tamale, April 2022
- Water Resources Commission's Stakeholder Workshop on "Integrating Flood and Drought Management and Early Warning for Climate Change Adaptation in the Volta Basin (VFDM)" Project, 4th-6th April 2022, at Coconut Grove Regency Hotel, Accra.
- Technical meeting on the 'Volta Basin Climate Investment Plan', 4-7 May 2022, Ouagadougou, Burkina Faso; organized by the Volta Basin Authority.
- Ghana-World Bank 2nd Mission on Natural Capital Accounting (NCA), 13th -17th June 2022, at the Environmental Protection Agency (EPA), Ghana Statistical Service (GSS), and the Ministry of Environment, Science, Technology, and Innovation (MESTI).
- Symposium on "Generating Energy from Waste: The Experience of Ghana" at CSIR-WRI, 23rd June 2022.
- Healthy Food Africa Consortium Meeting in Lusaka, Zambia, 14-15th June 2022
- Project Launch: Transforming Institution to Advance women leaders in Science Technology Engineering and Mathematics, Organized by Institute for Environment and Sanitation Studies, Univ. of Ghana, Legon, August 2022
- Stakeholders meeting at Janga II Project Site, Organized by Savanna Agriculture Productivity Improvement Project (SAPIP), Tamale, August 2022
- Stakeholders' meeting for developing a Business case for the Tamale Water Fund, Organized by Catholic Relief Service, Tamale, September 2022
- Closing Workshop: The Tilapia Seed Project and the launch of Fish Farm Tracker App., Accra, 19th September 2022
- AQUAHEM project stakeholders' engagement; and international seminar on tilapia health Ghana Water Quality Study Phase II Stakeholder Workshop by the Ministry of Sanitation and Water Resources, held on 7th September 2022 at the Best Western Premier Hotel, Accra.
- Validation meeting on "Climate and Vulnerability Assessment for the Health Sector in Ghana", 4th & 5th October 2022, World Bank Ghana Country Offices; organized by the School of Public Health-University of Ghana/World Bank Group.
- International Technical Seminar on Tilapia Health, held by the Food and Agricultural Organization (FAO) of United nations (UN) in collaboration with Fisheries Commission, Ghana, at Volta Hotel Akosombo, 18th November, 2022.
- Funding Programme for Research and Development projects among Spanish and Ghanaian entities organized by the Economic and Commercial Office (Embassy of Spain), Accra, on 18th October, 2022
- Workshop on "Bridging the Gap: Science for the Public – Climate Change, 31 October - 3 November 2022, Arusha, Tanzania; organized by DANIDA Fellowship Centre.
- Technical workings session on "Enhancing e-agriculture structures and mechanisms for extension, surveillance and early warnings *(*Agriculture Early Warning System (AgriEWS)*"* 17th – 21st November 2022, Koforidua; organized by FAO/MoFA/ NADMO.

- Stakeholder Validation Workshop on the Market Assessment of Electrical and Electronic Equipment Waste Containing Mercury in Ghana on 21st January 2022 held at Alisa Hotel, Accra.
- National Technical Workshop on Nature Based Solutions Capacity Building and Development on National and Basin-Wide Projects, organized by the Water Resources Commission, on 15 - 17 February 2022 held at Coconut Groove Regency Hotel, Accra.
- Symposium titled 'Connecting the unconnected: Informal toilets and a safe circular water economy' from 28th to 29th March 2022 at Lancaster, UK. A paper was presented on "Drinking Water Quality from Two Urban Slums in Accra, Ghana: The Concept of the Last 100 Metres".
- African Risk Capacity (ARC) Drought Technical Working Group Meeting, 21-25 March 2022, Accra. Meeting organized by the National Disaster Management Organization.
- Capacity Development Programme on "Earth Observations for Water Resources Assessment and Monitoring" organized by EOAFRICA RDF, held at Erata Hotel, Accra, May 15 – 19, 2022
- Fourth General Assembly and Bi-Annual Meeting of the Africa Platform for African Union Interafrican Bureau for Animal Resources Consultative meeting to support African member states involvement and compliance with Fisheries and Aquaculture Global Instruments and promote their use. Dares Salam, Tanzania 28th to 30th March 2022.
- 3rd AfriCultureS User Workshop, 23rd March 2022, at Accra City Hotel. 'Enhancing Food Security in African AgriCultural Systems with the support of Remote Sensing Project' (AfriCultuReS) is a European Commission-funded Horizon 2020 project.
- Regional Institutions in Fisheries, Aquaculture and Aquatic Systems (Afripaas), Marrakesh Morocco. 18th to 22nd April 2022.
- WORKSHOP – AQUAHEM PROJECT: "Capacity Building in Aquatic and Environmental Health in West Africa", held at the Mensvic Grand Hotel in East Legon, Accra on April 26, 2022, Organized by the African Union Commission.
- CREAM Project- co-development/validation of Shared Socioeconomic Pathways for Pra and Densu River Basins, 11-15 July 2022, Kumasi & Koforidua; organized by CSIR-WRI.
- Future Africa Research Leader Fellowship (FAR-LeaF) Workshop on Transdisciplinary Research, held on 08-12 August 2022 at the Future Africa Campus in Pretoria, South Africa.
- National consultation workshop on "Establishment of the Hydrological Status and Outlook System in Ghana", 5th & 6th October 2022, Tomreik Hotel, Accra; organized by Ghana Meteorological Agency in collaboration with Water Resources Commission, UK Centre for Ecology and Hydrology and the World Meteorological Organization.
- Workshop on Upscaling private sector participation and science-based outreach in West Africa. 22nd -23rd June, 2022, Accra.
- "Aquaculture Ghana" Event by the Chamber of Aquaculture Ghana. 6th August, 2022, World Trade Center-Accra.
- First Technical Committee meeting of the Conserving Aquatic Biodiversity in African Blue Economy Project, Mombasa, Kenya. 20th- 21st September 2022.
- African Union Interafrican Bureau for Animal Resources Expert Consultative Workshop to Identify Priority Issues and Actions for Enhancing the Role of Women

in Aquatic Biodiversity and Environmental Management in Africa. Naivasha, Kenya 5th - 7th October 2022.

2.6 Employee Relations

2.6.1 Long Service Recognition

The 2022 Long Service Awards took place during an end-of-year party on 19th December, 2022. The retired staff honoured for their contributions to the Institute are shown in Table 2.1.

Table 2.1: Long Service Recognition in 2022

No.	Name(s)	Years Served
1.	Mr. Justus Teye	38 years
2.	Mr. Bernard L. Lartey	36 years
3.	Mrs. Agnes A. Darko	36 years
4.	Mr. Mattew Kwara	33 years
5.	Ms. Grace Dartey	32 years
6.	Dr. Isaac O. A. Hodgson	32 years
7.	Dr. Anthony A. Duah	31 years
8.	Dr. Emmanuel Obeng Bekoe	31 years
9.	Dr. Francis Y. K. Amevenku	30 years
10.	Mr. Sampson K. Boateng	30 years
11.	Mrs. Eva G. Agbozo	29 years
12.	Mr. Kingsley Okyere	15 years
13.	Mr. Carl Ofori Agyemang	10 years

2.7 National Service and Industrial Attachment

The Institute continued to support tertiary institutions towards the training of students as part of its corporate social responsibility and national capacity building activities. The duration of the training program for National Service Personnel was eleven (11) months while that of Industrial Attachment Personnel was between four (4) to twelve (12) weeks. The details are presented in Appendix V.

2.8 Industrial Visits to the Institute

The Parliamentary Select Committee on Environment, Science, Technology, and Innovation (MESTI) paid a one-day working visit to the Institute on Friday, 5th August 2022.

2.9 Membership of Committees and Boards

Staff continued to serve on various Committees and Boards such as:

- Technical Working Group to Develop a National Public Health Laboratory System Policy and Mandate for Ghana
- Africa Region, Regional Advisory Committee
- African Risk Capacity (ARC) Drought Technical Working Group
- African Risk Capacity (ARC) flood Technical Working Group
- Committee on CSIR Staff Allowances
- Consultative Group Committee of RSA of Ghana
- Council for Scientific and Industrial Research (CSIR), Council
- Council of Ghana Institution of Geoscientists
- CSIR Provident Fund Management Committee
- CSIR Research Staff Association (CSIR-RSA)
- CSIR - Water Research Institute Awards Committee
- CSIR - Water Research Institute Editorial Committee
- CSIR - Water Research Institute Estate Committee
- CSIR - Water Research Institute Housing and Office Allocation Committee

- CSIR - Water Research Institute Intellectual Property Right Committee
- CSIR - Water Research Institute Internal Management Committee
- CSIR - Water Research Institute Staff Welfare Management Committee
- CSIR - Water Research Institute Transport Committee
- CSIR - WRI Internally-Generated Fund (IGF) Committee
- CSIR - WRI Strategic Planning Committee
- CSIR - WRI Training Committee
- Editorial Board Member of the RSA-Southern Zone, for 2021-2022
- Editorial Board Member of the RSA-Southern Zone, for the 2021-2022 RSA year.
- Entity Tender Committee of the Ghana Geological Survey Authority
- Ghana Committee for UNESCO Intergovernmental Hydrological Programme (IHP)
- Ghana Forum for Agriculture Advisory Service and Support (GFAASS)
- Ghana National Screening Committee for DANIDA Grants
- Ghana Natural Capital Accounting (NCA) Ecosystem Services Technical Sub-Working Group (The Ghana-World Bank Natural Capital Accounting Program)
- Ghana Science Association
- Investment Advisory Committee (IAC) of the CSIR Provident Fund
- Lower Volta Basin Board
- Management Board of CSIR Mineral Water Company
- National AMR technical committee for Environment
- National Coordinating Committee on Drinking Water Quality Management
- Project Steering Committee of the Special programmes, Environmental Protection Agency (EPA)
- Research Staff Association of Ghana National Executive Committee
- Research, Extension Farmer Linkage Committee (RELC), NR-Tamale
- Research, Extension Farmer Linkage Committee (RELC), UER-Bolgatanga
- Research, Extension Farmer Linkage Committee (RELC), UWR-Wa
- Steering Committee of the GNPC Petroleum Geoscience
- Steering Committee on IWAVE Methodology in Water Resources Management in Ghana
- Sub-Committee of the CSIR @ 60 Anniversary Planning Committee on Scientific Symposium
- Technical Committee on Environmental Protection Standards on Effluent Quality
- Technical Committee of Intergovernmental Oceanographic Commission, UNESCO
- World Aquaculture Society- African Chapter, West Africa Region, Regional Advisory Committee
- Hazardous Chemicals Committee of the 6th Governing Board of Environmental Protection Agency - Ghana
- Project Committee for Household Water Treatment (HWT) Products

2.10 Staff Publications

Several members of staff produced journal papers, conference papers, technical and non-technical reports during the reporting year. Most of these reports/papers have been placed at the Institute's Library as reference materials. The details are shown in Appendix VI.

2.11 Internal Seminar and Workshop Programmes in 2022

Internal Seminar

The Institute held a seminar dubbed "Life after school: Championing science/chemistry-related careers" on the 15th - 16th September, 2022, at the CSIR-STEPRI conference room, Accra, to provide academic mentorship and career support for Senior High Secondary (SHS) School students towards identifying and developing fulfilling careers and academic opportunities. The event was well attended by students from selected secondary schools such as Saint Mary's, Accra High, Accra Girls, Accra Academy, Achimota and Legon Presbyterian Boys (Fig 2.2). The Seminar was funded by the Royal Society of Chemistry, United Kingdom.

Fig 2.2: Some SHS students who attended the internal seminar

TiSeed Closing Workshop

The Tilapia seed (TiSeed) project, began in February 2019, and was implemented by a consortium of international and local research institutes, led by International Food Policy Research Institute (IFPRI) and supported by CSIR-Water Research Institute – Ghana, KIT Royal Tropical Institute – Netherlands, and WorldFish – Malaysia. Other partners were the Fisheries Commission of Ghana and two private hatcheries (S-Hoint Ltd. and Crystal Lake Fish Farm Ltd.). TiSeed project was originally a 3-year project (February 2019 – January 2022), but was extended to September 2022 due to the impact of covid-19. The project ended with a closing workshop (Fig 2.3) organised on 19th September 2022 at Erata Hotel, Accra.

Fig 2.3: TiSeed Project Closing Workshop

2.12 Consultancy and Advisory Services

The Institute carried out several consultancy and advisory services for various donor agencies, corporate bodies, governmental and non-governmental organizations, universities and technical universities, public and private sector organizations as well as individuals. The consultancy and advisory services included the following:

- Evaluation of commercial tilapia starter feeds on the Ghanaian market
- Production and supply of tilapia fingerlings
- Assessment of waterbodies for cage fish farming

- Advisory services to Youth Entrepreneurs from Mamfe Yensuso in the Eastern Region
- Maintenance of reverse-osmosis treatment system for Bank of Ghana at Middle Income Group Housing (MIGHE) for Junior Staff located at Mataheko and Cedi House Office in Accra
- Installation of reverse-osmosis system at Bank of Ghana's Deputy Governor's residence at Osu
- Advisory services on groundwater exploration, borehole drilling, aquifer evaluation, pump, and water treatment installations
- Effluent quality assessment of the wastewater treatment plant for Phyto-Riker (GIHOC) Pharmaceuticals
- Effluent quality assessment of the wastewater treatment plant for Accra Brewery Limited
- Effluent quality assessment of the wastewater treatment plant for Accra Shopping Mall
- Effluent quality assessment of the wastewater treatment plant for Standard Chartered New Office Building
- Water quality monitoring and assurance for the Bolgatanga-Bawku-Polmekom Road Project by QGMI Construction UK, Limited
- Assessment of effluent quality for West Hills Mall Limited
- Assessment of effluent and drinking water quality for Nexans Kabelmetal Ghana Limited
- Quarterly assessment of water and sludge samples for West African Fish Ltd., Asikuma
- Monthly assessment of effluent quality for Tema Lube Oil Co. Ltd.
- Monthly assessment of effluent quality for China Harbour Engineering Company (Ghana) Limited at Tema
- Quarterly assessment of effluent quality for Movenpick Ambassador Hotel, Accra
- Assessment of wastewater quality for Environmental Services Limited
- Advisory services on avoidance of microbial contamination of water sources (Client: Sachet water producers)
- Water quality analysis (Client: Sachet water producers)
- Borehole water quality analysis (Client: Geocoast Eng. etc)
- Drinking water quality assessment of water treatment system at VALCO Company Limited, Tema
- Physico-chemical and bacteriological quality of boreholes and tap water from selected communities at Oyibi in the Damgbe West District
- The use of *Sargassum* seaweed for animal feed and fertilizer for Opportunities Industrialization Center (OIC)
- Public Utility Regulatory Authority (PURC) consultancy project on independent sampling and testing of GWCL distribution network in four (4) regions (Ashanti, Western, Eastern and Greater Accra)
- Routine monitoring of West Africa Fish River water and sediment samples

2.13 Capacity Building/Human Resource Development

2.13.1 Training

The Institute, through the research and technical staff in the various Technical Divisions/Unit, offered training in various forms to individuals, groups, Non-

governmental Organizations, and students of the Universities and Technical Universities.

2.13.2 Contribution to Training Programmes

- Examination of PhD Thesis from the Department of Civil and Environmental Engineering, School of Engineering, University of Energy and Natural Resources (UNER). Topic: Application of Geospatial and Bayesian Isotope Mixing Model to Assess Groundwater Pollution Around the Granvillebrook and Kingtom Dumpsites, Freetown, Sierra Leone.

2.13.3 Supervision and Co-Supervision of Masters and PhD Thesis

- Co-Supervision: Antibiotic profiling of gram positive and gram-negative bacteria isolates from Nile tilapia (*Oreochromis niloticus*). BSc. Dissertation (2022), KNUST, Kumasi, Ghana, 64pp.
- Co-supervision of a Final Year (PhD Microbiology) student at the Department of Theoretical and Applied Biology of Kwame Nkrumah University of Science and Technology, Kumasi.

2.14 Review of Manuscripts/Journals

- Review of the manuscript - Synthesis and photocatalytic degradation of dyes using δ-MnO2 nanostructures - submitted to Journal of Chemical Data Collections, Feb 2022
- Review of the manuscript - Biosynthesis of new green ZnO nano photocatalyst and use for the photocatalytic degradation of methylene blue dyestuff - submitted to the Journal of Dispersion Science and Technology, Feb 2022
- Review of the manuscript - RSM-BBD optimization approach for degradation and electrochemical sensing of Evan's blue dye using green synthesised ZrO2–ZnO nanocomposite - submitted to Journal of Inorganic and Nano-Metal Chemistry, March 2022
- Review of the manuscript - Photocatalytic activity of poly (methyl methacrylate) microcapsules coated with ZnO and TiO2 by ALD for water purification - submitted to the Journal of ACS Applied Materials & Interfaces, July 2022
- Review of the manuscript- NaBr-assisted aqueous synthesis of Perovskite-embedded PbBr(OH) hierarchical structures with ultra-stability and application in dyes photodegradation - submitted to the Journal of ACS Applied Nano Materials, Dec 2022
- Review of the manuscript - The spatial and temporal variation of diversity seaweed (rhodophyceae, Chlorophyceae, and phaeophyceae) in the Marchica Lagoon (North-East Morocco) - submitted to the International Journal of Marine Science (Springer)

3.0 RESEARCH AND DEVELOPMENT ACTIVITIES

3.1 FOOD SECURITY AND POVERTY REDUCTION

3. 1.1 FISHERIES AND AQUACULTURE

3.1.1.1 Breeding and Water Quality Assessment for Reproduction of African Bonytongue Fish, Heterotis niloticus, for Sustainable Culture in Earthen Ponds

(Research Team: Etornyo Agbeko – Principal Investigator, Dr. Francis Anani; Mrs. Patience D.K. Atsakpo; Dr. Kaboja Magna; Dr. Patrick Fiatsi; Mr. Eric Kretsi; Mrs. Mercy Johnson Ashun; Mrs. Lily Osei Konadu; Mr. Samuel Birikorang; Mr. Kelvin Donkor; Mr. Felix Ayarika; Mr. Evans Danquah)

Introduction

The African bonytongue (*Heterotis niloticus)* has high commercial value in African freshwater fisheries. It is one of the largest omnivorous benthic fish species in African fresh aquatic ecosystems. The African bonytongue possesses good growth rate and sizes range from 2500-6000 g in most fisheries. It has comparatively similar flesh qualities like tilapia (i.e. white muscles, high protein levels, lean fat and great taste). However, there is paucity of information on culturing and breeding of *H. niloticus* despite its being exploited for several decades.

Objective

The objective of the study was to investigate reproductive ecology and water quality characteristics for survival, growth and spawning of *H. niloticus* for its sustainable commercial production in earthen ponds.

Activities undertaken

In the reporting year, a total of 60 individual *H. niloticus* brood stocks of mean standard length and mean weight 50.0 ± 1.4 cm and 1152.0 ± 150.0 g, respectively, were randomly selected. Twenty (20) paired brood stocks comprising 10 males and 10 females were distributed into three (3) compartments in triplicates and denoted A, B and C. Reproduction characteristics were observed daily and biodata sampling was based on the number of nests, nest diameter, nest depth, status of egg, fry production and survival rate. Water quality parameters were monitored every two weeks based on standard analytical methods.

Key results achieved so far

The results indicated that the water quality was suitable for culturing *H. niloticus* (Table 3.1.1). Acidic (pH < 5.5) condition and dissolved oxygen concentrations (DO < 4 mg L^{-1}) inhibited spawning, although it could survive in DO less than 2 mg L^{-1}. The fish is an efficient bottom trophic feeder and it has high tolerance for temperature fluctuations. Increase in water level served as stimuli for reproductive activities to occur and the quality of water determined the timing of spawning.

Table 3.1.1: Water quality parameters for African bonytongue production during the study

Parameter	Mean (Min-Max)
Water depth (m)	0.83 (0.5 – 1.4)
pH	(5.91 - 6.40)
Temperature (°C)	30.59 (26.70 - 31.00)
Dissolved Oxygen (mg L^{-1})	4.13 (1.9 - 5.23)
Turbidity (NTU)	14.32 (13.67 -15.23)
Conductivity (µS cm^{-1})	135.60 (44.90 - 152.67)
Total Dissolved Solids (mg L^{-1})	112.45 (43.50 - 119.33)
Ammonium-Nitrogen (mg L^{-1})	0.60 (0.32 - 1.48)
Nitrite-Nitrogen (mg L^{-1})	0.001 (0.001 - 0.001)
Nitrate-Nitrogen (mg L^{-1})	0.005 (0.001 - 0.019)
Phosphate-Phosphorus (mg L^{-1})	0.12 (0.04 - 0.27)
Total Alkalinity (mg L^{-1})	42.51 (41.00 - 53.50)
Total Hardness (mg L^{-1})	48.60 (40.00 - 64.00)
Salinity (ppt)	0.06 (0.05 – 0.007)

Conclusion

It was concluded that the African bonytongue brood stocks exhibit slow growth when water quality deteriorates and there is inadequate vegetative cover along the riparian zone. The results corroborated other research findings that indicated that reproduction slows down and may be halted by fish size (weight), age and water quality.

Recommendation

At the end of the study, it was recommended that there is the need to source for good *H. niloticus* brood stocks from the wild and other farms to augment and/or replace those of the aged ones at ARDEC.

Impact of the study on the national economy

Mass breeding and commercial production of *H. niloticus* could serve as an alternative to Nile tilapia. This would make the aquaculture industry more resilient as additional and/or alternative revenue could be generated from the sales of this fish, thus opportunities for wider choices for fish production investments.

3.1.1.2 On-Station Evaluation of Different Tilapia Starter Feeds for Nile Tilapia, *Oreochromis niloticus* Fingerlings Production

(Research Team: Francis A. Anani – Principal Investigator, Etornyo Agbeko, Felix Ayarika, Kelvin Donkor, Patience D.K. Atsakpo, Mercy Johnson-Ashun, Lilly Ofori-Boateng, Evans Danquah and Eric Kretsi)

Introduction

Crude protein (CP) contents of most commercial tilapia starter feeds on the Ghanaian market are higher than 40% and their prices per kilogram being over 20.0 GHS/kg. The brand of feed used to produce tilapia fingerlings is influenced by cost, availability and fish growth performance. Hence, there was need to investigate the growth performance and cost-effectiveness of producing Nile tilapia fingerlings using different brands of commercial tilapia

starter feed currently available on the Ghanaian market so as to establish the most economic one.

Objective

The objective of the study was to investigate growth performance and cost-effectiveness of using different tilapia starter feeds to produce Nile tilapia fingerlings.

Activities undertaken

During the reporting period, the following activities were undertaken:

i. Fifteen (15) fine mesh netting hapas, each of dimensions 5.0 x 2.0 x 1.2 m (8.0 m^3 effective volume), and a stocking density of 500 fry $hapa^{-1}$ were used;
ii. Feeding trial was carried out on post-treated (mono-sex male tilapia) fry of initial mean weight of 0.06 ± 0.01 g;
iii. Five (5) tilapia starter feeds, namely *Aller Aqua*, *ARDECFeed*, *Koudijs*, *Naam Papa* and *Raanan*, randomnly coded *A*, *B*, *C*, *D* and *E* were tested on the tilapia fry;
iv. Two (2) replicates of the experimental set-ups were employed for each treatment;
v. Water quality parameters (ammonia, nitrate, nitrite, dissolved oxygen, temperature, pH and phosphate), fish survival and growth in all the feed treatments were monitored weekly.

Key results achieved so far

The following results were obtained from the study:

i. The costs per kilogram (kg) of the 5 feeds ranged from 6.24 to 19.90 Ghana cedis, with feed *D* being the least expensive whilst *B* was the most expensive;
ii. Nile tilapia fry fed with the various feed types attained final mean weight ranging from 17.34 to 23.62 g, with feed *B* being significantly higher ((Tukey's HSDT, $P < 0.05$);
iii. Water quality parameters recorded at the inlets and outlets of the ponds as well as within the experimental hapas of each feed type were similar and they fell within the following ranges: temperature, 29.5-33.7 °C; pH, 6.6-8.8; dissolved oxygen, 4.0–9.1 mg L^{-1}; turbidity, 19.1-84.5 NTU; conductivity, 45-83 µS cm^{-1}; ammonium-nitrogen, 0.118-0.473 mg L^{-1}; nitrite-nitrogen, < 0.001-0.027 mg L^{-1}; nitrate-nitrogen, < 0.001-0.363 mg L^{-1}; phosphate-phosphorus, 0.002-0.373 mg L^{-1}; total alkalinity, 12.5-45.5 mg L^{-1} and total hardness, 15.0-mg L^{-1}; and
iv. The cost analyses showed that it was least expensive (GHS 6.83) to use *D* to produce a kg of tilapia fingerlings whilst the most expensive (GHS 24.18) was B.

Conclusion

It was concluded from the study that growth performance indicators (final mean weights, specific growth rates, daily weight gains, feed conversion ratios and survivals) in the Nile tilapia fry that feeds *A*, *B*, *C*, *D* and *E* were fed with, showed that all the tilapia starter feeds were of good quality. For Nile tilapia fingerlings production costs (feed cost/kg fingerlings produced), feed *B* was the least economical whilst that of *D* was the most economical. All the five feeds did not negatively impact water quality.

Recommendation

It was recommended that starter feeds of lower production costs, lower incidence costs and higher profit indices should be opted by tilapia hatchery operators for fingerlings production. Tilapia starter feed producers should maintain optimal crude protein levels of their products to attract reasonably lower price.

3.1.1.3 Health Risk Implications of Polycyclic Aromatic Hydrocarbons (PAHs) in Grilled and Smoked Farmed Nile Tilapia (*Oreochromis niloticus*) Marketed in Tema, Ghana

(Research Team: Emmanuel Kaboja Magna – Principal Investigator, Mercy Johnson-Ashun, Lilly Osei Konadu, Michael Dabi, Francis Ofosu-Koranteng, Eugenia Borteley Badu, Emmanuel Ansah, Joseph Korpone Sakna)
Collaborating Agencies*: *Ghana Standard Authority and Kete-Krachi Nursing and Midwifery School

Introduction

Farmed tilapias are fed with feeds which could be sources of polycyclic aromatic hydrocarbon (PAH) contaminations due to the methods of processing such feeds. The residual levels of PAH in farmed fish may be amplified when it is smoked or grilled using burning wood or charcoal, thus posing health risks to consumers. However, grilled and smoked farmed tilapia, which has the potential to contain PAHs, has not received sufficient attention.

Objective

The general objective of the study was to assess the residues of the sixteen (16) priority PAHs in grilled and smoked farmed tilapia and to establish their potential health implications for consumers.

Activities undertaken

In the year under review, ten (10) samples of grilled and smoked farmed Nile tilapia were bought from five (5) different locations in the market centre in Tema, Ghana. An additional 5 fresh wild Nile tilapia samples as control, were obtained from fisher folks on the Volta Lake. All samples were stored in an ice chest packed with ice. The PAHs were extracted using a technique described by Tongo, *et al*. (2017), with a slight modification. Using GC-FID (HP-588) analyses of the cleaned extracts, the 16 key PAHs were identified. The limit of quantification (LOQ), the limit of detection (LOD), and the linear range values for each PAH molecule were computed to validate the analytical approach. The toxicity risk related to PAH levels in the samples was investigated by comparing measured quantities to permissible values and guidelines. Specific PAH levels, the total of all tested PAH elements, and PAH (carcinogenic groups) were all evaluated. The SPSS software package (version 20.0) was used to analyse the data. The statistical differences in mean PAH levels in the grilled, smoked, and the fresh tilapia were determined using One-Way ANOVA. Sum PAHs (∑PAHs), individual PAHs, and ∑PAH4 levels were obtained using descriptive statistics (standard deviations, mean, and range). The level of significance was set *at* $P < 0.05$.

Key results achieved so far

At the end of the reporting year, varying concentrations of PAH congeners were found in the samples, with those of the smoked having the highest (∑16PAHs), which were significantly higher ($P < 0.05$) than those of the grilled samples. Except for Nap, Phe, and IcdP (0.033 - 0.513 µg/kg), no PAH was detected in the fresh wild tilapia samples. Benzo(a)pyrene levels in grilled and smoked samples exceeded the recommended limit of 2.0 µg kg^{-1}. Compared to grilled samples, smoked samples had the highest estimated daily intake (EDI) value for all PAHs. The TEQ values for all fish samples were greater than the estimated screening value (SV) of 1.351E-06 µg kg^{-1}. The estimated excess cancer risk (ECR) for the smoked and grilled tilapia as well as the PAH4 index for all fish samples, exceeded the threshold levels. The 16 priority PAHs identified in the samples at various concentrations are shown in Table 3.1.2.

Table 3.1.2: Mean concentration (µg kg^{-1}) of PAH in smoked and grilled farmed tilapia from markets in Tema, Ghana

	Smoked farmed tilapia			**Grilled farmed tilapia**		
PAH	Mean	SD	Range	Mean	SD	Range
Nap	23.69	13.46	ND – 33.23	ND	ND	ND
Acy	19.56	8.04	ND – 36.23	0.07	0.01	0.058 - 0.09
Ace	3.28	1.88	ND – 4.53	0.31	0.12	0.126 - 0.47
Fle	20.46	11.77	ND – 29.78	ND	ND	ND
Ant	111.96	9.80	97.887 – 121.32	3.58	0.63	2.686 – 4.47
Phe	105.26	11.21	96.875 – 117.54	7.39	0.85	6.592 – 8.61
Flu	67.96	4.29	63.506 – 73.06	0.86	0.23	0.550 – 1.18
Pyr	42.33	8.73	ND – 72.66	7.84	3.73	1.244 – 10.45
*BaA	43.97	24.62	ND – 57.27	0.79	0.15	0.573 – 1.02
*Chr	56.14	31.39	ND – 70.98	2.50	1.01	1.077 – 3.93
*BbF	30.61	12.54	ND – 42.13	4.14	1.11	3.176 – 5.91
*BkF	27.73	15.59	ND – 35.94	3.87	1.59	1.022 – 4.67
*BaP	25.89	0.054	25.799 – 25.91	34.96	7.80	ND – 119.27
¨Icdp	24.77	3.61	19.700 – 29.92	15.02	8.40	ND – 18.94
¨DahA	8.06	1.52	6.107 – 9.42	5.61	1.51	3.471 – 7.75
¨BghiP	10.70	1.95	ND – 21.01	10.25	2.35	ND – 17.08
∑16PAHs	622.42		246.368 – 780.96	97.25		20.57 - 203.91
PAH4	156.62		25.799 – 196.30	42.408		4.82 – 130.15
LPAHs	494.63		258.268 – 616.63	23.375		12.91 – 30.27
HPAHs	127.78		51.606 – 164.32	73.860		7.66 – 173.64

*SD: standard deviation, ND: Not detected *Carcinogenic PAH and PAH used to derive the PAH4 Index ¨ Carcinogenic PAHs*

Conclusion

It was concluded that grilling and smoking processes were entirely responsible for the PAH levels measured in the samples used in this study. Consumption of the smoked tilapia had the highest carcinogenic risks and it posed a risk to consumers' health.

Recommendation

It was however recommended that continuous health risk surveillance of PAHs should be conducted in grilled and smoked farmed tilapia. It is also imperative to educate fish retailers and fishmongers about safer alternatives for processing and preserving fish.

3.1.1.4 Farming Practices among Small-Scale African Catfish Farmers in the Sunyani Zone in Bono Region of Ghana

(Research Team: T.D. Mensah – Principal Investigator, Seth K. Agyakwah, Ruby Asmah, Okyere K. Boateng – Fisheries Commission)

Collaborating Agency: Fisheries Commission, Bono Region

Introduction

Small-scale aquaculture in Ghana remains a crucial sector, with each producing less than 50 MT of fish per annum. The sector is mainly private driven and has the potential to contribute significantly to food and nutritional security, employment generation, increase household incomes; thereby sustaining economic growth and reducing poverty. Small-scale farmers generally practise extensive to semi-intensive aquaculture in earthen ponds, in contrast to the

intensive practices of commercial farmers. In recent times, there has been a paradigm shift to catfish culture, especially in the middle belt of the country, which could outstrip tilapia farming in the near future.

Objectives

The objectives of the study were to:

- understand farmer practices in the catfish production sector in the Bono region of Ghana;
- formulate strategies for farmer adoption to increase productivity; and
- identify the constraints confronting small-scale catfish farmers' operations.

Activities undertaken

The survey was carried out in the Bono region (Sunyani Zone) of Ghana, covering 30 active small-scale farmers involved in the culture of the African catfish. The survey team involved selected and trained staff from the Sunyani zone of Fisheries Commission in the region. A face-to-face interview was conducted on 30 randomly selected African catfish farmers, using a structured questionnaire that lasted for about an hour. The interviewees were either the owners or managers of the farms. Most of the interviews were conducted in the fish farms and in certain cases, in the homes or workplaces of the owners or the managers. Data obtained from the survey were analysed using excel spreadsheet and they were interpreted in graphs and tabular forms.

Key results achieved so far

It was found in the study that almost all the farmers interviewed were involved in other income generating ventures (Fig. 3.1.1) indicating fish farming as surplus to their incomes. The income bracket of most farmers did not exceed GHS 2000 per month, and 45% of farmers had 10% of their household income from fish farming (Fig. 3.1.2).

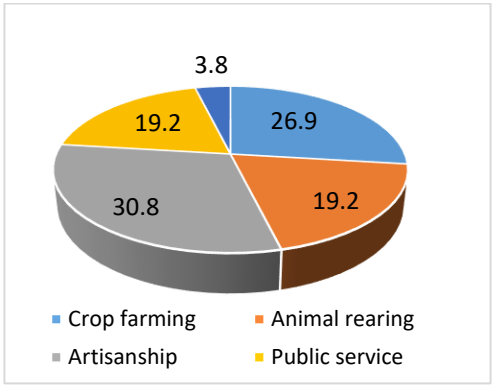


Fig. 3.1.1: Other livelihood ventures by farmer

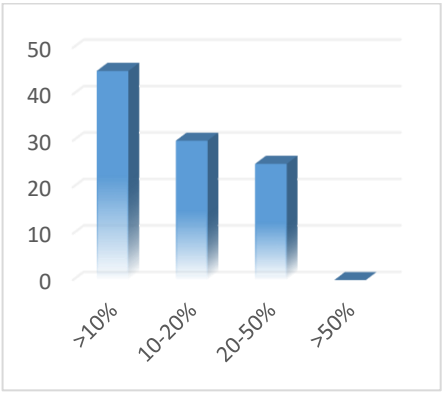


Fig. 3.1.2: Household income as a result of fish farming

The major culture system was earthen pond with few farmers using concrete and tarpaulin tanks (Fig. 3.1.3). The main source of water for fish culturing was stream/river (Fig. 3.1.4). Harvested catfish was either sold fresh or smoked within the community, surrounding markets or to restaurants (Fig. 3.1.5). Unaffordable fish feed was the key challenge facing the farmers and it accounted for over 70% of their production costs. The main available commercial feed was Raanan and it was highly expensive partly due to the high cost of transport from other parts of the country. Some other challenges confronting the small-scale farmers included lack

of knowledge in feed formulation, lack of feed processing equipment, lack of quality feed ingredients and inability to keep adequate record (Fig. 3.1.6).

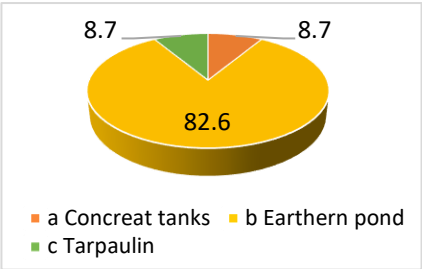


Fig. 3.1.3: Culture systems used by farmers

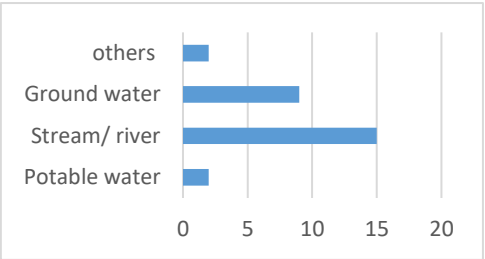


Fig. 3.1.4: Water sources available for use by farmers

Fig. 3.1.5: Market options available to farmers

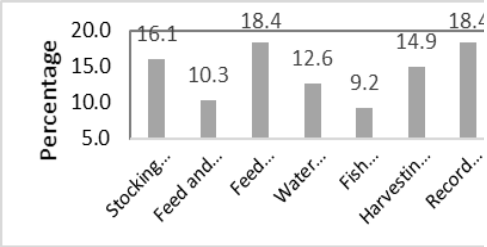


Fig. 3.1.6: Some challenges encountered by farmers

Conclusion

It was concluded that with effective monitoring and extension services, challenges facing the small-scale catfish farmers in the Bono region would be greatly reduced and their production levels will improve. Hence, it was recommended that the farmers should be provided with effective training and regular extension support.

3.1.1.5 Resilient Aquatic Food Systems: Cage Fish Culture in Reservoirs in the Northeast Region

(Research Team: Dr. Ruby Asmah – Principal Investigator, Dr Emmanuel Mensah, Mr Acheampong Addo, Mrs Adelina Akuamoah-Boateng, Dr Seth Agyakwah, Mr Martin Adakpeya)

Collaborating Agencies: International Water Management Institute, Fisheries Commission

Introduction

The government of Ghana in 2017 launched the One-Village-One-Dam initiative to construct small dams in each constituency in the Northern Region, and to rehabilitate existing ones. The Consultative Group for International Agricultural Research led project, Resilience Aquatic Food Systems, sought to enhance utilization of these dams in the North East Region of Ghana, for community development and to ensure food security through farmed fish production. This was expected to create additional income sources for the people in the riparian communities, particularly women and the youth.

Objective

The study aimed at enhancing food security in the North East Region through cage fish culture.

Activities undertaken

In the reporting year, project meetings were held via Zoom conferencing among the research team from the action implementing Institutions in Uganda and in Ghana to facilitate speedy procurement of project materials and equipment. Fish farmers' stakeholder and focus group discussions were held in Kumasi (for the middle sector) and in Bolgatanga (for the northern sector) of Ghana alongside primary and secondary data collection. Water quality and bacteriological analyses of water, sediment, and fish samples were conducted. Transmission electron microscopy analysis of fish samples was commenced.

Key results achieved so far

Water quality of four (4) dams sampled showed that the water was soft and low in major ions. The temperatures were ideal, but dissolved oxygen concentrations were quite low (Fig.3.1.7). The depths of water in the dams ranged from 3.5 to 6.8 m (Fig. 3.1.8).

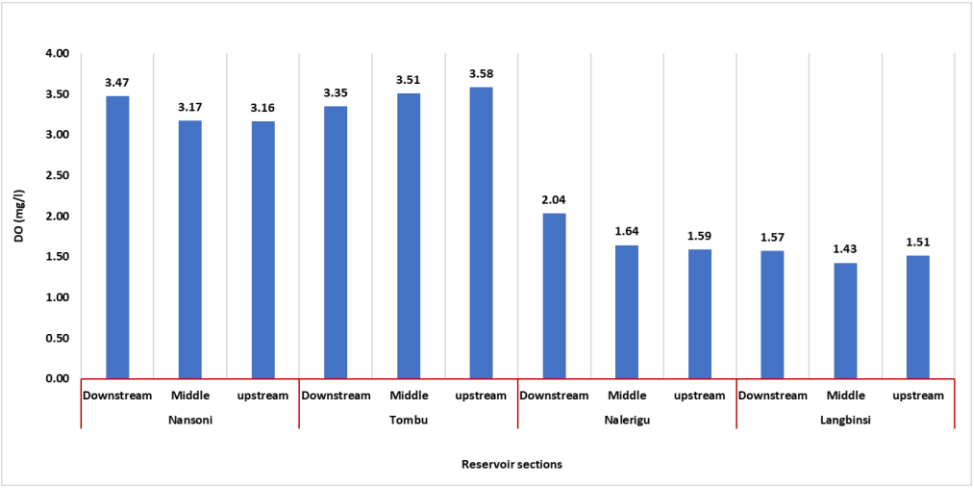


Fig. 3.1.7: Dissolved oxygen concentrations in the dams

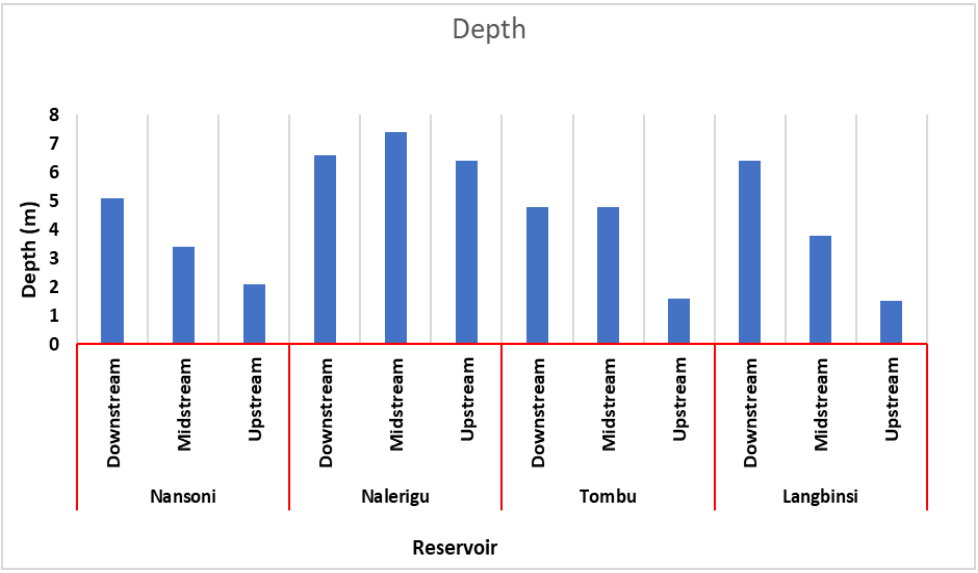


Fig. 3.1.8: Depths of water in the dams

Conclusion
It was concluded that the quality of water in the dams was fairly suitable for cage fish culture. However, the water quality changes with change in season. The shallow nature of the dams would require the installations of shallow cages, with maximum depths of about 2.0 m.

Recommendation
It was recommended that cage fish culture in the dams would require the use of aerators and there should be further water quality monitoring in the dams.

3.1.1.6 Genetic Evidence of the Unique Identity of the West African Mangrove Oyster (*Crassostrea tulipa*) along the Southern Coast of Ghana

(Research Team: Rhoda Lims Diyie – Principal Investigator, Sam Addo, Emmanuel Armah, Judith Wayo, Mercy Oppong, Charlse Boateng, Mike Y. Osei-Atweneboana)
Collaborating Agency: University of Ghana, Department of Marine and Fisheries Science

Introduction
The West African mangrove oyster, *Crassostrea tulipa* is endemic to the coast around the Gulf of Guinea and it is usually mistaken for other similar species. The error margin on shell-based characteristics, such as form, structure, colour, and muscle scar for the identification of oysters is awfully high, because of plasticity in shell morphology (Ignacio *et al*, 2000). Accurate information on oyster diversity and evolution are vital for conservation and effective management purposes.

Objectives
The objective of the study was to carry out molecular characterization of the West African mangrove oysters, *Crassostrea tulipa*, which is endemic to the coastal waters of Ghana and the sub-region. This was to establish its genetic identity, and the phylogenetic relationship between it and other *Crassostrea* species to help clear the long-standing confusion of it being a synonym of *C. gasar*. The study also investigated the population structure of oyster samples from three different ecotypes of *C. tulipa*, utilizing mitochondrial cytochrome oxidase I (COI) genes as markers.

Activities undertaken
Within the reporting period, Oysters were randomly collected from four (4) sampling sites, namely Whin (W), Volta (V), Densu (D) and Narkwa (N). A total of 320 samples, 80 per site were collected. They were washed thoroughly with distilled water and transported on ice to the laboratory. The samples were stored at 4 ^{o}C until subsequent analyses. The individual shell length, height and weight were measured. The shells were opened from the posterior end and shucked with a sterilized stainless-steel knife into a clean glass beaker. Each individual adductor muscles of the oysters were weighed and they were taken through the processes of oven-drying, homogenization, digestion, serial dilutions, filtration, identification and analyses following standard protocols, depending on the respective contaminant to be extracted or isolated. DNA was extracted using the Quick-DNA Miniprep Plus kit 4068 (Zymo Research, USA) for genetic analysis, after which they were amplified, sequenced and microsatellite analysed. The samples were analysed for the presence of six (6) microbes (*Total Coliform, Escherichia coli, Vibrio cholera, Listeria* spp, *Aeromonas* spp., *and Salmonella* spp.), seven (7) heavy metals (Mercury, Arsenic, Cadmium, Lead, Copper, Zinc and Iron), and microplastics. The non-carcinogenic risk of consuming heavy metals through oysters was estimated. The Hazard Index (HI) as well as the Carcinogenic risks (TR) were also estimated.

The data were statistically analysed using the statistical package SPSS 22.0 (SPSS, USA.). The means and standard deviations of the various contaminants in the oyster species were calculated. Multiple range post hoc Tukey tests were employed to determine the statistical significance of the differences in data from the 4 different sites at 95% confidence level.

Key results achieved so far

Results from the study indicated that *Crassostrea tulipa* was observed on the coastal waters of Ghana and it was genetically distinct from *C. gasar* and the other *Crassostrea* species.

Conclusion

It was concluded that *Crassostrea tulipa* occurring on the coastal waters of Ghana was confirmed as genetically distinct from *C. gasar* and other *Crassostrea* species, as no single analysis undertook in the present study confirmed their similarity. The overall high levels of genetic diversity of *C. tulipa* represented a positive trait for hatchery-based aquaculture and it could satisfactorily aid the development of selective breeding programmes in Ghana. The molecular information obtained from this study also has implications for the proper management of wild-harvested oysters in Ghana.

Impact of the study on national economy

A focal shift to diversification of culture species in Ghana to include native stocks of oysters would create a more resilient aquaculture sector, which would generate additional revenue aside from that of Nile tilapia, to guard against catastrophes that characterize the culture of single species.

3.1.1.7 Accelerating Aquaculture Development in Ghana through Sustainable Nile Tilapia Seed Production and Dissemination

(Research Team: Seth Koranteng Agyakwah – Principal Investigator, Catherine Ragasa, Ruby Asmah, Emmanuel T.D Mensah, Froukje Kruijsson, Sena Amewu, Matthew Oyih and Acheampong Addo)

Collaborating Agencies: International Food Policy Research Institute (IFPRI) - USA, Fisheries Commission - Ghana, KIT Royal Tropical Institute – Netherlands, WorldFish – Malaysia

Introduction

The TiSeed project was a multidisciplinary, multi-actor, multicomponent research. It covered effectiveness analyses, processes and impact evaluations surrounding specific interventions on productivity of small-scale fish farming, brood stock management, sustainable seed distribution, seed quality monitoring, fish farming and feed production business models, certification system and extension services, including use of ICT tools. The interventions were implemented in Ghana, among six (6) focused regions, viz: Bono, Bono East, Ahafo, Ashanti, Eastern and Volta regions. The study, was funded by the Government of Netherlands and CGIAR Research Programs on Policies, Institutions and Markets (PIM) and Fish Agri-Food Systems (FISH).

Objectives

The objectives of the study were to address challenges confronting Nile tilapia seed system and extension services towards improving productivity, profitability and sustainability of cage and pond tilapia farming in Ghana, with particular focus on women and youth small-scale farmers. The TiSeed project aimed at improving the quality and service level of public and private hatcheries whilst increasing knowledge in best aquaculture management practices,

access to and use of high-quality tilapia seed for new or existing small-scale pond and cage tilapia producers.

Activities undertaken

During the year under review, the genetic quality among sixteen (16) populations of farmed Nile tilapia in Ghana were assessed using five (5) microsatellite markers (UNH154, UNH222, UNH995, GM531, and GM538) to estimate levels of genetic variations among them. Genetic parameters were analysed using GenAlex statistical package, MegaX and web-based Genepop, to determine variations among them using pairwise genetic distance and genetic identity. In addition, comparative study on the growth performance and economic parameters of three (3) strains of Nile tilapia ('Akosombo' generation 11, 'Huawei' and 'Fishreit') in cages under small-scale commercial farm management practice at the University of Ghana Farms and development, testing and training of over 120 fish farmers on the use of a newly developed 'Fish Farm Tracker App' (Fig. 3.1.10), a mobile application tool, were undertaken.

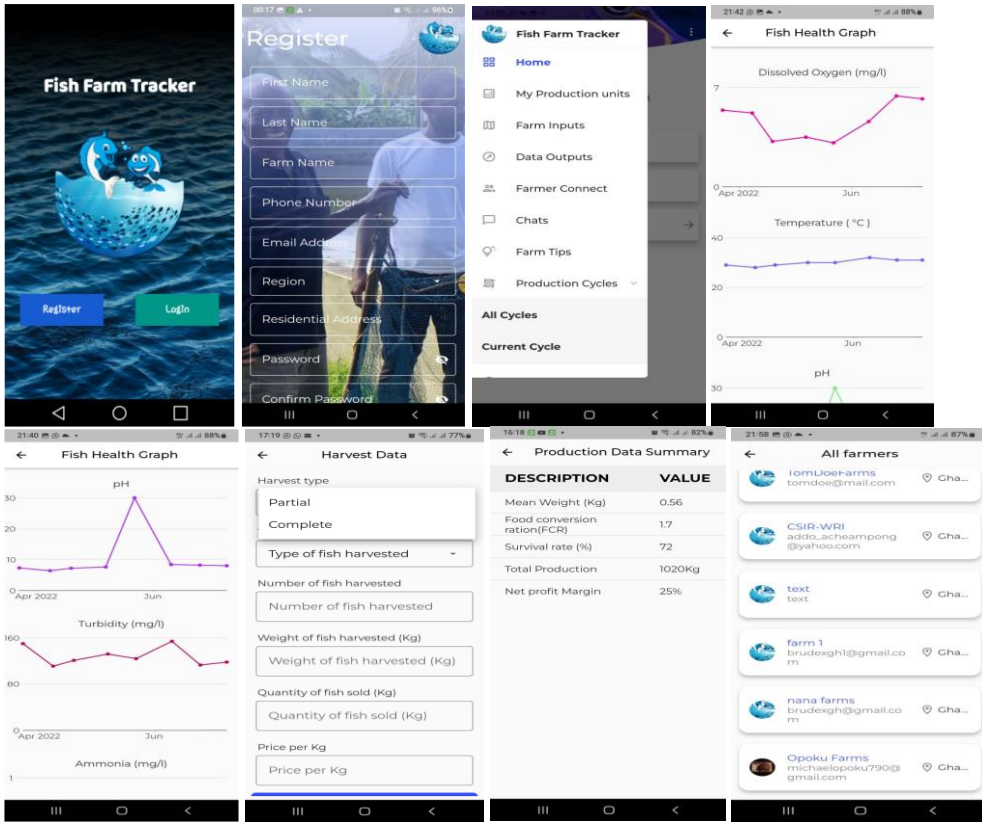


Fig. 3.1.10: Some features of the Fish Farm Tracker App

Key results achieved so far

Results from the study showed that the Nile tilapia seed farmed in Ghana were of varied genetic sources (locally improved Volta strains, foreign GIFT derivatives and mixture of unimproved populations). Technical knowledge and skill level of small-scale pond and cage Nile tilapia farmers, as well as hatchery operators in 6 regions were enhanced. A 3-tier certification protocol, which provides effective guidelines for best aquaculture practice, and easier for small-scale farmers to comply with, was developed. Enhancement of data collection

and farm management offered smart fish marketing and platform for farmers' communication and knowledge sharing. Nursery model was established in the Ghanaian aquaculture industry. Productivity and profitability of cage and pond tilapia farming were improved among adopters of shared technical knowledge and technologies. The study supported different stages and actors of the seed value chain, and has developed ICT tools for enhanced fish farm management and business development. These included:

- distribution of certified broodstocks, hapa nets and fish feed to 25 hatcheries in Ahafo, Ashanti, Bono, Bono East, Eastern and Volta Regions. These strengthened operations of hatcheries for improved productivity and distribution of quality (healthy and safe) fingerlings to nurseries and farms, through technical support on biosecurity and farm certification protocols;
- establishment of tilapia seed nurseries to reduce fish mortality during long distance transportation as well as promotion and use of larger-size fingerlings and their safe delivery (good packaging and handling practices) to farms for increased productivity;
- provision of intensive training and technical support to hatcheries on broodstock management and to fish farmers on good aquaculture practices;
- development and launching of Fish Farm Tracker© Mobile Application online on both Android and iOS platforms. The Fish Farm Tracker app is an innovative digital solution for general fish farm records keeping, production management, basic fish health and water quality monitoring, business and economic management, real-time online fish marketing, farmer-to-farmer and farmer-to-client chat platform and extension support service to fish farmers; and
- production of 18-episodes TV/Online based documentary – drama serial, as an extension mechanism for easy and faster learning, towards enhanced adoption of 'good' aquaculture management practices.

Conclusion

It was concluded that TiSeed project intervention in the aquaculture industry would improve the quality and service level of public and private hatcheries, as well as increase access to and use of high-quality fish seed for new or existing producers, with specific attention for women and the youth. The introduction and establishment of nursery model in the Ghanaian aquaculture industry will bring efficiency and improve sustainability in the tilapia seed delivery system and grow-out operations. The project, therefore, complemented the government's effort to improve productivity and profitability of fish farming, particularly supporting small-scale farmers and youth employment in the sector, through *Aquaculture for Food and Jobs (AFJ)* initiative.

Impact of the study on national economy

The TiSeed project intervention in the aquaculture industry will boost fish production and reduced postharvest losses through effective smart marketing technology, as well as increase fish contribution to the gross domestic product (GDP).

3.1.1.8 The Freshwater Oyster Fishery in Northern Ghana

(Research Team: Dr. Miriam Yayra Ameworwor – Principal Investigator, Dr. Ruby Asmah, Dr. Emmanuel T.D. Mensah and Mr. Martin Adakpeya)

Introduction

Freshwater oysters/mussels are bivalves belonging to the Order Unionida. The endemic family occurring in Africa is Etheriidae with *Etheria elliptica* as the only known species. In Ghana, *E. elliptica* occurs in all major rivers in northern Ghana including Black, White and Red Volta, Oti, Daka, and Nasia and it serves as cheap protein source for rural households in its area of distribution (Ampofo-Yeboah & Owusu-Frimpong, 2014). Though there has been no account of commercial culture of the species in Ghana, its potential as a major source of livelihood for rural inhabitants when it is developed through aquaculture, cannot be overemphasized (Akélé *et al*., 2017). For a commercial culture to provide the needed result, its profitability, ease of production and economic importance of its fishery must be assessed, and indigenous knowledge presents an important data source for such assessments (Nyumba *et al*., 2018).

Objective

The study was aimed at assessing the state of the freshwater oyster fishery towards a proposed study on the culture of the species in Northern Ghana.

Activities undertaken

The study was undertaken in three communities along the White Volta River, namely Nawuni (9°45′1″ N, 1°10′1″ W) in the Tolon District of the Northern Region, Yapei (9º10′ 0″ N, 1º10′ 00″ W) and Ntereso (9º7′46″ N, 1º12′12″ W) in the Central Gonja District of the Savannah Region. Primary data were collected through interviews. Key informants were selected from the three study communities by snowball sampling. Informants were interviewed on harvesting, processing, and marketing of the oyster. Information was also sought on distribution of the fishery along the major rivers and the challenges facing it. (Fig. 3.1.9).

a.  b. 

Fig. 3.1.9: Interviewing some respondents at Nawuni: (a) Chief fisherman (b) Oyster processor

Key results achieved so far

The results indicated that the species was common along the White and Black Volta rivers and the Oti River. Along the White Volta the species was exploited by seven (7) communities. In the Gonja communities visited, such as Yapei, Gbarto, Apaso, and Ntereso where it also occurred, the oysters were not patronized as food. The species was found to be eaten only by some tribes which included Dogombas, Hausas, Fulani, Grusi and Ewes (mostly those that settled among the Dagombas). Harvesting starts when water levels recede (especially in the dry season) and oyster beds are exposed or almost exposed. This usually occurs from February to April. Harvesting was done using a specialized hoe to detach the organism from its

attachment. Harvested oysters were transported in canoes to processing grounds at the riverbank. Processing is mostly by smoking prior to marketing. The shells are discarded and not used in any profitable way. Major challenges facing the fishery were inaccessibility of oysters all year round, heavy dependence on firewood for processing, and limited demand for the finished product since it is not eaten by some tribes.

Recommendation

It was recommended that culture of the species should be carried out in cost effective holding facilities. In addition, improved and energy efficient processing methods should be employed. Also, the shells should be processed to add value.

3.2 CLIMATE CHANGE, ENVIRONMENTAL MANAGEMENT AND GREEN TECHNOLOGY

3.2.1 POLLUTION AND WASTE MANAGEMENT

3.2.1.1 Preliminary Study of the Governance and Quality of Some Lagoons in Ghana

(Research Team: Dr. Marian A. Amu-Mensah – Principal Investigator, Dr Isaac Hodgson; Martha Duku Agyeman; Gertrude Nortey; Lady Frimpong; Hawa Ahmed and Mario Danban, Dr. Gloria Addico)
Collaborating Agencies: CSIR - Science Technology Policy Research Institute

Introduction

Governance of Lagoons are based on principles or general ideas produced to help formulate policy for the socio-economic benefit of users. The interpersonal interaction with the lagoon's environment that has been subjected to adaptation within the specific context of the lagoon community provides well-tested knowledge for the protection or conservation of the water. Therefore, the activities of those who control, access and use the lagoon are engaged to determine the nature of activities, whether formal or informal, and its impact on the lagoon's water quality and the adaptation measures in view of climate change. The formal principles are the legal water policies and the informal are the norms or indigenous practices. These principles help to regulate the access, control and use of the lagoons and ecosystem.

Objectives

The goal of the study was to identify and help improve on definate institutional challenges and anthropogenic causes leading to over-exploitation and degradation of the Sakumo 1 and 11, Mokwe, and Songor lagoons while examining the pollution status. The specific objectives were to:

- assess the pollution and sedimentation levels in the lagoons;
- investigate useful and effective institutional systems for lagoon/wetland conservation and long-term governance;
- assess threats and challenges in lagoon/wetland governance;
- give direction for the necessary wetland ecosystem conservation; and
- provide policy recommendations and guidelines for lagoon/wetlands conservation.

Activities undertaken

Activities carried out in the reporting year included in-depth interviews conducted with government officials in four government district offices. A total of 100 respondents from two communities were surveyed from each lagoon area using purposive sampling, supported by snowballing methods for selection. Photographs were taken to document observable activities that had an impact on the lagoon. The Shannon-Weiner Diversity Index H'(loge) for the biocenosis was used as an indicator for the relative abundance of the different taxa present at each lagoon. Grab water and sediment samples were taken from the upstream and downstream of the lagoons (Fig. 3.2.1) and analysed for physiochemical parameters such as suspended solids, phosphates, nitrates, dissolved oxygen and metals. Other parameters including pH, temperature, conductivity, total dissolved solids and alkalinity were analysed in-situ using the appropriate instruments.

Fig.3.2.1: Taking sediment samples in Sakumo II

Key results achieved so far

The study showed that there were no well-packaged informal principles to reduce the degradation of the lagoons. Collaboration between the formal sector and the informal sector on how to regulate the access, control and use of the lagoons was not in operation, except during meetings where government agenda is discussed occasionally. Macroinvertebrates were not recorded at Sakumo I and Mokwe lagoons. Low macroinvertebrate populations were recorded at Sakumo II during the study. Sakumo II and Mokwe lagoons did not record any macroinvertebrates using the Shannon-Wiener Index. The seven (7) Macroinvertebrate taxa recorded during the study were all encountered at Sakumo II.

Conclusion

It was concluded from the study that local knowledge should be adequately packaged to form part of government policy since most the government policies did not support the welfare and interest of the communities as built-up areas close to the lagoons keep increasing.

Recommendation

At the end of the reporting year, it was recommended that land-zoning and new building codes should be implemented to reduce the vulnerability of the lagoons. Climate-smart institutional systems (rules and regulations) should be introduced to address the issue of water degradation, in the study areas. Specific role should be assigned to the formal and informal sectors to ensure effective governance. There is the need to train and learn from community members on how to apply sustainable natural resource management in order to increase the resilience of food production.

Impact of the study on national economy

The study provided information in support of Article 21 of UN Charter, the Declaration on Human Rights in terms of indigenous peoples. The results, demonstrated a commitment to the creation of new knowledge, and use of that knowledge to improve on human lives, and to help solve the various socio-economic issues facing societies living around waterbodies. The report, also support the sustainability of water resources of Ghana under the Water Resources Commission Water Act 552 of 1996.

3.2.1.2 Empowering Citizen and Community Adaptation to Systemic Risks from Climate Change (EMPOWER)

(Research Team: Ing. Dr. Emmanuel Oboubie – Principal Investigator, Dr Prosper Bazaanah, Dr. Marian Osei, Mr Alex Gaisie-Essilfie and Mr Bismark Akurugo)

Collaborating Agencies: University of Reading, University of Surrey, Water Resources Commission, and Development Institute – NGO

Introduction

Climate change is having impacts on individual livelihoods and prosperity, yet plans for adaptation strategies have been limited to government and the private sector. This ongoing study propose, amongst others, to empower citizens to co-develop adaptation strategies by identifying climate change threat vectors and interventions tailored to local context; and combine environmental science with systems analysis of social, political, economic, legal and technological factors using participatory systems mapping, including both the direct and indirect impacts of climate change. The outcome of the study will be strategies empowering citizens to protect their families and communities by better understanding climate change risks and the multiple constraints and opportunities for adaptation.

Objectives

The objectives of the study were to:

- pilot a novel participatory approach to co-develop adaptation strategies for citizens and local communities, empowering them to protect themselves from complex systemic risks;
- draw on multiple perspectives to analyse climate change adaptation options in light of their feasibility, along with complementarity across interventions, ethical considerations, and who to engage with and when;
- reconcile adaptation options with multiple desired outcomes over the longer term (e.g. biodiversity protection, livelihoods and community development, air quality, public health, recreation and cultural values, etc.);
- address a key 'adaptation gap' by empowering bottom-up action on climate change, and also prompting a more active role in citizenship to help tackle structural and governance limitations around climate change adaptation; and
- identify further gaps for environmental and social research to track systemic risks affecting local communities and implement and evaluate interventions.

Activities undertaken and key results achieved so far

The Ghana case-study was conducted in the Lower Volta Basin (LVB) and covered communities located upstream (Ada East, Anloga, Sokpoe, Agave, Ada Foah, Ave-Seva, Akatsi North, Tosukpo, Fuveme, Ave-Dakpa, Sikor, Bleamezado, Dikato, Agorbledokoe) and downstream (Agbetikpo, Dove, Volo, Mafi-Tsakpo, Ayiwata, Awadiwoe) of the Basin. The activities were implemented through two workshops. In workshop one, the study did purposive sampling of 24 participants to identify climate risks/threats faced by individuals, their households, and their communities. They also linked the consolidated threats to the supporting/primary factor and identified provisional interventions for adapting to the climate threats. Views of the participants were modelled using the Participatory System Mapper (PRSM), to allow visualization of the links between the supporting factors, climate threats and interventions. Most of the participants linked climate threats to food and water security, housing, and workplace conditions. The participants also outlined interventions they employed in the face of climate threats. For instance, irrigation methods are used to combat drought episodes, which influence food and water security. During heavy rains and cold

episodes from sea breeze, they used warm clothing and also consumed special herbal concoctions to keep warm.

Invasion of alien plant species was of concern for participants, as these weeds cover the surface of the Volta River, making fishing near-impossibility, which turn to alter their livelihoods. Individuals stated that these species were introduced into the region from recent climate change events. The weeds were removed either by individuals or through community labour. To tackle the issues of coastal and riverine flooding, individuals heaped a mixture of weeds, charcoal debris, and sandbags, to block flooding from the sea. In addition, gullies are created around homes to re-channel the floodwaters while buffer zones were created from local materials like palm fronds, sand and cassava barriers, and tools such as cutlasses and hoes, to reduce occurrences of bushfires. On individual basis, this creation of buffer zones was considered to be expensive (e.g., hiring labour), but could be less expensive using the community labour approach. Though no specialized technical experience was needed to create buffer zones, knowledge of wind direction and the timing for burning around the buffer is relevant to ensuring that neighbouring farms are not destroyed. Debris from the buffer creation were also used as mulch and charcoal. In the same vein, afforestation was undertaken to mitigate high/low winds, but participants considered the intervention to be time-consuming and expensive. The prevalence of drought/ erratic (unpredictable) rainfall compelled the people to adopt different irrigation strategies to supplement rain-fed agriculture. Irrigation was expensive as only few farmers could afford. Although materials for irrigation were available in the communities, the cost of hiring pumps, technical expertise, fuel and maintenance of equipment was beyond the financial capacity of some farmers.

During high temperatures, devices like air conditioners and fans are considered options for cooling down by individuals and families. Though these devices were considered to be socially acceptable and improve individuals' health, they are expensive. In cold weather conditions, warm clothes (like jackets, pullovers, raincoats etc) are often used, while others consume local gin ("*akpeteshie"* or *"attire*") to keep warm. A disadvantage of this intervention was the potential to increase drunkenness and alcoholism, leading to undesirable consequences, like domestic violence, loss of jobs, savings, family, and community respect. Regarding flooding and coastal erosion, sandbags and debris from charcoal are used as less-expensive strategies for raising riverbanks and creating artificial blockages to water intrusion. The rise is sea level, tidal waves and saltwater intrusion were unique climate threats identified by the downstream communities. During such events, individuals and families are evacuated/ relocated to higher grounds, and sometimes canals are created to drain seawater. Due to saltwater intrusion, the downstream communities do harvest and store water for household use.

In workshop two, the participants were categorised into upstream and downstream communities of the LVB, to discuss how the interventions were being implemented, given their different contexts and climatic experiences. The interventions were also modelled, together with the threats in the PRSM. The PRSM of the climate threats and interventions, linking the supporting factors are shown in Fig 3.2.2.

Recommendation

It was recommended that since most of the trade-offs were time-consuming and expensive, low-cost and sustainable pathways for tackling climate threats and implementing long-term interventions could be areas for uptake by further studies in developing plans and policies to 'mainstream' the uptake of community-led climate adaptations.

Impact of the study on national economy

Disasters from climate change are bound to happen and individuals, families, and communities should be ready to adopt preventive/remedial measures. The study showed the different intervention strategies being used to mitigate climate threats at the local level. Climate actions could be effective using a bottom-up approach as against the often top-down approach. We caution against the state's obsession with the centralization of climate policies and decisions. Bottom-up approaches could contribute to the creation of an open, positive, and participatory environment that enables people to share knowledge and climate experiences and contribute to climate adaptation. We also highlight that participatory systems mapping is an all-inclusive tool that could be tailored to understanding local needs, and climate experiences and developing real-time and practicable interventions against climate change. By allowing the participants to develop ownership in terms of the threats they identified, and interventions selected, it increased saliency, motivation, and enabled the formulation of context-dependent climate adaptations at the community level.

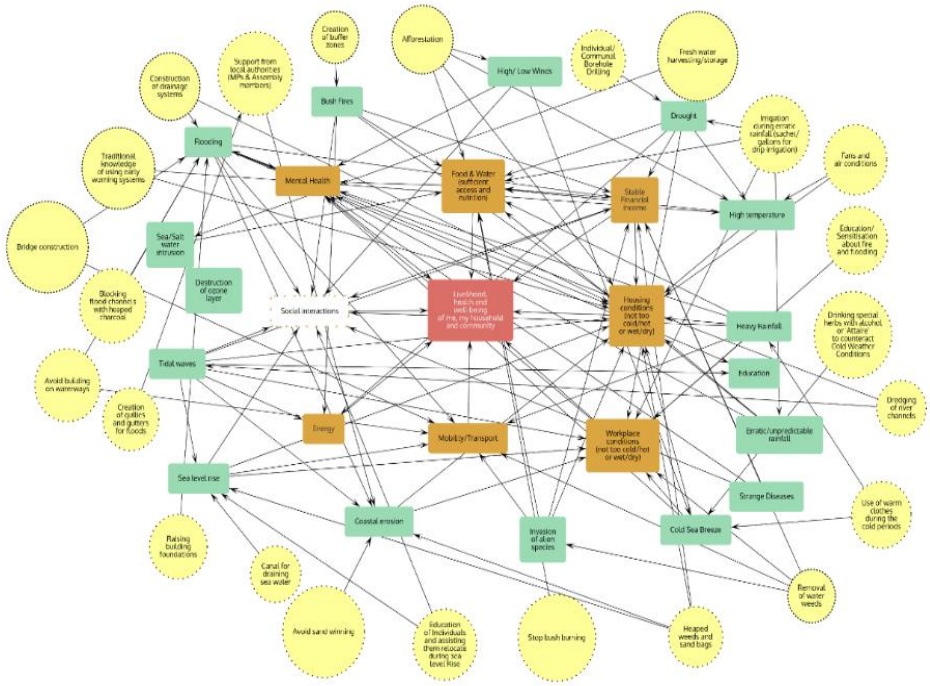


Fig. 3.2.2: Modelled participant's climate threats, supporting factors and interventions using the PRSM (Red box is the primary factor, brown boxes represent the supporting factors, climate threats/risks are shown in green boxes, with yellow circles denoting the interventions)

3.2.1.3 Design and Assessment of Resilient and Sustainable Interventions in Water-Energy-Food-Environment Mega-systems (FutureDAMS)

(Research Team: Ing. Dr. Emmanuel Obuobie – Principal Investigator, Ing. Dr. Deborah Darko, Dr. Prosper Bazaanah, Mr. Mark Osei-Owusu, Ing. Frank Oblim, Sylvia Amponsah and Clarrisa Nutsugah)
Collaborating Agencies: University of Manchester, Geography Department - University of Ghana, Centre for Ecology and Hydrology, University of Southampton, and several other UK Academic institutions

Introduction

FutureDAMS is a multi-partner collaborative research programme led by the University of Manchester and funded by the UK Research Councils through the Global Challenges Research Fund. The vision of FutureDAMS is of a world in which all developing countries make progress to the achievement of the SDGs and the delivery of emissions reductions necessary for the Paris Climate Change Agreement by selecting, designing, financing, and managing dams to meet local, national and regional development needs and preferences. One of the goals of FutureDAMS is to transform how new dams and systems of new and existing dams are assessed, selected, designed, and operated to provide water, food, and energy security for all. FutureDAMS is being implemented in West Africa (Ghana/Volta Basin), East Africa (Ethiopia/Nile Basin) and Asia (Myanmar/Irrawaddy Basin).

Objectives

The objectives were to:

- deepen perception of how nexus system interventions (new dams, or systems of dams, and their operation) cascade through socio-economic, engineered, ecological and political systems, and use this knowledge to help stakeholders develop and negotiate solutions that are economically, socially and environmentally beneficial;
- enhance the technical and institutional capacity of partner and non-partner researchers and policy-makers to ensure that dam decision-making leads to expected economic, social, and environmental outcomes; and
- create a cross-disciplinary network of global researchers and policy-influencers and inter-disciplinary tools for dam decision-making, which will continue to operate after programme completion and that can transfer learning to the 'next generation' of nexus system planners worldwide.

Activities undertaken and key results achieved so far

Some activities undertaken and their related results in the reporting period included:

***Co-ordination and networking*:** The CSIR team promoted the objectives of the FutureDAMS project in Ghana and the Volta Basin, through building networks and relationships and raising awareness of the project with key stakeholders (e.g., Volta River Authority, Bui Power Authority, GRIDCO, Energy Commission, Water Resources Commission, Ghana Irrigation Development Authority, and private sector organizations).

***Creation and demonstration of water-energy simulation training platform*:** In the reporting year, the FutureDAMS project team at CSIR and Manchester University, in partnership with Ghanaian energy and water planning organizations (GRIDCo, Energy Commission, Volta River Authority, Bui Power Authority, Water Resources Commission, Ghana Irrigation Development Authority-GIDA) created a fully operational next generation online energy-water system analysis and design tool, with an online version of Ghana energy-water model that has been built for teaching and training. On March 3, 2022, the project team demonstrated/trained the Ghanaian stakeholders in the online energy-river basin simulator and presented an online video-based training programme which allows individuals to train

themselves in the theory and practice of the new integrated multi-sector model. The platform/online courses can be accessed via the link (https://www.nexus-strategy.org/online-training/).

***Stakeholders' knowledge exchange workshops*:** The CSIR team, in collaboration with the Manchester University and IIED-UK, organized two knowledge exchange workshops focused on benefit sharing in dam development. The first workshop, which was held on 8th February 2022 at the Golden Tulip (now Lancaster) Hotel in Accra, focused on the principles, experiences and lessons learnt around benefit sharing on dam development from around the world. The second workshop was held on 11th March 2022 at the Alisa Hotel in Accra and was focused on practical lessons on dam benefit sharing from the West African Region. The main objective of the workshops was to provide a platform for stakeholders in the water, energy, environment and food sectors to exchange knowledge and experience on practical experiences regarding the processes of implementing resettlement/benefit sharing plans, what worked/failed and why, top constraints and how they were addressed, and main lessons for current and future dam development in Ghana. Stakeholder organizations that participated in the two workshops included the Water Resources Commission, Volta River Authority, Environmental Protection Agency, Bui Power Authority, Ghana Irrigation Development Authority and the University of Ghana. Some highlights from the two workshops were:

- The construction of previous hydropower dams at Akosombo, Kpong and Bui often involved the resettlement of local communities. Yet, current practices of benefit sharing often involve short-term compensations which do not support the livelihoods of resettled communities.
- Participants suggested that benefit-sharing should be seen as a 'sustainability intervention', with long-term development opportunities for dam-affected people, beyond compensation for lost assets.

***Preparation of a technical report on interdisciplinary study*:** The joint team of FutureDAMS at the University of Ghana, the CSIR FutureDAMS prepared a full draft of a working paper on the Ghana interdisciplinary study. Titled 'Learning and change in large dam development in Ghana', the paper sets out to investigate whether Ghana's past experiences in building hydropower dams have informed learning and change in the construction of the ongoing Pwalugu-multi-purpose dam and future dam construction in the country. The paper was reviewed by the editors of the FutureDAMS working paper series and the team is at present working on a revised version for publication.

***Participation in online webinar series*:** The team participated in four FutureDAMS general project meetings and technical meetings of thematic areas. The team also participated in two online webinar meetings.

***Publication*:** The team contributed to the publication of four journal articles and a manuscript accepted for publication in Nature Sustainability.

Impact of the study on national economy

When completed, the project will deliver knowledge and innovative tools that will transform how new dams and systems of new and existing dams are assessed, selected, designed, and operated to provide water, food, and energy security for Ghana.

3.2.1.4 Multi-scale Flood Monitoring and Assessment Services for West Africa (MiFMASS)

(Research Team: Dr. Emmanuel Obuobie – Principal Investigator, Mr. Mark Osei-Owusu, Franz Alex Essilfie-Gaisie and Sylvia Amponsah)

Collaborating Agencies: Centre for Space Science and Technology Education (Nigeria), Department of Earth Sciences - University of Ghana (Ghana), Institut Supérieur d'Etudes Spatiales et Télécomunications (Burkina Faso), Volta Basin Authority (Burkina Faso), Centre Universitaire de Recherche et Application en Teledetection - University Félix Houphouët-Boigny (Cote D'Ivoire)

Introduction

The Multi-scale Flood Monitoring and Assessment Services for West Africa (MiFMASS) database was developed to capture the quantitative and qualitative extent of a flood event for Disaster Management Organizations (DMOs), governments and international organizations in providing impactful support to affected areas in the event of a disaster. Apart from strengthening the capacities of Disaster Management Organization's and other target groups in the use of Earth Observation (EO) data for flood monitoring, assessment and management, the database is updatable and could provide timely information to Disaster Management Organization's before, during and after flood events. This database could aid in the identification of hotspots and implementation of targeted interventions across the countries of interest. It could also assist in developing flood vulnerability maps using spatial layers of factors that may contribute to the occurrence of floods. MiFMASS is being implemented at multiple spatial scales, i.e., national and local/basin scale.

Objectives

The study aims at enhancing the efficiency of flood monitoring, assessment and management in five ECOWAS countries (Benin, Burkina Faso, Cote d'Ivoire, Ghana and Nigeria) by providing earth observation-based services on real time basis to disaster management organizations and boosting their human capacity to adapt to these services. The specific objectives were to:

- review existing national databases and develop a regular updated regional scale flood event database for Ghana, Nigeria, Burkina Faso, Benin and Cote d'Ivoire;
- establish a flood forecasting system to provide near real-time information on impending floods to allow for ample planning;
- establish an image acquisition, processing and analysis system to map flood extent during/immediately after, flood events from RS data;
- develop a damage assessment module that will assist DMOs evaluate the degree of damage after flood events; and
- enhance the capacities of DMOs to take over the service after the completion of the project.

Activities undertaken

Activities undertaken in the reporting period included operationalization of regional flood event database, stakeholder engagement and training workshops, setup of routine flood alert services, participation in regional workshops and participation in online project meetings: The CSIR-WRI team participated in several online project meetings where progress of activities and implementation challenges were discussed and resolved.

Expected outcome

The study when completed will integrate earth observation data from multiple sources and state-of-the-art processes to deliver products and services that will improve the management of floods in the project countries. The project will review existing flood event databases in the project countries to identify challenges to address and develop a regional database that will

link to the national databases for automatic updates. Further, available Synthetic Aperture Radar (SAR) images from the European Space Agency (Sentinel-1, 2, 3) would be used to improve the mapping of flood extent and reduce the time lag between flood events and the production of such maps. In addition, new and powerful open access software applications (e.g., QGIS, R, SNAP, WOIS, etc.) for image processing and analysis would be used to ensure sustainability.

Impact of the study on national economy

On completion, the study is expected to enhance service delivery by the national disaster management organizations (NADMO) which will reduce fatalities and damages induced by floods in Ghana.

3.2.1.5 Building Climate Resilience into River Basin Management (CREAM)

(Research Team: Dr. Emmanuel Obuobie (Principal Investigator), Dr. Emmanuel Obeng Bekoe, Dr. Francis Amevenku, Dr. Deborah Darko, Dr. Barnabas Amisigo, Stephen Asugri Jnr, Ing. Gabriel Appiah, Sylvia Amponsah, Mark Osei-Owusu, Franz Alex Gaisie-Esilfie, and Bismark Akurugu)

Collaborating Agencies: CSIR-Food Research Institute, Kwame Nkrumah University of Science and Technology, Hydrological Services Department, Ghana Meteorological Agency, SIRCOOL Bottled Water Company Ltd, Geological Survey of Denmark and Greenland, Aarhus University, and Central Queensland University.

Introduction

CREAM is a five-year project funded by the Ministry of Foreign Affairs of Denmark. It aims at creating a knowledge base and capacity for integrating climate change, shared socioeconomic pathways, land-use/-cover change and other future development scenarios into river basin management to enhance climate resilience, livelihood, water-food-energy security, and environmental conservation.

Objectives

The specific objectives were to:

i. improve the data basis for high-resolution, bias-corrected climate change (CC) projections for use in impact studies and to analyse trends in extreme climate events in the two study basins;
ii. further develop and test methodologies for integrating climate change scenarios shared socio-economy pathways (SSPs) and land-use/-cover change in an ensemble of water resource modelling tools, to assess impacts on basin water resources;
iii. improve the evidence and tools for assessing, valuing and integrating water-related ecosystem services which are emptied into river basin management;
iv. develop an interdisciplinary framework for supporting stakeholder dialogue and negotiations in water resources management (WRM);
v. analyse stakeholder constraints to effective water governance and develop strategies to introduce innovative, effective policies and measures and enhance resilience;
vi. enhance the capacity of Researchers, PhD students and stakeholders on how to incorporate climate resilience into water management.

Activities undertaken

Activities undertaken during the year included project co-ordination/leadership through the provision of guidance to implement the different work packages; monitoring of existing equipment; data collection; visiting Denmark to work with project partners at GEUS and Aarhus University; Organizing, participating and facilitating the fourth project annual planning meeting held on 8th-10th November 2022 in Accra; Organizing and facilitating two

(2) stakeholder engagements for co-developing and validation of the Shared Socioeconomic Pathways (SSPs) for the Pra and Densu River Basins; organizing, participating and facilitating several virtual meetings to discuss workpackage progress and challenges; publishing two (2) papers and preparing two (2) manuscripts submitted to journals for consideration.

Expected outcome

The study when completed will create a knowledge base and capacity for integrating climate change and other future development scenarios into river basin management to enhance climate resilience, livelihood, water-food-energy security, and environmental conservation. This will be achieved through research and capacity building, underpinned by the development of an innovative interdisciplinary framework that integrate system-based modelling and optimization with hydrological, ecological, economic, and social data.

Impact of the study on national economy

The innovative tools developed in the study will be used to support water management at national and regional scale. The output will also contribute to Ghana's achievement of the Sustainable Development Goals, particularly Goals 1 (no poverty), 6 (clean water and sanitation) and 13 (climate action).

3.2.1.6 Dangote Sugar Project-Ghana: Baseline Hydrological Study Report

(Research Team: Ing. Dr. Emmanuel Obuobie – Principal Investigator, Dr. Kwadwo Ansong Asante, Dr. Barnabas Amisigo, Ing. Dr. Deborah Darko, Ing. Gabriel Appiah, Dr. Prosper Bazaanah, Dr. Sylvester Boadi, Ing. Frank Teye Oblim, Jacob Agyekum, Fraz Alex Gaisie-Essilfie, Victor Nii Mante)
Collaborating agency: Water Resources Commission

Introduction

The study was carried out to conduct a preliminary hydrological baseline and feasibility study for Dangote Sugar Refinery PLC, Nigeria, at a proposed project area located in the Atebubu-Amantin, Sene West and Sene East Districts in the Bono East Region of the Republic of Ghana. It was to inform the application for water abstraction permit from the Water Resources Commission of Ghana for the abstraction of water from the Volta Lake/Sene River to irrigate 25,000 ha of sugar cane plantation in the project area; inform the design of an irrigation facility, other physical infrastructure as well as the protection of assets and services in the project area; inform the operation of the proposed irrigation project, under current and future climate change conditions; and serve as the basis for applying for a water abstraction permit from the Water Resources Commission of Ghana.

Objectives

The main objective of the study was to conduct a hydrological study to generate baseline data and information that will form the basis for conducting a full feasibility study and design of the proposed sugar project. The specific objectives were to:

- conduct hydrological investigation for the irrigation of the project area;
- assess water availability for irrigation throughout the year based on monthly water demand and assessment of local effect on the Volta Lake water level; and
- study the effects of water abstraction from Lake Volta on the hydropower generated by Akosombo Dam.

Activities undertaken

During the year under review, water and sediment samples were collected on the Volta Lake at two (2) km interval for a stretch of about 24 km towards Yeji. Water samples were collected with a 2.0 L Van-Dorn water sampler from 0.5 m below the surface and 0.5 m above the sediment, into pre-cleaned 1000 ml plastic sample bottles. The sample bottles were first rinsed with the lake water before collecting the samples. Surface water from River Sene was also sampled by first rinsing the bottle and gently lowering the sample bottle in horizontal position into the water with the mouth of the bottle directed upstream, taking measures to avoid suspended/floating debris. Thus, surface water samples were collected at the subsurface in order to avoid the colloidal layer as this can influence the concentration of certain parameters. River Sene (about 90 km) was sampled at four (4) km interval where there was access and sediment samples collected as well. In addition, samples were taken from the proposed pumping stations. *In-situ* readings were taken for pH, TDS, conductivity, temperature, time of sampling, water depth, dissolved oxygen and transparency.

Separate sediment samples were collected with an Ekman grab for heavy metals and pesticides analyses. The samples were labelled, preserved with nitric acid (for metal analyses) and kept in insulated boxes preserved with ice. All the collected samples were transported to the CSIR – WRI laboratories in Accra for analyses.

Key results achieved so far

The results indicated that the pH values of River Sene, the Volta Lake and at the pumping stations were within WRC Target Water Quality Range (TWQR) of 6.5 to 8.5 pH units which indicated that the water was satisfactory for irrigation. Turbidity values recorded from the Volta Lake ranged from 2.79 – 6.10 NTU with only one site exceeding the water quality guideline value of 5 NTU. Turbidity values recorded from River Sene samples ranged from 1.29 – 61.9 NTU with the midstream towards the upstream (SR13 – SR21) recording significantly higher (p <0.05) turbidity readings. Turbidity ranged from 2.89 to 39.3 NTU with a mean of 14.4 NTU at the pumping stations. All the total suspended solids (TSS) values recorded from the various sampling stations were less than the TWQR threshold of 50 mg/L. Sodium, chloride, potassium, total hardness, calcium and magnesium concentrations were all low in all the samples collected from the Pumping Station, River Sene and Volta Lake and thus acceptable and suitable for irrigation. Concentrations of the measured nutrients (nitrate, sulphate, phosphate, ammonia and nitrite) from both the Volta Lake, River Sene and the pumping stations were mostly below detection limits and where detected, the levels were quite low and within the available guidelines. The mean dissolved oxygen (DO) for all the sampling sites were above 5.0 mg/L indicating that all the water bodies were well oxygenated.

The sodium adsorption ratio (SAR) values for the Volta Lake (0.285 – 0.401), River Sene (0.354 – 0.707) and Pumping Stations (0.286 – 0.341) were below the TWQR for SAR (i.e. 2.0). The sodium adsorption ratio (SAR) is an irrigation water quality parameter used in the management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural irrigation. Using Solway's water quality index, both the Volta Lake and River Sene could be classified as Class one (1) surface waters and conform to the available FAO irrigation water guidelines.

Conclusion

It was concluded from the study that both surface waters were in a good state and the results did not point to pollution at the time of the study.

3.2.1.7 Photoelectrochemical Degradation of Bisphenol A in Water Using Expanded Graphene-Polypyrrole-Magnetite Nanocomposite Electrode

(Research Team: Dr William W. Anku – Principal Investigator, Dr Onoyivwe Monday Ama, (b) Dr Uyiosa Osagie Aigbe, (c) Dr Otolorin Adelaja Osibote, (d) Dr Kaushik Pal)
Collaborating Agencies: DST-CSIR National Center for Nanostructured Materials, Pretoria, South Africa; Cape Peninsula University of Technology, Cape Town, South Africa; Chandigarh University, Punjab, India

Introduction

Water quality deterioration and absence of potable water supply is an issue of great concern in recent years due to the pollution of water bodies with organic contaminants. Bisphenol A (BPA) is a synthetic organic compound used in the production of polycarbonate plastics which are components of food containers. Polycarbonate effluents contain high amounts of BPA which can cause prostate cancer, cardiovascular diseases, diabetes mellitus, hormonal imbalance, liver and reproduction problems. Several methods including physical adsorption, chemical and biological degradation are applied for the removal of these pollutants. However, these methods are either inefficient or give rise to hazardous by-products resulting in secondary contamination. An appropriate technique for the removal of these pollutants is photoelectrochemical degradation.

Objectives

The study was aimed at investigating the removal of bisphenol A from wastewater using expanded graphene-polypyrrole-magnetite nanocomposite (EG-PPy/Fe_3O_4) electrode. The objectives were to:

i. synthesise an EG-PPy/Fe_3O_4 composite electrode;
ii. characterize the synthesised electrodes; and
iii. assess the potential of the synthesised photoelectrode to remove bisphenol A in wastewater.

Activities undertaken

Activities carried out in the reporting period included synthesis and characterization of the EG-PPy/Fe_3O_4 electrode. The characterization was done using SEM-EDX spectrometer. Photoelectrochemical degradation experiment was then conducted. Photoelectrochemical activity of the synthesized photoanodes was studied in a photo-reactor containing H_2SO_4/HNO_3, the working electrode (1 cm × 1 cm) Ag/AgCl in a (saturated KCL), (3.0 MKC) as the reference electrode, and platinum foil as the counter electrode. The dye degradation was performed under constant magnetic stirring for 2 hours. An amount of 5ml of the dyes were extracted at every 20 min interval and the concentrations of the dyes remaining in each extracted dye solution were determined using a PerkinElmer model Lambda 35 UV–Vis spectrophotometer.

Key results achieved so far

As shown from the SEM-EDX Analysis, the PPy was observed to encapsulate the Fe_3O_4 nanoparticle. The SEM image of the EG-PPy/Fe_3O_4 showed successful decoration of PPy/Fe_3O_4 on the EG sheets. The EDX result showed the presence of C, O, and Fe, confirming the successful synthesis of the EG-PPy/Fe_3O_4 nanocomposite (Fig. 3.2.3)

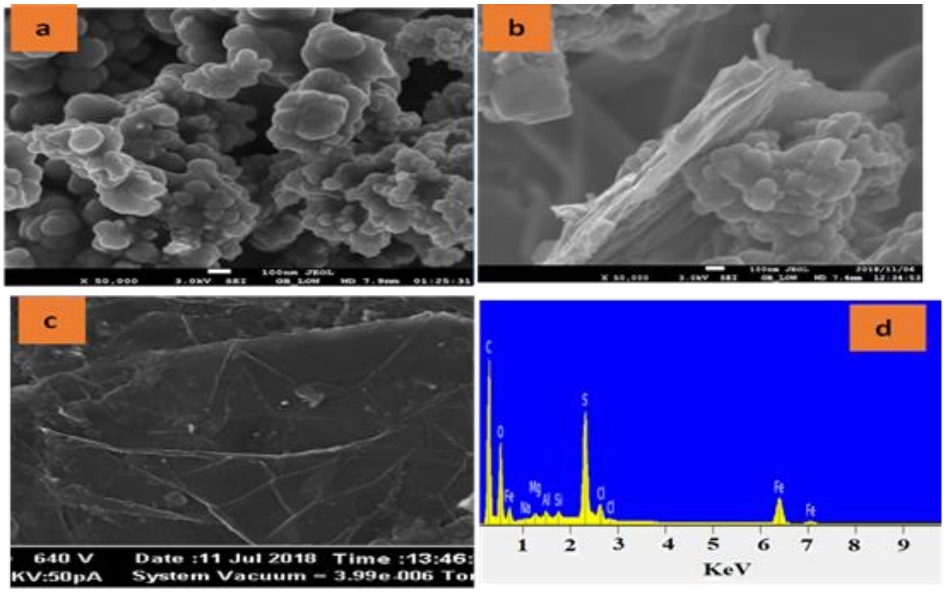


Fig. 3.2.3: SEM Image of (a) Fe_3O_4, (b) PPy/Fe_3O_4, (c) EG-PPy/Fe_3O_4 and (d) EDX of EG-PPy/Fe_3O_4.

The cyclic voltammogram analysis of EG and EG-PPy/Fe_3O_4 electrodes showed that the EG-PPy/Fe_3O_4 electrode displayed a higher current than the EG electrode. Therefore, the EG-PPy/Fe_3O_4 electrode was expected to be more effective (Fig. 3.2.4).

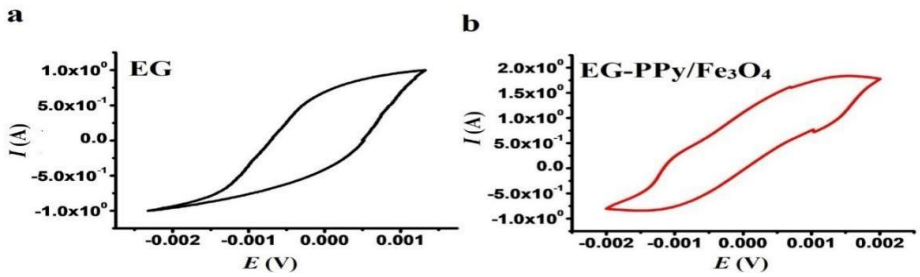


Fig. 3.2.4. Cyclic voltammetry (CV) of (a) EG and (b) EG-PPy/Fe_3O_4

The result of the EG-PPy/Fe_3O_4 photoelectrode showed that the original peak intensity of the dye (black coloured peak) decreased with increasing time indicating the degradation of the dye with progression of time within the wavelength of 250 to 300 nm. The effectiveness of the degradation of BPA was carried out with three different photoelectrodes and techniques as shown in Fig.3.2.5 (b) and (c), respectively. The degradation efficiency of BPA was monitored in terms of time against degradation. In Fig.3.2.5 (b), it could be observed that EG-PPy/Fe_3O_4 yielded a better degradation efficiency. In terms of the techniques, the photoelectrochemical technique showed a better degradation efficiency (Fig.3.2.5 c).

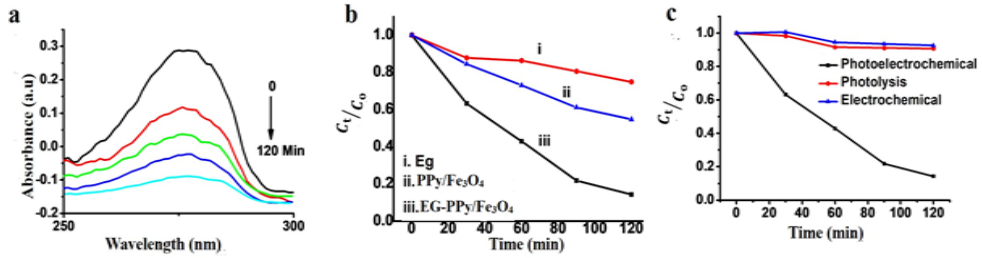


Fig.3.2.5: (a) UV-V is degradation profile of BPA dye in first 120 mins by EG-PPy/Fe_3O_4 electrode (b) BPA degradation efficiencies of (i) EG (ii) PPy/Fe_3O_4 (iii) EG-PPy/Fe_3O_4 and (c) Degradation profile of BPA on the bases of photolysis, electrochemical and photoelectrochemical degradations

3.2.1.8 Surface Water Ecological Studies at Newmont Golden Ridge Limited, Akyem Mine

(Research Team: Dr Ruby Asmah – Principal Investigator, Dr Kwadwo A. Asante, Rev'd Dr Gloria Naa Dzama Addico, Mrs Regina Banu, Mr Theodore Quarcoopome, Dr Samuel Armoo, Mr Godwin Amegbe, Mr Victor Mante, Mr Acheampong Addo, Mr Divine Hotor, Mr Bright Awunor, Mr Jonas Darkey)

Introduction

Newmont Golden Ridge Limited (NGRL), Akyem Gold Mine is a Greenfield open pit operation located in the Birim North District of the Eastern Region of Ghana. The site is located about three (3) km west of the district capital, New Abirem. Within the catchment area of the mine are two major rivers; the Pra and the Mamang Rivers. There is a water storage dam (WSD) at the plant site which is a source of water for mineral processing and about 309 hectares. Water in the WSD is sourced from the Pra River and from surface run-offs. As part of its commitment to safe mining and sustainable exploitation of natural resources, Newmont Golden Ridge Limited (NGRL), Akyem Gold Mine, contracted the Institute to undertake monitoring of the two major rivers, the Pra and the Mamang rivers within the catchment area of the mine and report findings on regular basis.

Objectives

The main objective of the study was to assess the ecological status of the water storage dam (WSD) and to reduce the density of fish stock in the facility.

The specific objectives were to:

i. determine the quality of water in the WSD and the main sources of water to the WSD; including the Pra River and water from pit dewatering and how these vary on seasonal basis
ii. determine the quality of sediment in the WSD and how these vary on seasonal basis.
iii. assess the ecological state of the WSD in relation to the types, diversity and relative abundance of fauna and flora in the water and sediment and how these vary on seasonal basis.
iv. assess the distribution and relative abundance of water borne disease vectors in the WSD and the prevalence of water-related diseases in the closest communities.
v. identify the types of fish species and diversity, fish composition and community structure, as well as condition factor (K) or physiological well-being of the fish.
vi. determine the health status of fish in the WSD.

Activities undertaken

In the year under review, water, phytoplankton, macrophytes, macroinvertebrates and fish samples were collected from the WSD and sampling stations on the Pra and Mamang Rivers. The surface water samples were collected at the subsurface in order to avoid the colloidal layer as this can influence the concentration of certain parameters. Temperature, pH, conductivity and dissolved oxygen were measured *in situ* with a WAGTECH Maji Multi parameter (WAG-WE5800) equipment. Samples for dissolved metal analyses were collected and filtered into pre-cleaned plastic bottles and acidified with nitric acid to a pH < 2 for the dissolved metals to remain in solution. Sediment samples from the WSD and the two rivers were also collected using an Ekman grab into polyethylene bags. All the collected samples were stored in insulated boxes with ice and transported to the CSIR-WRI laboratories in Accra for analyses. The physico-chemical parameters were determined according to the methods described in the Standard Methods for the Examination of Water and Wastewater (APHA-AWWA-WEF, 2017). Water samples for metal concentration were digested with concentrated nitric acid, while sediment samples were digested with nitric acid and hydrogen fluoride combination in an Ethos Microwave Digester prior to analysis by the Atomic Absorption Spectrometer (AAS). All metals were analysed by the AAS (using flame or graphite furnace technique, and cold vapour technique specifically for Hg).

Results achieved so far

All the pH values fell within the Environmental Protection Agency (EPA, Ghana, 2003) acceptable range of 6 – 9 pH units for effluent quality guidelines for discharges into natural water bodies. The measured turbidity values were below the EPA guideline of 75 mg/L and therefore satisfactory. The total suspended solids values were between 5.00 and 8.00 mg/L which were below the EPA effluent quality guideline of 50 mg/L. The average total dissolved solids value of 174 mg/L was below the EPA guideline value of 1,000 mg/L. Total hardness, calcium, magnesium, sodium, potassium and chloride concentrations measured were within the accepted values on drinking water guidelines. Dissolved oxygen concentrations varied between 6.44 and 7.72 mg/L for the surface waters and 6.30 and 7.40 mg/L for the bottom waters making the WSD oxygenated. In this assessment, BOD values ranged between 3.10 and 3.90 mg/L while COD varied from 28.8 to 73.6 mg/L. Both BOD and COD concentrations were below the EPA thresholds of 50 and 250 mg/L, respectively. Concentrations of nutrients were low in the WSD. Free and total cyanide were not detected at any of the three sites in the WSD, thereby satisfying the EPA guidelines. Concentrations of all the analysed trace metals were either low or below the detection limits.

The main fish species comprised a mixture of young and mature adults all of which were in very good physiological conditions. Based on abundance, benthic omnivores were dominant followed by piscivores and aufwuch-detritus and herbivores with semi pelagic omnivores being the least represented. The poor representation of forage fish biomass gave indication of imbalance and instability in the food web. Species diversity index and species evenness parameters were high whilst species richness was average indicating altogether stable ecology and healthy environment. No water-related disease vectors were found in the WSD but a pool of water serving as breeding ground for mosquitoes was found near the Pra River at the pumping station. Trace metal levels in edible fish from the WSD were either not detected or very low and within ranges suitable for human consumption.

Impact of the study on national economy

The results of the study would help the company successfully manage the environment to ensure sustainable development of the natural resources.

3.2.1.9 Driving Eco-Innovation in Africa: Capacity Building for a Safe Circular Water Economy (RECIRCULATE)

(Research Team: Dr. Kwadwo Ansong Asante – Principal Investigator, Dr. E. O. Bekoe, Dr. A. Y. Karikari, Mr. Mark O. Akrong, Mr. Gabriel Appiah, Mr. Samuel Kanati, Mr. Bright Laboan)
Collaborating Agencies: CSIR Institute of Industrial Research (CSIR-IIR), CSIR Crops Research, Institute (CSIR-CRI), Lancaster University

Introduction

Recirculate is an international collaboration led by Lancaster University with partners from Ghana (Council for Scientific and Industrial Research), Nigeria (University of Benin), Botswana (Botswana International University of Science and Technology), Kenya (African Technology Policy Studies Network), Malawi (National Commission for Science and Technology) and Zambia (Copperbelt University). The Recirculate project supports new partnership-based approaches to enable African Researchers make transformational impact through working with, in and for their communities and developing robust, durable and equitable partnerships with UK researchers. This is carried out through solution-focused research, interdisciplinary co-designed research and capacity building.

There are five (5) Work Packages (WP) under the Recirculate Project. In Ghana, CSIR is focusing on two work packages, WP2 and WP3. Work Package two (2) is being executed by CSIR-Water Research Institute (CSIR-WRI) and CSIR-Institute of Industrial Research (CSIR-IIR) while Work Package three (3) is being done by CSIR-Crops Research Institute, CSIR-WRI and CSIR-IIR. What makes RECIRCULATE so unique is recognizing the importance of research in entrepreneurial learning and knowledge exchange in co-creating appropriate solutions for Africa.

Objective

The overall goal was to grow capacity and capability in Africa's eco innovation community.

Activities undertaken

Work Package Two (2) (Water for Sanitation and Health)
Environmental Monitoring; Drain Water and Drinking Water Quality at Madina Zongo and Gbegbeyise, Accra

This is an important part of the Lancaster University-led Global Challenges Research Fund (GCRF) sponsored project RECIRCULATE: Driving Eco-Innovation in Africa – capacity building for a safe circular water economy. This involved weekly monitoring of drain water in 2 selected communities, Madina Zongo in the Ga East Municipality and Gbegbeyise, near Dansoman in Ablekuma West Municipality, all in the Greater Accra region of Ghana, in addition to assessing the drinking water quality from the Ghana Water Company Limited (GWCL) distribution point to their homes (via polytanks, containers and cups, sachet water) in order to trace where contamination begins, a term referred to as "the LAST 100 Metres". The project installed two (2) weather stations in the two study communities to complement and validate some parameters measured *in-situ* during sampling. Drinking water sampling in the two communities commenced in September, 2020 and ended in March, 2022.

Work Package three (3) (Water for Food Production)

Irrigation scheduling using CROPWAT

Cropwat module was used to compute amount of water and time of water application.

Soil sampling/gravimetric moisture determination
Soil samples were taken before and a day after each irrigation schedule, to monitor field moisture content.

Stomatal conductance and Leaf Relative water content measurement
Stomatal opening and leaf water status were measured to know the physiological responses of plants.

Plant tissue/soil sampling/Chlorophyll content measurement
Older leaves of the plant and soil were sampled every two weeks to analyse for nitrate (NO_3) and ammonia (NH_4) concentrations to ascertain N-uptake dynamics**.** Chlorophyll B concentration was also measured in that regard.

Plant growth and biomass measurement
Measurement on maize plant height was done every week and taken from the surface of the soil to the tip of the new/last emerging leaf while above ground biomass was monitored every 30 days.

Grain harvesting and yield quantification
Maize cobs were harvested, shelled and grain quantified according to replicates and treatments.

Results achieved so far
***Work Package three (3)*:** Anaerobic digestion of bio-waste results in two by-products; biogas and digestate. The latter is rich in nutrients that can be used in crops production, improve poor soil fertility and mitigate recent fertilizer scarcity in Ghana and Africa at large. However, to the best of our knowledge the fertilization potential of digestate to replace the scarce synthetic fertilizers in West African cereal crops production systems has not been explored. Two years of agronomic field trials were conducted to compare the performance of digestate and synthetic (nitrogen-phosphate-potassium = NPK) fertilizer on maize nitrogen (N) uptake, growth and grain yield under rain-fed, tropical crops production system. Digestate combined with NPK (D+NPK) treated plants had the highest leaf mineral N uptake followed by sole nitrogen-phosphate-potassium (NPK), sole Digestate (D) and the un-amended control. D+NPK, D and NPK recorded same stem height, grain mineral N uptake and grain yield were higher than the un-amended control. Digestate from waste valourization technologies has the agronomic potential to substitute synthetic fertilizers and will help bridge fertilizer needs in African crops production systems as well as closing the nutrient loop.

3.2.1.10 BANK OF GHANA: Borehole Drilling at Selected BoG Offices in Hohoe and Takoradi

(Research Team: Mr. Collins Okrah – Principal Investigator, Mr. Eric Darko and Mr. Felix Ofosu)

Introduction
The cost incurred by the Bank of Ghana (BoG) to provide water to meet the daily water demand of the staff and the numerous customers has had a large financial burden on their annual budget. To solve this problem, the management of BoG decided to drill boreholes for regular and potable water supply to the facility in Hohoe and Takoradi. Consequently, BoG signed a contract in June 2022 with CSIR-WRI to provide a borehole facility and supply treated water to the bank.

Objectives

The objectives were:

i. drilling and construction of high yielding borehole; and
ii. installation of pump and treatment system on the boreholes at Hohoe and Takoradi Regional Offices.

Activities undertaken and key results achieved so far

In the reporting year, the selected potential points at Hohoe and Takoradi BoG Regional Offices were drilled to the recommended depths of 75 m and 50 m, respectively. The boreholes were cased to the bottom, and the airlift yield measured 80 lpm and 60 lpm at Hohoe and Takoradi, respectively. The water strike zones were fitted with uPVC screens, as shown in Table 3.2.3.

Table 3.2.3: Strike zones at the study areas

No	Site	GPS Cord.	Depth (m)	Screen	Yield (lpm)
1	BoG Office, Takoradi	4.89439N, 1.75263W	50	16-22, 28-34, 40-46	70
2	BoG Office, Hohoe	7.15429N, 0.47744E	70	35-48, 54-66	75

Samples of the water were taken to the laboratory for physico-chemical analysis to assess their suitability for potable use. As a result of the successful drilling of the boreholes, a Pedrollo 1.5-hp submersible pump has been installed on the boreholes to withdraw the groundwater for treatment.

Conclusion

The major aquifer zones of the borehole were intercepted at depths ranging from 16 to 46 m at Takoradi and 35 to 66 m at Hohoe. Manganese was the only parameter that affected the water quality at Hohoe. After treatment with a reverse osmosis system, the quality of the water improved to an acceptable level to produce potable water. The treated water can be used for any purpose, including drinking.

Impact of the study on national economy

The provision of water from the borehole facility ensures a sustainable supply to serve the staff of the bank and clients of the bank on a daily basis.

3.2.1.11 Monitoring and Maintenance of Water Treatment Facility at the Regional Office of Bank of Ghana, Tamale

(Research Team: Dr. Emmanuel T. Mensah – *Principal Investigator*, Gerard Quarcoo, Zita Naangmenyele Abuntori, *Emmanuel* M. Obeng Bekoe, Abdul Latif Salifu)
Collaborating Agencies*: *Bank of Ghana, Tamale

Introduction

Adequate supply of potable water is one of the prerequisites for a healthy life. The suitability of water for various purposes (drinking and domestic use) is expressed by its quality. These purposes cannot be achieved if the water quality is deteriorated by contaminants. Drinking water containing pathogenic organisms and toxins could pose risk to human health. Hence, continuous monitoring of borehole water quality and the treatment system is necessary.

Objectives

The objectives were to:

i. monitor the water treatment devices and assess its efficiency by examining the treated water quality for potable use;
ii. assess the bacteriological and physico-chemical quality of the treated water and compare findings with WHO guidelines and Ghana standards for its potability; and
iii. provide technical advice and recommendations.

Activities undertaken and results achieved so far

Activities undertaken included monthly changing of water filters and conducting quarterly bacteriological and physico-chemical water quality analysis.

At the end of the study, pathogenic organisms such as Total and Faecal coliforms, *Escherichia coli, Faecal streptococcus, Clostridium* spp. *and Pseudomonas aeruginosa* were not found in the water samples. The total heterotrophic bacteria recorded in all the water samples collected within the period was within safe limit for drinking purposes. All the parameters conformed to the Ghana Standards GS 175-1(2017) and WHO guidelines (2017) for drinking water (Table 3.2.4).

Table 3.2.4: Summary of laboratory analyses

Sample Identity	**Total Coliform (cfu/100ml)**	**Faecal Coliform (cfu/100ml)**	***E. coli* (cfu/100ml)**	***Enterococci* (cfu/100ml)**	***Clostridium spp.* (cfu/1ml)**	***Pseudomonas aeruginosa* (cfu/100ml)**	**Total Heterotrophic Bacteria (cfu/1ml)**
BoG (kitchen)	0	0	0	0	0	0	98 – 330
BoG (Main premises)	0	0	0	0	0	0	198 – 405
Ghana Standards	0	0	0	0	0	0	-
WHO Guidelines	0	0	0	0	0	0	500

Conclusion

The results gathered indicated that the water treatment system installed is efficient and the water is bacteriologically safe for potable use.

Impact of the study on national economy

The determination of bacterial contaminants is relevant since it's an indicator of faecal contamination. The study provided evidence of the bacteriological quality of water consumed at the facility and contributed to ensuring good health and well-being of consumers at the facility.

3.2.1.12 Assessment of the Trophic Status of 6 Freshwater Lakes in Ghana Using Dissolved Inorganic Nitrogen (DIN) Concentrations

(Research Team: Humphrey F. Darko – Principal Investigator, Dr. K.A. Asante, Victor Mante, Michael Afram, Jude Quansah)
Collaborating Agency: Water Resources Commission (WRC)

Introduction

Eutrophication causes aquatic environment degradation as well as problems for different purposes of water uses. The most profound are water and environmental quality degradation, algal blooms, reduced water clarity, oxygen depletion, alteration of taste and odour, fish deaths, loss of biodiversity including ecosystem services and negative impacts on human health. Eutrophication also reduces aesthetic values of waterbodies and increases management cost issues. Phosphorus(P) and nitrogen (N), in the form of phosphate and nitrate, respectively, are considered responsible for eutrophication degradation**.** Therefore, continuous monitoring of N and P in our lakes to assess eutrophication is essential for the effective management of our lakes for drinking water abstraction and other uses of the water.

Objective

The aim of the study was to investigate seasonal nitrate and phosphate concentrations of six (6) freshwater lakes in Ghana and use dissolved inorganic nitrogen concentrations to determine their trophic status.

Activities undertaken

In the year under review, water samples were collected from the Weija Reservoir, Lake Bosomtwe, Barekese Reservoir, Baafikrom Reservoir, Brimsu Lake, and Lake Volta (Main Volta) at Kpong, and brought to the laboratory for analysis of physico-chemical parameters using standard procedures. The samples were collected in February and July 2022 to represent the dry and wet seasons. The results of the analysis are shown in Tables 3.2.1 and 3.2.2.

Key results achieved so far

The trophic status of the lakes was determined using Ghana Raw Water Criteria and Guidelines for Protection of Aquatic Ecosystems. Using these criteria, lakes with DIN values <0.2 are oligotrophic; lakes with DIN values from 0.5 – 2.5 are mesotrophic, those with DIN values from 2.5 – 10 are eutrophic; and those >10 are hypertrophic. In the dry season, Weija Reservoir, Brimso Reservoir and the Volta Lake (Main Volta) were observed to be mesotrophic in the order Brimso Reservoir > Weija Reservoir > Volta Lake, while Baafikrom Reservoir, Barekese Reservoir and Lake Bosomtwe were oligotrophic in the order Baafikrom Reservoir > Barekese Reservoir > Lake Bosomtwe. In the wet season, Weija Reservoir, Brimso Reservoir and Barekese Reservoir were mesotrophic in the order Barekese Reservoir > Brimso Reservoir > Weija Reservoir. In the wet season, Lake Bosomtwe, Baafikrom Reservoir, and Volta Lake were oligotrophic, and were in the order Lake Bosomtwe > Baafikrom Reservoir > Volta Lake.

The Redfield ratio of 7:1 (mass ratio) of DIN: SRP indicated P limitation in Weija Reservoir, Brimso Reservoir, and the Volta Lake in the dry season. This means that any additional input of P into the lakes may stimulate algal blooms that can shift the lakes from mesotrophic to eutrophic conditions, further degrading the water quality.

Again, the Redfield ratio (i.e., the balance between N and P is an important ecological indicator of eutrophication and ecosystem productivity) of Weija Reservoir, Brimso Reservoir and Barekese Reservoir in the wet season indicated P limitation. Any additional input of P

into the lakes could lead to harmful algal blooms that could shift the lakes from mesotrophic to eutrophic conditions, causing degradation of water quality and other negative environmental impacts on the ecosystem.

Table 3.2.1: Dissolved Inorganic Nitrogen (DIN), PO_4-P and DIN: SRP values for February 2022

Lake/February 2022	NO_2-N	NO_3-N	NH_3-N	DIN	PO_4-P	DIN: SRP
Weija Reservoir	0.12	0.42	0.81	1.34	0.06	21.0
Baafikrom Reservoir	0.002	0.20	0.13	0.34	0.12	2.8
Brimso Reservoir	0.04	0.56	1.06	1.66	0.13	12.7
Barekese Reservoir	0.02	0.09	0.03	0.15	0.08	1.9
Lake Bosomtwe	0.004	0.03	0.001	0.04	0.12	0.31
Volta Lake (Main Volta)	0.003	0.31	0.22	0.53	0.06	7.9

Table 3.2.2: Dissolved Inorganic Nitrogen (DIN), PO_4-P and DIN: SRP values for July 2022

Lake/July 2022	NO_2-N	NO_3-N	NH_3-N	DIN	PO_4-P	DIN: SRP
Weija Reservoir	0.001	0.001	0.81	0.81	0.03	30.1
Baafikrom Reservoir	0.001	0.27	0.13	0.41	0.06	7.0
Brimso Reservoir	0.001	0.12	1.06	1.18	0.06	19.0
Barekese Reservoir	0.283	0.63	0.11	1.03	0.09	10.8
Lake Bosomtwe	0.11	0.36	0.001	0.47	0.16	3.0
Volta Lake (Main Volta)	0.007	0.11	0.001	0.11	0.49	0.24

Conclusion
It was concluded from the study that it was necessary to reduce N and P from human activities into the lakes.

Impact of the study on national economy
The information provided by the study is essential for developing best management practices to reduce N or P transport from land into the lakes, and for predicting future trends in eutrophication of the lakes.

3.2.1.13 Removal of Iron and Manganese from Aqueous Solution Using Brown Coal
(Research Team: Dr Franklin Obiri-Nyarko – Principal Investigator, Mr. Jude Ofei Quansah, Dr. Anthony Yaw Karikari, Sandra Asare)

Introduction
High levels of iron and manganese in drinking water production cause aesthetics and operational problems such as bad taste, colour, staining, pipeline blockage, corrosion of the metallic parts, and deposition in the water leading to high turbidity and high production costs. In addition, excessive iron and manganese concentrations in water above the WHO acceptable concentrations of 0.3 mg/l and 0.4 mg/l, respectively, for human consumption may result in life-threatening diseases such as diabetes, pulmonary track disorder, heart failure, Parkinson illness, bronchitis and hinder childhood development.

Objectives
The study was conducted to investigate the efficacy of Brown Coal as a low-cost adsorbent in removing Iron and Manganese from water under batch experimental conditions.

Activities undertaken

During the year under review, kinetic, equilibrium, thermodynamic and solution pH adsorption experiments were conducted for better grasp of the adsorption characteristics and the mechanisms underpinning iron and manganese removal by the brown coal. The brown coal (BC) was obtained from a local super market located in the central part of Accra. BC was washed with distilled water to remove undesirable particles and dried at room temperature for 3 hours. After drying, BC was sieved using a number 200 standard soil sieve (75 µm) and kept in a desiccator to prevent contamination. Batch experiments were performed by reacting 1.0 g of BC with 50 mL of iron and manganese standard solutions (10 mg/L) in a 50 mL conical tube at room temperature (25 °C) and an agitation speed of 150 rpm in a shaking incubator. After the reaction, using a vacuum pump (FB 70155, Fisher band) the mixtures were filtered to separate BC from the Iron and Manganese solutions. The residual Iron and Manganese concentrations were analyzed using an Atomic Adsorption Spectroscopy (Agilent Technologies 240 FS 200 Series AAS).

Results achieved so far

The 1/n values for Iron and Manganese were 0.714 and 0.770, respectively. n values greater than one means it is good (favourable). Therefore, in a system where there is a simultaneous adsorption of Iron and Manganese onto Brown Coal, removal of Iron will be favoured more since it has a higher n value (1.40) than Manganese (1.30). This is conforming with the K_F values of 0.053 and 0.046 for Iron and Manganese, respectively. Also, from the Langmuir isotherm, Q_m for Iron was 1.89 mg/g which is greater than that of Manganese (1.74 mg/g), suggesting that Brown Coal has greater adsorption ability for Iron than Manganese. The 1/n and K_F values obtained from the slope and intercept of ln (Ce) versus ln (qe) are shown in Table 3.2.6.

Table 3.2.6: Langmuir and Freundlich constants for Iron and Manganese on Brown Coal

Adsorbate	Langmuir isotherm				Freundlich Isotherm		
	Q_m (mg/g)	K_L(L/mg)	R^2		K_F (L/g)	$1/n$	R^2
Iron	1.89	0.017	0.747		0.053	0.714	0.987
Manganese	1.74	0.015	0.928		0.046	0.770	0.971

Conclusion

It was concluded that based on the equilibrium data, the adsorption isotherm was better fitted to the Freundlich model indicating a heterogeneous coverage of Iron and Manganese on the outer surface of Brown Coal. The maximum adsorption of Iron and Manganese from the Langmuir isotherm was 1.89 mg/g and 1.74 mg/g, respectively. In general, the results of this investigation showed that Brown Coal has high adsorption capacity and can be used as an efficient and cost-effective adsorbent for the removal of Iron and Manganese from ground water.

3.2.1.14 Microplastics in Sediment, Cultured and Wild Fish in the Lower Volta Basin in Ghana

(Research Team: Dr. Pennante Naa Ayikailey Bruce-Vanderpuije – Principal Investigator, Dr. Ruby Asmah, Miss Yaa Asabea Agadzi, Ishmael Norvimagbe)
Collaborating Agencies: Institute of Coastal Environmental Chemistry, Hereon Zentrum, Geestatcht, Germany

Introduction

Knowledge of the fate, spatial distribution, and transport pathways of microplastics in the Ghanaian environment is limited. There are possibilities of plastic waste inputs from households, industrial wastewater effluent discharges, and waste plastics from aquaculture equipment/activities contaminating major rivers and lakes; which are sources of freshwater fishes in Ghana. Most frequently detected polymer types in marine and freshwater environments include polyethylene and polypropylene.

Objective

The study sought to examine the spatiotemporal distributions and types of microplastics (MPs) in caged/cultured fish, wild fish, sediments, and in the water of the lower Volta Lake.

Activities undertaken

During the reporting period, sampling of cage cultured and wild fishes was conducted over wet and dry seasons at the Lower Volta River in Ghana, between the months of April and August, 2022, at Agodorme (Volta Region), Kpong and Asikuma (Eastern Region). A total of 700 fish samples consisting of 23 fish species were sampled. In addition, sediment samples were collected from the various sites using an Ekman grab sampler. All samples were stored on ice in an ice chest, and transported to the laboratory for analysis.

Key results achieved so far

The study showed that there was significant difference ($P < 0.05$) between the abundance of MPs in the gills and in the guts of fish from each site and for each season (Fig. 3.2.6 a and b). The percentage (%) abundance of MPs per gram estimated was higher in the gills than in the guts for both cultured and wild fishes at all sites for both seasons, but vice versa for the wild at Kpong (Fig. 3:2.7 a, b and c). Different shape types of MPs, and their distributions, were detected in gut and gill tissues. Fibres were the predominant shape of MPs identified in the two organs, followed by fragments and then sheets. Fibres were most abundant in counts and in % for both cultured and wild fishes in both seasons at all sites while sheets were the least and they were only detected in the cultured species at one site in the wet season. No beads and foams were detected. More fibres were observed in the gills of cultured fishes than those of the wild. The abundance of MPs in the sediment between the 3 sampling sites ranged from 198-459 MPs/180 g and a mean abundance of 346 ± 133.97 MPs/180 g for the dry season, that for the wet season ranged from 137-487 MPs/180 g, with a mean of 304 ± 175.55 MPs/180 g. A summary of the number/abundance of MPs in the various sampling sites is presented in Table 3. 2.5.

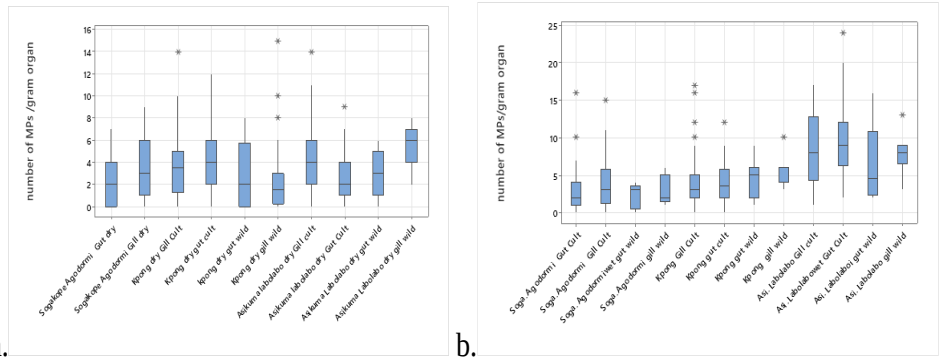
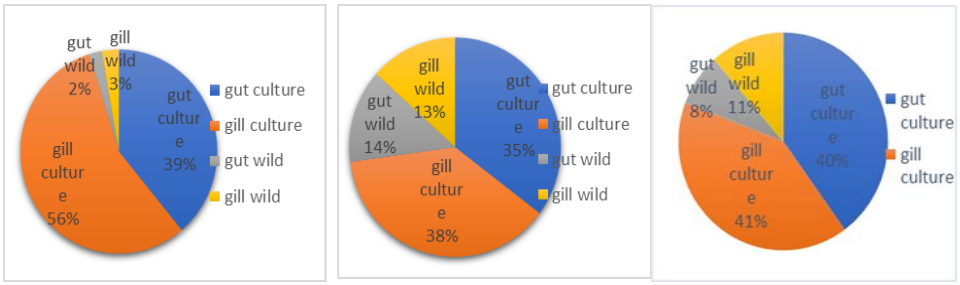


Fig. 3.2.6: Number of MPs found in different tissues; gut and gill, from cultured and wild source at each site in the (a) dry season and (b) wet season



(a) Sogakope Agodormi (b) Kpong (c) Asikuma Labolabo

Fig. 3.2.7: Percentage abundance of MPs in guts and gills of wild and cultured fish at the study areas

Table 3.2.5: Summary data on number of microplastics in sediments at the various sampling sites in the Lower Volta Basin

Location	**Dry season**	**Wet season**
Sogakope Agodormi	Abundance (MPs/60g)	Abundance (MPs/60g)
Upstream	154	304
Midstream	154	174
Downstream	151	9
Total	459	487
Mean ±std	153 ± 1.73	162.33 ± 147.85
Kpong University Farm		
Upstream	34	32
Midstream	23	9
Downstream	25	68
Landing site	116	28
Total	198	137
Mean ±std	49.5 ± 44.95	34.25 ± 24.64
Asikuma Labolabo		
Upstream	218	45
Midstream	38	84
Downstream	125	159
Total	381	288
Mean ± std	127 ± 90.02	96 ± 57.94

std = standard deviation

3.3 BIOMEDICAL AND PUBLIC HEALTH

3.3.1 BIOMEDICAL, BIOSAFETY AND ETHICS

3.3.1.1 Developing a Novel Tool Using miRNA for Diagnosis of Female Genital Schistosomiasis

(Research Team: Joshua Adjah – Principal Investigator, Ruth Ayanful-Torgby – PhD, Dr. Elias Asuming-Brempong, Dr. Rachida Tahar, Prof. Daniel Boakye, Manfred Asiedu)
(Collaborating Agency: Noguchi Memorial Institute for Medical Research)

Introduction

Urogenital schistosomiasis (US) is a chronic parasitic disease that is endemic in Ghana and is caused by *Schistosoma haematobium*. Female Genital Schistosomiasis (FGS) is a pathology of UGS due to the parasite's ova present in the upper and/or lower genital tract and affects about 56 million females (girls and women) in Africa. FGS is difficult to diagnose, presents unspecific pathological symptoms, and is implicated in risk associated with certain sexually transmitted infections (STIs) and gynecological disorders if left untreated. The WHO report on FGS in 2015 indicated that most clinicians were unaware of the disease because it is not described in the medical textbooks and treatment guidelines in schistosomiasis endemic countries. Current challenges in treating schistosomiasis and its related pathologies are due to a lack of biomarkers or rapid diagnostics to monitor the disease progression and subsequent prevention in the end stages including immune dysregulation and tissue damage caused by the migrating worm or eggs dislodged sites (tissues or organs). Therefore, there is a need for the development of effective tools for the early diagnosis and prognosis of disease pathologies.

Objectives

The aim of the study was to develop a miRNA signature protocol for the grading of different stages of FGS to enhance prompt, accurate diagnosis and treatment at health facilities. The specific objectives were to:

i. determine the prevalence of FGS among female populations in three schistosomiasis-endemic communities along the Weija Dam in Greater Accra, Ghana;
ii. assess miRNA expression profiles in samples ranging from mild to severe cases of FGS; and
iii. generate information on FGS that will help enhance the accuracy of diagnosis in schistosomiasis endemic regions in Ghana.

Activities undertaken and results achieved so far

Activities carried out in the reporting period included selection of 387 participants and screening 282 aged 15 to 50 years from three schistosomiasis endemic communities (Tomefa, Adakokpe and Torgakokpe) along the Weija Dam. All participants assented to the study by signing written informed consent (above 18 years) or parental consent (below 15 years of age) and were not virgins or pregnant. The participants were screened for urogenital schistosomiasis. Only nine (9) participants (1.04%) had genital schistosomiasis (*S. haematobium* eggs in their urine samples). Fifty (50) participants including seven (7) individuals with urogenital schistosomiasis were selected for cervicovaginal and blood sampling. Vaginal cytological examinations and urine samples were examined for *Schistosome* eggs and cell morphological changes. The summary of the preliminary results is shown in Fig. 3.3.1. Whole blood in RNA preservation has been sent to an advanced facility for miRNA sequencing and further transcriptomic analysis.

Impact of the study on national economy

The study, when completed, would identify specific miRNAs associated with schistosomiasis that could predict FGS and efficiently discriminate FGS from other urogenital-related infections to develop a diagnostic test.

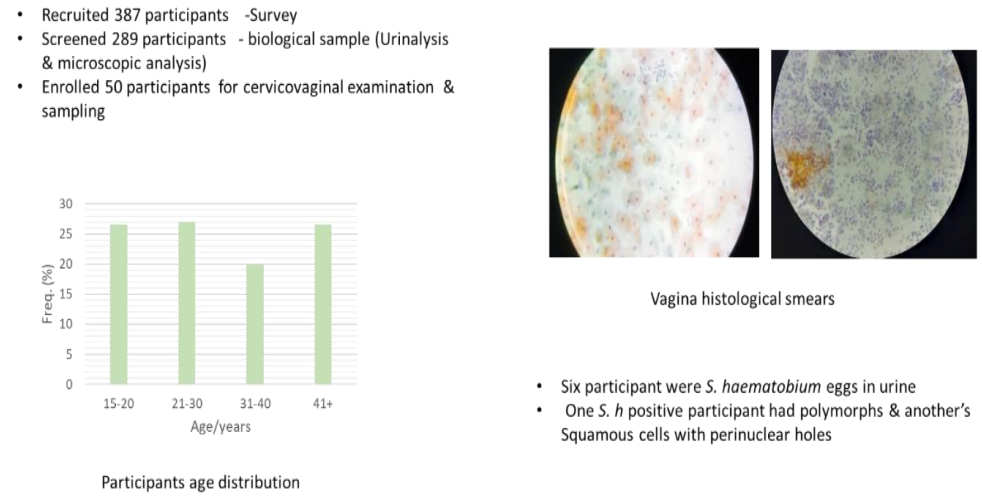


Fig. 3.3.1: Summary of the preliminary results

3.3.1.2 Developing Innovative Scalable Solutions to Entomology Gaps and Cross-Border Transmission of Onchocerciasis (DISSECT): Piloting the Toolkit for Breeding Sites Assessment

(Research Team: Prof. Mike Yaw Osei-Atweneboana – Principal Investigator, Dr. Lawrencia Osae-Nyarko – Research Scientist (Data management), Frank Twum Aboagye – Senior Technical Assistant (Entomologist), Kwame Mawutor Ahiabu– Technical officer (Entomologist), Sem Shelipstics – Technical Officer (Data collector), Manfred D. Asiedu – Technical officer (Data management)

Introduction

Mass Drug Administration (MDA) with Ivermectin, given either on annual or bi-annual basis, to control onchocerciasis has led to reduction in disease transmission in many countries including Ghana. The World Health Organization (WHO) roadmap for elimination of Neglected Tropical Diseases (NTDs) by 2030, targets the elimination of onchocerciasis through interruption of transmission. At present, there are no standardized blackfly entomological monitoring and evaluation tools available for programmatic use on a large scale. Also, techniques for identification of blackfly breeding sites developed and used for selecting breeding sites for larviciding since the 70s, have not been updated. Hence, there is the need to develop sensitive tools and other relevant support systems including entomological evaluation techniques.

Despite the need for entomological assessments and thresholds to verify interruption of transmission of onchocerciasis, there is little operational guidelines to inform and standardize current entomological techniques, including blackfly breeding sites assessment methods. Therefore, developing innovative and scalable solutions to entomology gaps and cross-border transmission of onchocerciasis (DISSECT) has become necessary to help address the entomological gaps that hinder progress towards onchocerciasis elimination in endemic countries within WHO elimination timelines as well as provide accurate comparison of data from different countries.

Objectives

The objectives were to:

i. conduct a desk review to identify blackfly breeding sites and communities within 5 km radius of the breeding sites;
ii. select potential and active breeding sites for prospection of immature stages of blackflies;
iii. assess community-based knowledge and history of onchocerciasis transmission and blackfly nuisance in communities within 25 km radius Ghana-Cote D'Ivoire border; and
iv. standardize entomological data collection toolkit for breeding site assessment.

Activities undertaken and results achieved so far

Activities carried out included desktop review and development of maps for identification of breeding sites and communities within 5 Km radius in the study districts; training on breeding sites assessment; community entry and mobilisation; selection of communities for study and conducting of community survey; and breeding site identification and prospection for blackflies.

From the desk review and information obtained from District Health Management Team (DHMT) and the communities, a total of 59 communities were selected in the four districts for the study; Jaman South (n=14), Dormaa West (n=23) and Dormaa Municipality (n=13) in the Bono Region as well as Bia East District (n=9) in the Western North. The highest number of active breeding sites of seven (7) and four (4) potential breeding sites were recorded in the Jaman South District. The Dormaa Municipality, Dormaa West District and Bia East District had two (2), twelve (12) and three (3) communities, respectively, listed as potential breeding sites. A total of twenty- seven (27) communities in the study area had no breeding sites. The only active breeding site in the Bia East District was located at Fosukrom, which is beyond 20 Km from the Ghana-Cote D'Ivoire Boarder. The physicochemical analysis of water bodies indicated that temperature of the breeding sites ranged from 25.83 to 26.90°C (Fig. 3.3.2).

The age of selected participants ranged from 18 to 105 years with a mean (SD) age of 45(17) years. Most (62%) of the participants were farmers, followed by traders (16%), then students (4.9%) and the remaining 17.6% consisted of other professionals, retired personnel and the unemployed in the selected sites. Knowledge on onchocerciasis was low as only 120 out of the 430 surveyed population indicated they know onchocerciasis. Nonetheless, 113 participants out of the 120 participants could give a brief accurate description of the disease. A greater proportion (264; 61.5 %) indicated blackfly was a problem in their communities and biting numbers of blackfly were between 1 to 10am. Sixteen (16) out of the thirty-five (35) communities had all respondents indicating that blackfly was a nuisance in their communities. The information gathered on breeding sites as well as the community knowledge on onchocerciasis and blackfly presence indicated blackfly endemicity in ten (10) communities. It was recommended that further monitoring and evaluation should be carried out to determine endemicity of blackfly and variations in different seasons as well as determine the prevalence of onchocerciasis infection.

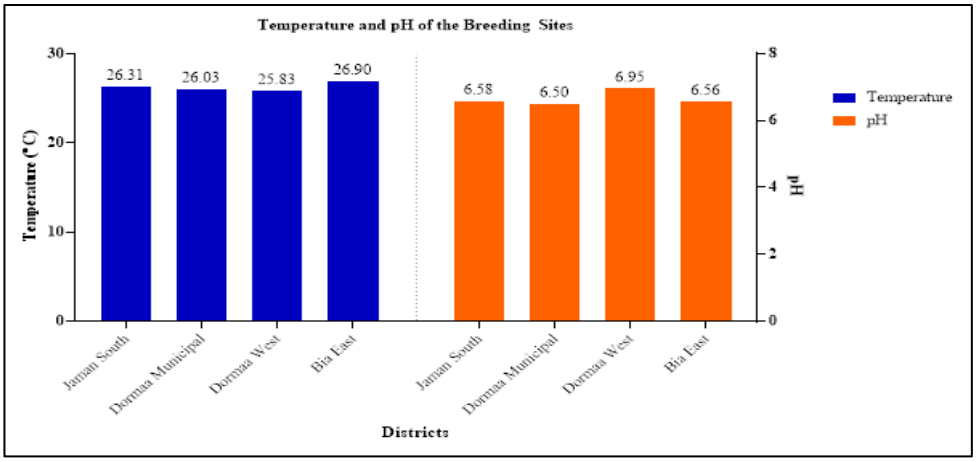


Fig 3.3.2: Physicochemical properties (temperature and pH) of the breeding sites

Impact of the study on national economy

Identification of active breeding sites in endemic communities through the use of the breeding site assessment toolkit are part of efforts to standardise entomological data collection procedures and consequentially eliminate onchocerciasis. This will result in improved health and economic benefits of affected people and hence the economy of the nation.

3.3.1.3 Developing Appropriate Prescription and Guidelines for the Treatment and Prevention of Urinary Tract Infections in Elderly Nursing Homes in Accra; The Molecular Way

(Research Team: Mr. Emmanuel Odartei Armah – Principal Investigator, Mr. Bright K. Idun, Miss Freda Kwarteng Boampong, Mr. Isaac Agyapong, Mr. Mawutor Kwame Ahiabu, Miss Mercy Oppong, Dr. Lawrencia Osae-Nyarko, Prof. Mike Yaw Osei Atweneboana)

The study seeks to investigate the occurrence of antimicrobial resistance of pathogens causing urinary tract infections among the older people in nursing homes in Accra. The pathogens studied included the following: *Escherichia coli (E. coli), Klebsiella pneumoniae (K. pneumoniae), Proteus mirabilis (P. mirabilis), Enterococcus faecalis (E. faecalis), and Pseudomonas aeruginosa (P. aeruginosa).* The specific objectives of the study were to:

i. determine the prevalence of pathogens associated with urinary tract infections (UTIs) in nursing homes;
ii. establish the antibiotic sensitivity of these pathogens;
iii. determine the antibiotic resistance genes in these pathogens;
iv. assess the risk factors associated with these resistances; and
v. assess the nutritional status of the older people between the ages of 50 -95 years.

Activities undertaken

Purposive sampling technique was used in the study in selecting participants between the ages of 55 to 99 years, as the target population is older persons resident in nursing homes. A total of five (5) old persons' nursing homes with a total of 118 respondents were selected for the study. The five (5) nursing homes were located in the following communities in the Greater Accra Region of Ghana: Sakumono, Amamole, Afiaman, Kuntunse and Dedeiman. In total, 28.8% (n =34) of the participants were men whilst 71.2% (n =84) were females. The

distribution of recruited participants (number of participants, percentage) from the nursing homes are as follows: Sakumono (15,12.7%), Amamole (28 ,23.7%), Dedeiman (27, 22.9%), Afiaman (19,16.1%) and Kutunse (29, 24.6%). Before sampling, introductory letters, information sheets and consent forms were made available to obtain permission and consent of facilities and participants as well as provide adequate information on the study.

Urine samples collected in sterile containers were analysed following the instructions for processing URIT 10V strips. The urine specimens were stored on ice at low temperatures (2–8°C) in a cooler and transported to the BPHRU Parasitology lab. The urine samples were analysed within four (4) hours of collection. Microscopic urinalysis was performed after chemical urinalysis. Urine samples were tested for nitrites (positive or negative) and leukocyte esterase (≥70/μL value was considered positive) predetermined to maximize sensitivity. A positive dipstick was a test result with a ≥70/μL leukocyte esterase and/or nitrite positivity (Little *et al*.,2006), and/or a reflex microscopy requiring ≥10 WBC/HPF (Mody *et al*.,2014) for the diagnosis of a Urinary Tract Infection (UTI). Urinalysis diagnosis was made using criteria of abnormality.

Results achieved so far

It was observed that the colour of urine samples was amber in 43 (36.44%) of the 118 analysed samples and straw in 75(63.56%). Turbidity values obtained indicated that 110 (89.63%) out of the 118 urine samples analysed were clear whiles eight (8) (10.37%) were cloudy. From 118 study participants, 105 samples (88.98%) had pH values ranging from 4.8 to 7.4 and 13 (11.02%) had a basic pH (≥7.4). Analysis showed that three (3) (2.54%) and nine (9) (7.62%) out of the samples analysed were haematuria and pyuria by microscopy, respectively. Only one (1) (0.84%) out of the 118 samples analysed was positive for both pyuria by microscopy and haematuria. Nitrituria samples were 12 (10.16%) out of the 118 samples whilst leukocyturia samples were 53 (44.91%) using the criteria of abnormality. A total of 8 (6.77%) of the 118 analysed samples were both positive for nitrituria and leukocyturia. Samples positive for nitrite and/or leucocyte were 55 (46.61%). Only one (1) (0.85%) sample was positive for blood, nitrite and leucocyte esterase. The detailed Urinalysis variables are shown in Table 3.3.1.

Conclusion

The results obtained (colour, appearance and dipstick analysis) coupled with the low cost and ease of application and at the bedside, make it a cost-effective method applicable in the first levels of care for the early detection of geriatric populations at risk; therefore, allowing appropriate care to reduce severe morbidity and deaths.

Table 3.3.1: Urinalysis test variables on study participants

Specific gravity	**1,000**	**1,005**	**1,006**	**1,01**	**1,015**	**1,02**	**1,025**	**1,03**
(*n* = 118)	0 (0)	1 (0.85%)	0 (0)	20(16.95%)	36 (30.51%)	38(32.20%)	11(9.32%)	12(10.17%)
pH	***5.0***	***6.0***	***6.5***	***7.0***		***7.5***	***8.0***	***8.5***
(n=118)	36 (30.51%)	64 (54.24%)	3(2.54%)	3 (2.54%)		8(6.78%)	1(0.85%)	3(2.54%)
Blood		**Negative**		**Traces**	1+	2+		3+
(n=118)		115(97.46%)		3(2.54%)	0(0%)	0(0%)		(0%)
***Proteins* (mg/dL)**	***Negative***	***Traces***		***1+***	***2+***	***3+***		***≥2,000***
(*n* = 118)	111(94.07%)	3(2.54%)		3 (2.54%)	1(0.85%)	0(0.0%)		0 (0.0%)
***Urobilinogen* (mg/dL)**		***Negative***		***1.0 traces***	***2.0***	***4.0***		***≥8.0***
(*n* = 118)		118 (100.0%)		0 (0%)	0 (0%)	0 (0%)		0(0%)
***Leukocytes* (cells/μL)**		***Negative***		***15 traces***	***1+***	***2+***		***3+***
(*n* = 117)		32 (27.35%)		32(27.35%)	37(31.62%)	7(5.98%)		9 (7.69%)
***Ketones* (mg/dL)**		***Negative***		***5.0 traces***	***15(low)***	***40 (moderate)***		***≥80 (high)*****
(*n* = 118)		118(100%)		0 (0.0%)	01(0%)	0 (0%)		0 (0%)
***Glucose* (mg/dL)**		***Negative (<30.0)***		***1+***	***2+***	***3+***		***4+***
(*n* = 118)		116(98.31%)		0 (0.0%)	0(0%)	0(0.0%)		2(1.69%)
Nitrite		***Negative (<0.2)***				***Positive***		
(*n* = 118)		106 (89.83%)				12 (10.17%)		

***Not all patients have complete urine dipstick variables; **only two study participants with glucosuria > 1+.**

3.3.1.4 Evaluation of the Efficacy of NUF500 Filtration Device for Removal of Viruses

(Research Team: Dr Samuel Armoo – Principal Investigator, Gideon Twieku, Nana Aso Amonoo, Manfred Asiedu, Dr. Yaw Adjei Anane, Dr Elias Asuming-Brempong, Prof. Mike Y. Osei-Atweneboana)
Collaborating Agencies: Easy Water for Everyone (EWFE)

Introduction

Infectious pathogens in surface and groundwater can be present as bacteria, viruses or protozoa. These pathogens include *Vibrio cholerae*, Shigella, Legionella, *Escherichia coli* as well as viruses. Endemic communities of these water-related infectious pathogens are characterized by poor sanitation, low socio-economic status and limited public health awareness. It was against this background that the Institute in collaboration with Easy Water for Everyone (EWFE) carried out the study which was a follow-up to a collaborative study which demonstrated the efficacy of the device to remove bacterial pathogens from surface and groundwater sources.

Objective

The objective was to explore the potential of the NUF500 filtration device to filter viral pathogens of public health importance in Ghana.

Activities undertaken

In the reporting year, collection of water samples were undertaken in two communities: Tomefa and Manheam, which are located at the banks of the Weija dam in the Ga-South Municipality (Fig.3.3.3) of the Greater Accra Region of Ghana. Inhabitants of these communities rely on water from this dam for their daily livelihoods. Grab water samples were collected from five points on the banks of the Weija dam in Tomefa and Manheam. For each sampling point, 10 litres of water were collected, out of which 1 litre was stored in a clean

sample container as a pre-filtration sample. The 9 litres were processed through the NUF500 filtration device. For each site, 1 litre of NUF500-filtered water was collected into a new sample container. For all samples, RT-PCR runs were performed at both pre-filtration and post- NUF-500 filtration (Fig 3.3.4). Both pre- and post-filtration samples were transported on ice to the laboratory for analysis.

Water samples were concentrated into pellets using the skimmed milk flocculation technique. For each sample, 20 uL of bovine respiratory syncytial virus (BRSV) was added as an extraction control. RNA was extracted in a Level 2 biosafety cabinet using the Liferiver® viral DNA/RNA extraction kit (Shanghai ZJ Bio-Tech Co., Ltd.) according to standard protocol.

Complementary DNA (cDNA) was produced from extracted RNA using the PhotoScript II First Strand cDNA synthesis kit (New England Biolabs, USA). The cDNA was then used as a template for real-time PCR (RT-PCR) diagnosis of a range of viral pathogens of public health importance. Each RT-PCR mix (total volume of 10 uL) contained 5 uL of B-R 1-step SYBR green master mix by Quanta Biosciences (Maryland, USA), 1 uL of 2-uM Primer mix, 2 uL of sterile double distilled water, and 2 uL of template cDNA. Cycling conditions included: an initial denaturation at 94 C for 3 mins; followed by 45 cycles of denaturation at 94 C for 45 seconds, annealing at 59 C for 45 seconds, ending with an extension at 72C for 45 seconds. All RT-PCR runs were performed on the Bio-Rad CFX PCR Detection system (Bio-Rad, USA).

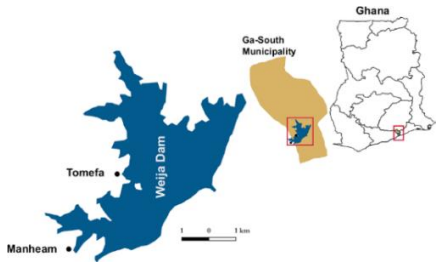


Fig.3.3.3: Map showing the location of sampling communities

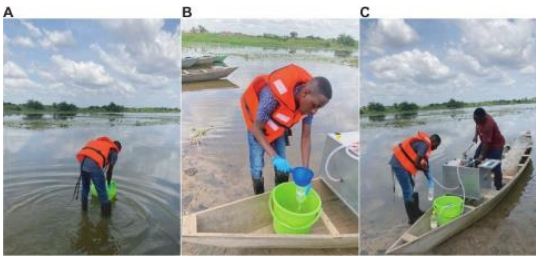


Fig 3.3.4: Collection of water samples and NUF500 filtration process. (a) Grab sampling (b) Collection of 1 litre of pre-filtration water sample (c) NUF500 filtration and collection of 1 litre of post-filtration sample

Results achieved so far

Detection of the BRSV extraction in all samples signified the elimination of PCR inhibitors. In addition, the detection of human mitochondrial DNA and pepper mild mottle virus was evidence of human activity. Key findings include the detection of the diarrheal causing Rotavirus A virus in pre-filtration samples and the removal of the virus after filtration. Hepatitis A virus was also detected in 40% of pre-treatment samples, but significantly reduced to 10% of samples at post-filtration.

Conclusion

It was concluded that the NUF500 filtration device has the potential to revolutionize access to drinking water in the rural poor in Africa. However, there is the need for more studies in different sites with increased sample sizes to gather more evidence to support the findings from the study.

Recommendation

It was recommended that there should be extensive application of the NUF500 filtration device in many rural poor settings. However, given that the NUF500 filtration device was not able to remove all viruses from the water source, it was recommended to supplement the device with UV filtration from the sunlight, which is abundant in Africa. The UV filtration from the sun will be a low-cost form of chemical filtration.

Impact of the study on national economy

Improved water sources through the application of this device will directly help to achieve targets 3 (good health and well-being) and 6 (clean water and sanitation) of the United Nations Sustainable Development Goals (SDGs). Good health and well-being can directly reduce poverty (goal 1 of the SDGs).

APPENDICES

APPENDIX I: Membership of the Internal Management Committee (IMC)

1.	Prof. Mike Y. Osei-Atweneboana	Director (Chairman)
2.	Dr. Anthony Y. Karikari	Deputy Director
3.	Dr. Emmanuel Obuobie	Head, Surface Water & Climate Change Division (SWCCD)
4.	Rev. Dr. Gloria N. D. Addico	Head, Environmental Biology, Biotechnology and Health Division (EBBHD)
5.	Dr. Elias Asuming-Brempong	Head, Biomedical and Public Health Research Unit (BPHRU)
6.	Dr. Kwadwo A. Asante	Head, Environmental Chemistry and Sanitation Engineering Division (ECSED)
7.	Dr. Ruby Asmah	Head, Fishery and Aquaculture Division (FAD)
8.	Mr. Collins Okrah	Head, Groundwater and Geoscience Division (GWGD)
9.	Mr. Sampson K. Boateng	Head, Administration Division (AD)
10.	Mr. Oswald K. Nyimebaare	Head, Finance Division (FD)
11.	Dr. Collins Tay	Head, Commercialization Division
12.	Dr. Francis Assogba Anani	Officer-In-Charge, ARDEC – Akosombo
13.	Dr. William Wilson Anku	Vice-president, Research Staff Association (RSA) – Local
14.	Mr. Samuel Kanati	Rep. CSIR Association of Administrators, Ghana (CAAG)
15.	Mr. Godwin Amegbe	President, Senior Staff Association (SSA) – Local
16.	Mr. Francis A. Boakye	Chairman, Trade Union Congress (TUC) – Local
17.	Mrs. Claudia Bentum	Administrative Officer (Secretary)

APPENDIX II: STAFF STRENGTH

List of Senior Members

No.	Name	Designation
1.	Prof. Mike Y. Osei-Atweneboana	Director, Principal Research Scientist
2.	Dr. Anthony Y. Karikari	Deputy Director, Chief Research Scientist
3.	Dr. Collins Tay	Principal Research Scientist
4.	Rev. Dr. Gloria N. Dzama Addico	Principal Research Scientist
5.	Dr. Kwadwo A. Asante	Principal Research Scientist
6.	Dr. (Mrs.) Ruby Asmah	Principal Research Scientist
7.	Mr. Oswald K. Nyimebaare	Principal Accountant
8.	Mr. Sampson K. Boateng	Principal Administrative Officer
9.	Dr. (Ing.) Emmanuel Obuobie	Senior Research Scientist
10.	Ing. Frederick Y. Logah	Senior Research Scientist
11.	Mr. Collins Okrah	Senior Research Scientist
12.	Mr. Humphrey F. Darko	Senior Research Scientist
13.	Mr. Theodore Quarcoopome	Senior Research Scientist
14.	Mrs. Regina Banu	Senior Research Scientist
15.	Mr. Mark O. Akrong	Senior Research Scientist
16.	Mr. Michael Kumi	Senior Research Scientist
17.	Mrs. Sarah Penstil	Senior Research Scientist
18.	Dr. (Mrs.) Marian Amu-Mensah	Senior Research Scientist
19.	Dr. Samuel Armoo	Senior Research Scientist
20.	Dr. George T. Mensah	Senior Research Scientist
21.	Dr. Francis A. Assogba	Senior Research Scientist
22.	Dr. (Mrs.) Deborah Darko	Senior Research Scientist
23.	Dr. Agbeko Etornyo	Senior Research Scientist
24.	Dr. Seth K. Agyakwah	Research Scientist
25.	Dr. Elias Asuming-Brempong	Research Scientist
26.	Dr. Franklin Obiri-Nyarko	Research Scientist
27.	Mr. Patrick A. Mainoo	Research Scientist
28.	Mr. Gerard Quarcoo	Research Scientist
29.	Dr. Emmanuel Tetteh-Doku Mensah	Research Scientist
30.	Mr. Solomon A. Owiredu	Research Scientist
31.	Ms. Saada Mohammed	Research Scientist
32.	Mr. Evans Manu	Research Scientist
33.	Dr. (Mrs.) Rhoda Lims Diyie	Research Scientist

34.	Mr. Michael Dorleku	Research Scientist
35.	Mr. William E. Arko	Research Scientist
36.	Mrs. Zita Naangmenyele Abuntori	Research Scientist
37.	Mr. Edward J. Tettevi	Research Scientist
38.	Dr. (Mrs.) Ruth Ayanful-Torgby	Research Scientist
39.	Dr. Pennante N. A. Bruce-Vanderpuije	Research Scientist
40.	Dr. William W. Anku	Research Scientist
41.	Dr. Mariam Y. Ameveworwor	Research Scientist
42.	Dr. Frank Adu-Nti	Research Scientist
43.	Dr. Raymond Kojo Agbadzi	Research Scientist
44.	Dr. Yaw Adjei Anane	Research Scientist
45.	Dr. Prosper Bazaanah	Research Scientist
46.	Dr. Patrick S. K. Fatsi	Research Scientist
47.	Dr. Obed Fiifi Fynn	Research Scientist
48.	Dr. Emmanuel Koboja Magna	Research Scientist
49.	Dr. Lawrencia Kwarteng	Research Scientist
50.	Dr. Betty Oppong Bandoh	Research Scientist
51.	Dr. Akua Kyerewa Botwe	Research Scientist
52.	Dr. Appiah Ebenezer Koranteng	Research Scientist
53.	Dr. Sylvester A. Boadi	Research Scientist
54.	Mr. Kwabena O. Benson	Scientific Secretary
55.	Mrs. Patience D. K. Atsakpo	Chief Technologist
56.	Mr. Emmanuel O. Armah	Principal Technologist
57.	Ms. Ayesha A. Amadu	Principal Technologist
58.	Mr. Ralph Tagoe	Principal Technologist
59.	Mrs. Martha D. Agyemang	Principal Technologist
60.	Mrs. Sandra V. Asare	Principal Technologist
61.	Mrs. Abigail Nunoo Akuetteh	Principal Technologist
62.	Mrs. Lilly O. Konadu	Principal Technologist
63.	Mrs. Mercy Johnson-Ashun	Principal Technologist
64.	Ms. Hawa Ahmed	Principal Technologist
65.	Mr. Bismark A. Akurugu	Principal Technologist
66.	Ing. Gabriel Appiah	Principal Technologist
67.	Mr. Franz A. Gaisie-Essilfie	Principal Technologist
68.	Mr. Faisal A. Nuru-Ahmed	Principal Technologist
69.	Mr. Mark Osei-Owusu	Principal Technologist
70.	Mr. Jude O. Quansah	Principal Technologist

71.	Mr. Isaac Owusu-Frimpong	Principal Technologist
72.	Mr. Martin A. Adakpeya	Principal Technologist
73.	Mrs. Lady B. A. Adomako	Principal Technologist
74.	Mrs. Theodora L. E. Agbotui	Principal Technologist
75.	Mr. Haruna Zaid	Principal Technologist
76.	Mr. Jacob Agyekum	Principal Technologist
77.	Mr. Divine W. Hotor	Principal Technologist
78.	Mr. Emmanuel Adu-Ofori	Principal Technologist
79.	Mr. Deryl N. O. Kuevi	Principal Technologist
80.	Dr. Nyamadi Akpene Aku	Principal Technologist
81.	Mr. Imoro Nfayem	Principal Technologist
82.	Mr. Emmanuel K. Opoku	Principal Technologist
83.	Mr. Eugene Sintim Gyabaah	Principal Technologist
84.	Mr. Sumabe Kasim Balagra	Principal Technologist
85.	Ms. Adelina Akuamoah Boateng	Principal Technologist
86.	Ing. Patricia Granaham	Principal Technologist
87.	Ing. Frank T. Oblim	Principal Technologist
88.	Mrs. Karyn Ewurama Quansah	Principal Technologist
89.	Nana Aso Amonoo	Principal Technologist
90.	Ms. Queenstar Dedei Quarshie	Principal Technologist
91.	Mr. Acheampong Addo	Principal Technologist
92.	Mr. Ebenezer Ofosu-Nkrumah	Marketing Officer
93.	Mrs. Claudia Bentum	Administrative Officer
94.	Mr. Samuel Kanati	Administrative Officer
95.	Mrs. Rebecca Tekpertey	Administrative Officer
96.	Mrs. Lydia Kusi	Administrative Officer
97.	Mr. Victor Agyemang	Administrative Officer
98.	Ms. Sylvia Amponsah	Public Relations Officer
99.	Mrs. Doris Damoah	Accountant
100.	Mrs. Regina A. Atsu	Accountant
101.	Mr. Mark Boateng Ofori	Accountant
102.	Ms. Sem Shelipstics	Accountant
103.	Mr. Simon K. Anane	Estate Officer

List of Senior Staff

No.	Name	Designation
1.	Mr. Mohammed M. Bello	Chief Technical Officer
2.	Mr. Salifu Abdul-Latif	Chief Technical Officer
3.	Ms. Joyce J. Osibo	Chief Library Assistant
4.	Mr. Christopher Y. Nfojoh	Chief Technical Officer
5.	Mrs. Benedicta Osei-Tutu	Chief Administrative Assistant
6.	Ms. Millicent Adu-Boakye	Chief Technical Officer
7.	Mr. Samuel A. Antwi	Chief Auditing Assistant
8.	Mr. Francis A. Boakye	Chief Technical Officer (Systems Administrator)
9.	Mr. Ebenezer N. D. Koranteng	Chief Marketing Assistant
10.	Mrs. Esther Mate-Ahmed	Chief Accounting Assistant
11.	Mrs. Priscilla Ampofo-Yeboah	Chief Administrative Assistant (Secretary)
12.	Mr. Serapis A. Asiedu	Chief Technical Officer
13.	Mr. Victor Nii Mante	Chief Technical Officer
14.	Mr. Michael D. Afram	Chief Technical Officer
15.	Ms. Yaa Asabea Agadzi	Chief Technical Officer
16.	Mr. Alex Yeboah	Chief Accounting Assistant
17.	Mr. Alfred A. Adjei	Chief Accounting Assistant
18.	Ms. Genevieve G. Kwogana	Chief Administrative Assistant (Secretary)
19.	Mr. Emmanuel M. Obeng Bekoe	Chief Technical Officer
20.	Mr. Serlom Borbor	Chief Technical Officer
21.	Ms. Murjanatu Abdul-Hamid	Chief Technical Officer
22.	Ms. Linda A. Nuamah	Principal Technical Officer
23.	Mr. Richard K. Kwapong	Principal Assistant Printer
24.	Mr. Eric Y. Darko	Principal Technical Officer
25.	Mr. Edem K. Ayegbe	Principal Works Superintendent
26.	Mr. Richard Kuddy	Principal Technical Officer
27.	Mr. Daniel K. Amoah	Principal Technical Officer
28.	Ms. Esther A. Sowah	Principal Technical Officer
29.	Mr. Godwin Amegbe	Principal Technical Officer
30.	Mrs. Matilda A. Asinor	Principal Accounting Assistant
31.	Mrs. Dorothy Krodua	Principal Administrative Assistant (Secretary)
32.	Mr. Evans V. Osei	Principal Technical Officer
33.	Mr. Ebenezer D. Mensah	Principal Works Superintendent
34.	Ms. Salima Abdulai	Principal Administrative Assistant
35.	Ms. Joyce O. Appiah	Principal Administrative Assistant

36.	Mrs. Dora D. Ocran	Principal Library Assistant
37.	Mrs. Cecilia Dwamena-Yeboah	Principal Administrative Assistant (Secretary)
38.	Ms. Joyceline Asare-Bediako	Principal Administrative Assistant
39.	Mr. Lawson Maxi-Millian Abaah	Principal Technical Officer
40.	Mr. Fredrick Sakyi	Principal Stores Superintendent
41.	Mr. Isaac Kwarteng	Senior Works Superintendent
42.	Mr. Anthony Arko	Senior Security Officer
43.	Mr. John K. Mensah	Senior Stores Superintendent
44.	Mr. Lawrence Yawson	Senior Technical Officer
45.	Mr. Bright K. Idun	Principal Technical Officer
46.	Mr. Felix J. Ofosu	Technical Officer
47.	Mr. Abdul-Rahaman Mohammed-Sadat	Technical Officer
48.	Ms. Dorothy Lomo-Mainoo	Technical Officer
49.	Ms. Getrude Nortey	Technical Officer
50.	Ms. Deborah Adjei	Technical Officer
51.	Ms. Rachel Agyemang	Technical Officer
52.	Ms. Naa Adjeley Kuma	Technical Officer
53.	Mr. Amidu Mahmud	Administrative Assistant
54.	Ms. Lucy Adu	Administrative Assistant
55.	Ms. Felicity Hope Mortey	Auditing Assistant
56.	Ms. Rita Atiemo	Accounting Assistant
57.	Mr. Michael Arthur	Assistant Transport Officer
58.	Mr. Joseph Danso	Assistant Transport Officer
59.	Ms. Clarissa Y. Nutsugah	Senior Marketing Assistant
60.	Mr. Isaac Agyepong	Technical Officer
61.	Mr. Kwame Mawutor Ahiabu	Technical Officer
62.	Mr. Bright Selorm Amedorme	Technical Officer
63.	Mr. Manfred Dakorah Asiedu	Technical Officer
64.	Mr. Michael Mawuenyiga Agbeti	Technical Officer
65.	Mr. Kwame Anim Afriyie	Technical Officer
66.	Mr. Benjamin Boakye Tenkorang	Purchasing Assistant
67.	Mr. Joshua Ferguson	Administrative Assistant
68.	Nana Afua O. Boateng	Administrative Assistant
69.	Ms. Nawal Moro Buri	Technical Officer
70.	Mr. Mario Chrisk	Technical Officer
71.	Mr. Samuel Birikorang	Technical Officer
72.	Mr. Evans Tarko Dankwa	Technical Officer
73.	Mr. Innocent Kwakugah	Accounting Assistant

74.	Mr. Paa Kobina Sagoe Gyapong	Accounting Assistant
75.	Mr. Thompson G. Nyamesah	Technical Officer
76.	Mr. Issahaku Tofic	Technical Officer
77.	Ms. Eunice Nyarko Darko	Accounting Assistant
78.	Ms. Rejoice Darkey	Marketing Assistant
79.	Mr. Samuel Kwadwo Debrah	Technical Officer
80.	Mr. Kelvin Kweku Donkor	Technical Officer
81.	Ms. Amanda Maasoyuor Karbo	Administrative Assistant
82.	Ms. Grace Kwaku-Anim	Technical Officer
83.	Ms. Joyce Kplorla Kusorgbor	Technical Officer
84.	Mr. Joel John Otchere-Baffour	Technical Officer
85.	Ms. Abena Konadu Owusu-Senya	Technical Officer
86.	Ms. Abigail Sefah	Marketing Assistant
87.	Mr. Gideon Twieku	Technical Officer
88.	Mr. Frank Twumasi Oppong	Technical Officer
89.	Ms. Doretta Enyonam Yirenkyi	Purchasing Assistant
90.	Ms. Victoria Lilian Sackey	Administrative Assistant
91.	Ms. Doris Derpog Nyime-Baare	Administrative Assistant
92.	Ms. Abigail Dede Ometse Quaynor	Administrative Assistant
93.	Ms. Cindy Xolali Anane	Technical Officer
94.	Mr. Emmanuel O. Ayim	Security Officer
95.	Mr. Frank Goka	Security Officer
96.	Mr. Issah Hamidu	Security Officer
97.	Mr. Charles S. Bonful	Security Officer
98.	Mr. Kassim B. Seidu	Security Officer
99.	Mr. Jones Ofori	Security Officer
100.	Mr. Cephas Dzah	Security Officer
101.	Mr. Anthony K. Morkeh	Security Officer
102.	Mr. Mike Ben Niekye	Security Officer
103.	Mrs. Doris Obeng Bekoe	Front Desk Officer
104.	Mr. Alexander Siaw	Works Superintendent
105.	Mr. Mario Danban Kugre	Technical Officer

Staff Distribution among the Divisions and Sections

Division/ Section	Senior Members	Senior Staff	Junior Staff	Total
Directorate	2	-	-	2
Commercialization	3	4	1	8
Library Section	-	2	-	2
IT Section	-	4	-	4
Printing Section	-	1	-	1
Surface and Climate Change	12	1	-	13
Ground Water and Geoscience	9	5	-	14
Environmental Chemistry and Sanitation Engineering	16	14	-	30
Environmental Biology, Biotechnology and Health	9	10	-	19
Biomedical and Public Health Research Unit	21	9	3	33
Fishery and Aquaculture	19	7	9	35
Finance	5	13	-	18
Audit Unit	-	2	-	2
Administration				
• Personnel Section	5	16	2	23
• Transport/Mechanic Workshop Section	-	5	5	10
• Estate Section	1	1	14	16
• Security Section	-	10	13	23
Total	102	102	47	251
Contract Appointment				
• Directorate	1	1	-	2
• CSIR College of Science and Technology (CCST)	2	-	-	2
• Research Grant Office	1	-	-	1
• EMPOWER	1	-	-	1
• Fishery and Aquaculture Division	-	-	6	6
• Administration Division (Estate)	-	-	1	1
• Environmental Chemistry and Sanitation Engineering Division	1	1	-	2
Total	6	2	7	15
Overall Total	**108**	**104**	**54**	**266**

APPENDIX III: HUMAN RESOURCE ACTIVITIES

Promotion/Upgrading

Senior Members

No.	Name	Division/Section	From	To	Effective Date of Promotion/ Upgrading
1.	Mr. Victor Agyemang	Administration	Technical Officer	Administrative Officer	01-Feb.-2021
2.	Dr. Emmanuel Koboja Magna	Fishery & Aquaculture	Principal Technologist	Research Scientist	01- Oct- 2021
3.	Dr. Lawrencia Kwarteng	BPHRU	Principal Technologist	Research Scientist	01 - July - 2021
4.	Dr. Betty Oppong Bandoh	BPHRU	Principal Technologist	Research Scientist	01 - July -2021
5.	Mr. Emmanuel Adu-Ofori	ECSED	Technologist	Principal Technologist	31- July – 2019
6.	Dr. Obed Fiifi Fynn	GWGD	Principal Technologist	Research Scientist	1 - July - 2021
7.	Ing. Frank Oblim Teye	SWCCD	Technical Officer	Principal Technologist	1 - May - 2022
8.	Dr. Sylvester Afram Boadi	SWCCD	Principal Technologist	Research Scientist	31- Dec - 2021
9.	Mr. Acheampong Addo	Fishery & Aquaculture	Technical Officer	Principal Technologist	30 - Sep -2021
10.	Nana Aso Amonoo	BPHRU	Technical Officer	Principal Technologist	1- May -2022
11.	Ms. Queenstar Dedei Quarshie	BPHRU	Technical Officer	Principal Technologist	31 - July -2021

Senior Staff

No.	**Name**	**Division**	**Previous Designation**	**Current Designation**	**Effective Date**
1.	Ferguson Joshua	Finance	Clerk Grade1	Accounting Assistant	30 - June - 2021
2.	Rita Atiemo	Finance	Clerk Grade1	Accounting Assistant	4 - July - 2021
3.	Mario Kugre Danban	Admin / Transport	Traffic Supervisor	Technical Officer	15 - Nov - 2021

Transfer

No.	Name	Designation	Category of Staff	Division/Section	From	To	Date
1.	Ms. Regina Donkor	Principal Auditing Assistant	Senior Staff	Audit Directorate H/O	CSIR-WRI	CCST	10 - Jan - 2022
2.	Ms. Felicity Mortey	Auditing Assistant	Senior Staff	Audit Directorate H/O	Audit Directorate H/O	CSIR-WRI	10 - Jan - 2022
3.	Ms. Rachel Agyemang	Technical Officer	Senior Staff	BPHRU	CSIR-WRI	CSIR-CRI	1- Sept - 2022

Compulsory Retirement

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Retirement
1.	Dr. Emmanuel Obeng Bekoe	Senior Research Scientist	Senior Member	SWCCD	03-Feb.-2022
2.	Dr. Isaac O. A. Hodgson	Chief Research Scientist	Senior Member	ECSED	02-Mar.-2022
3.	Mr. Carl Ofori Agyemang	Research Scientist	Senior Member	GWGD	02-May-2022
4.	Dr. Francis Y. K. Amevenku	Senior Research Scientist	Senior Member	FAD	17-May-2022
5.	Dr. Anthony A. Duah	Senior Research Scientist	Senior Member	GWGD	25-Jun-2022
6.	Mr. Sampson K. Boateng	Principal Administrative Officer	Senior Member	AD	18-Dec.-2022
7.	Mrs. Agnes A. Darko	Chief Administrative Assistant	Senior Staff	AD	14-Feb.-2022
8.	Mr. Kingsley Okyere	Assistant Transport Officer	Senior Staff	AD-Transport	03-May-2022
9.	Ms. Grace Dartey	Principal Technologist	Senior Staff	ECSED	13-Jul-2022
10.	Mrs. Eva G. Agbozo	Chief Administrative Assistant	Senior Staff	AD	28-Aug.-2022
11.	Mr. Mattew Kwara	Senior Assistant Transport Officer	Senior Staff	AD-Transport	11-Dec.-2022
12.	Mr. Bernard L. Lartey	Senior Printing Assistant	Junior Staff	CD	23-Aug.-2022
13.	Mr. Justus Teye	Senior Technical Assistant	Junior Staff	FAD	30-Sept.-2022

Death

No.	Name	Designation	Category of Staff	Division/Section	Effective Date
1.	Micahel Atanga	Security Officer	Junior Staff	Admin-Security	02-June-2022

Resignation

No.	Name	Designation	Category of Staff	Division/Section	Effective Date
1.	Stephen Asugre Jnr.	Principal Technologist	Senior Member	SWCCD	30-Jan.-2022

Contract Appointment

No.	Name	Designation	Staff Category	Division	Effective Date
1.	Prof. Joseph A. Ampofo	Chief Research Scientist	Senior Member	CSIR-WRI	01-Jan - 2022
2.	Dr. Barnabas Akurigo Amisigo	Principal Research Scientist	Senior Member	CSIR-WRI	01 - Jul - 2022
3.	Dr. Hederick R. Dankwa	Principal Research Scientist	Senior Member	CCST	01 - Jan - 2021
4.	Dr. Kwabena Kankam-Yeboah	Chief Research Scientist	Senior Member	CCST	01-Sept.-2021
5.	Prof. Isaac O. A. Hodgson	Chief Research Scientis	Senior Member	ECSE	01 - Jul - 2022
6.	Salissu Shafui	Labourer	Junior Staff	F&A	01 Feb.-2020
7.	Grace Narh	Literate Helper	Junior Staff	F&A	02 Sept.-2020
8.	Enoch Ahadzi	Farm Hand	Junior Staff	F&A	01 Feb.-2020
9.	Mohammed Sani	Farm Hand	Junior Staff	F&A	01 Feb.-2020
10.	Owiredu Darkwah	Farm Hand	Junior Staff	F&A	01 Feb.-2020
11.	Stephen Amanor Tetteh	Farm Hand	Junior Staff	F&A	01-Jan.-2020
12.	Samuel Annang	Driver	Senior Staff	Administration	01-Apr.-2021
13.	Seidu Eliasu	Gardener	Junior Staff	IGF	16-Jul-2021
14.	Eunice Abaah	Technical Officer	Senior Staff	IGF	01-Nov.-2020
15.	Dr. Marian Amoakowah Osei	Research Scientist	Senior Member	EMPOWER	01-Dec.-2021
16.	Benjamin Forson	Security Guard	Junior Staff	IGF	15-Mar.-2021

New Appointments

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Appointment
1	Dr. Nyamadi Akpene Aku	Principal Technologist	Senior Member	BPHRU	12-May-22
2	Mr. Birikorang Samuel	Technical Officer	Senior Staff	FAD	12-May-22
3	Mr. Dankwa Evans Tarko	Technical Officer	Senior Staff	FAD	12-May-22
4	Mr. Sintim Eugene Gyabaah	Principal Technologist	Senior Member	ECSED	01-Aug-22
5	Mr. Akon – Yamga Louis Akong	Senior Marketing Clerk	Junior Staff	CD	04-May-22
6	Mr. Gyapong Paa Kobina Sagoe	Accounting Assistant	Senior Staff	Finance	09-May-22
7	Mr. Imoro Nfayem	Principal Technologist	Senior Member	BPHRU	09-May-22
8	Mr. Kwakugah Innocent	Accounting Assistant	Senior Staff	Finance	01-Jun-22
9	Dr. Botwe Akua Kyerewa	Research Scientist	Senior Member	BPHRU	12-Aug-22
10	Dr. Appiah Ebenezer Koranteng	Research Scientist	Senior Member	FAD	01-Aug-22
11	Mr. Sumabe Kasim Balagara	Principal Technologist	Senior Member	BPHRU	01-Aug-22
12	Mrs. Lydia Kusi	Admin. Officer	Senior Member	ADMIN	01-Sep-22
13	Ms. Adelina Akuamoah Boateng	Principal Technologist	Senior Member	FAD	05-Sep-22
14	Mr. Thompson G. Nyamesah	Technical Officer	Senior Staff	GWGD	03-Oct-22
15	Mr. Issahaku Tofic	Technical Officer	Senior Staff	GWGD	03-Oct-22
16	Ms. Victoria Lilian Sackey	Admin Asst.	Senior Staff	ADMIN	03-Oct-22
17	Ms. Doris Derpog Nyime-Baare	Admin Asst.	Senior Staff	ADMIN	03-Oct-22
18	Ms. Abigail Dede Ometse Quaynor	Admin Asst.	Senior Staff	ADMIN	03-Oct-22
19	Ms. Linda Brako	Senior Clerk	Junior Staff	ADMIN	01-Sep-22
20	Ing. Patricia Granaham	Principal Technologist	Senior Member	SWCCD	3 - Oct – 2022
21	Ms. Anane Cindy Xolali	Technical Officer	Senior Staff	EBB&HD	3 - Oct – 2022
22	Mrs. Karyn Ewurama Quansah	Principal Technologist	Senior Member	EBB&HD	12 - Sept – 2022

APPENDIX IV: HUMAN RESOURCES DEVELOPMENT

No.	Name of Officer	Designation	Training Required	Division/Section	Date Started	Expected Date of Return	Programme Duration	Sponsorship Status	Remarks
1.	Issac Kwarteng	Senior Works Superintendent	BSc. Mechanical Engineering (KNUST)	ADMIN. Transport	May, 2021	May, 2023	2years	Self-Sponsorship	Ongoing
2.	Clarissa Y. Nutsugah	Senior Marketing Assistant	MBA Marketing (Univ. of Ghana)	CD	Jan, 2021	Jan, 2023	2years	Self-Sponsorship	Ongoing
3.	Linda Nuamah	Principal Technical Officer	PhD. Environmental Science & Engineering (Hohai Univ. China)	EBB&D	Sept, 2016	Dec, 2020	4years	Scholarship	Extended
4.	Daniel K. Amoah	Principal Technical Officer	MSc. Water Supply & Environmental Sanitation (KNUST)	ECSED	Oct, 2020	Oct, 2022	2years	Self-Sponsorship	Ongoing
5.	Ayishetu Wortey	Senior Clerk	BBA Human Resource Management (Methodist Univ. College Ghana)	ADMIN.	Aug, 2019	Aug, 2023	4years	Self-Sponsorship	Ongoing
6.	Matilda A. Asinor	Principal Accounting Assistant	MBA in Accounting and Finance	FINANCE	Sept, 2021	Sept, 2023	2years	Self-Sponsorship	Ongoing
7.	Bismark Awinbire Akurugu	Principal Technologist	PhD. Earth Science (Univ. of Ghana)	GWGD	Aug, 2019	Aug, 2023	4years	Scholarship	Ongoing
8.	Mark Osei Owusu	Principal Technologist	PhD. Water Resources Engineering Management (KNUST)	SWCCD	Sept, 2019	Nov, 2023	4years	Scholarship	Ongoing
9.	Mohammed Bello Mustapha	Chief Technical Officer	MPhil. Sanitation Studies (Univ. of Ghana)	EBB&HD	Jan, 2021	Jan, 2023	2years	Self-Sponsorship	Ongoing
10	Serapis Asiedu Appiah	Chief Technical Officer	MPhil Environmental Science (Sanitation and Engineering)	ECSED	Nov, 2021	Oct, 2023	2years	Self-Sponsorship	Ongoing
11	Yaa Asabea Agadzi	Principal Technical Officer	MPhil. Aquaculture (CCST)	FAD	Oct, 2020	Oct, 2022	2years	Scholarship	Ongoing
12	Doris Obeng-Bekoe	Front Desk Officer	Bachelor of Arts Business Studies (Wisconsin International Univ. College)	ADMIN.	Sept, 2019	Sept, 2023	4years	Self-Sponsorship	Ongoing
13	Benson Kwabena Owusu	Scientific Secretary	PHD. Environmental Science (Univ. of Ghana)	CD	Aug, 2018	Aug, 2022	4years	Self-Sponsorship	Ongoing
14	Collins Okrah	Senior Research Scientist	PhD. Geological Engineering (KNUST)	GWGD	Oct, 2016	Oct, 2020	4years	Self-Sponsorship	Yet to submit certificate
15	Franz Alex Gaise Essilfie	Principal Technologist	PhD. Climate Change and Land Use (KNUST)	SWCCD	Sept, 2019	Sept, 2023	4years	Scholarship	Ongoing
16	William Ekow Arko	Research Scientist	PhD. Environmental Engineering (China Univ. of Geosciences, Wuhan)	ECSED	Sept, 2019	Sept, 2023	4years	Scholarship	Ongoing
17	Patrick A. Mainoo	Research Scientist	PhD. Geophysics (KNUST)	GWGD	Sept, 2019	Sept, 2023	4years	Scholarship	Ongoing
18	Dorothy Lomo-Mainoo	Technical Officer	MPhil. Applied Parasitology (Univ. of Ghana)	EBB&HD	Jan, 2022	Jan, 2024	2years	Self-Sponsorship	Ongoing
19	Faisal A. Nuru	Principal Technologist	PhD. Applied Health Sciences (Univ. of Aberdeen, UK)	BPHRU	March, 2022	Mar, 2025	3years	Scholarship	Ongoing
20	Michael Kumi	Senior Research Scientist	PhD. Chemistry (Univ. of Johannesburg, South Africa)	ECSED	Jan, 2020	Jan, 2024	4years	Self-Sponsorship	Ongoing
21	Richard Kuddy	Principal Technical Officer	MSc. Environmental Science (IHE DELFT, Netherlands)	ECSED	Oct, 2020	Oct, 2022	2years	Foreign (Full-Time)	Extended

APPENDIX V: NATIONAL SERVICE AND INDUSTRIAL ATTACHMENT

Summary of National Service /Industrial Attachment in 2022

Institution of National Service Personnel	**Number of Students**	**Institution of Industrial Attachment Personnel**	**Number of Students**
Kwame Nkrumah University of Science and Technology	14	Kwame Nkrumah University of Science and Technology	21
University of Ghana	17	University of Ghana	32
University of Cape Coast	3	University of Cape Coast	1
University of Development Studies	2	Koforidua Technical University	1
Accra Technical University	5	Accra Technical University	4
Koforidua Technical University	3	University College of Agric and Environmental Studies	2
University for Professional Studies	1	University for Professional Studies	2
Budapest Business School	1	University of Energy and Natural Resources	2
Total	46	University of Mines and Technology	1
			66
		Overall Total	112

List of National Service Personnel Posted to the Institute in 2022

NO.	NAME	INSTITUTION	PROGRAMME	DIVISION
1.	Amoako Emmanuel Debrah	KNUST	BSc. Aquaculture and water Resources Management	FAD
2.	Akuamoah Boateng Philippa	KNUST	BSc. Aquaculture and Water Resource Management	FAD
3.	Asare Boadi Clinton	KNUST	BSc. Aquaculture and Water Resources Management	FAD
4.	Mohammed Naael	UDS	BSc. Biotechnology and Molecular Biology	BPHRU
5.	Asante Vanessa Abena	UG	BSc. Biological Sciences	BPHRU
6.	Asante Stephanie	UG	BSc. Biological Sciences	BPHRU
7.	Addae Joshua	KNUST	BSc. Biochemistry	BPHRU
8.	Peters Ian Ekow	UCC	BSc. Biochemistry	BPHRU
9.	Tamakloe Dave Bryan Mawuli	UG	BSc. Biological Sciences	BPHRU
10.	Akpanya Raphael	KNUST	BSc. Biological Science	BPHRU
11.	Ametefe Edna Akpene	KNUST	BSc. Biochemistry	BPHRU
12.	Narh Joshua Tetteh	Koforidua Technical University	HND. Civil Engineering	SWCCD
13.	Amoah Papa Kwaku Nyamekye	KNUST	BSc. Geological Engineering	SWCCD
14.	Dankwah Nora Adu	KNUST	BSc. Agriculture	SWCCD
15.	Kusi Sarpong Precious	KNUST	BSc. Agriculture	SWCCD
16.	Ampofo Emmanuella Boateng	UG	BSc. Biological Science	EBB&H)
17.	Boadi Jessica	UG	BSc. Biology Science	EBB&HD
18.	Kumi Nana Ama Ohene	UG	BSc. Biological Sciences	EBB&HD
19.	Amoasi Frank	UG	BSc. Biological Sciences	EBB&HD
20.	Vanderpuye Alfred	UG	BSc. Biological Sciences	EBB&HD
21.	Ainooson Ewurafua Mensima	UG	BSc. Biological Sciences	EBB&HD
22.	Fuh Ivy	Accra Technical University	HND Science Laboratory Technology	EBB&HD
23.	Aryee Beryl Naa Ayikaikai	UG	BSc. Biological Science	EBB&HD
24.	Ayesu Festus Yebaoh	UG	BSc. Biological Science	EBB&HD
25.	Antwi Kwabena Israel Safo	UG	BSc. Biological Science	EBB&HD
26.	Peggy Annan	Koforidua Technical University	HND. Food Technology	EBB&HD
27.	Hayfron George Duker	UG	BSc. Biological Science	EBB&HD
28.	Dzakpasu Nicholas Woedem	UG	BSc. Biological Science	EBB&HD
29.	Anyigba Nice	Accra Technical University	HND. Science Laboratory Technology	ECSED
30.	Ofosu Edmund Kwabi	Accra Technical University	HND. Science Laboratory Technology	ECSED
31.	Nortey Joseph Laryea	KNUST	BSc. Chemistry	ECSED

List of National Service Personnel Posted to the Institute in 2022 (Cont.)

NO.	NAME	INSTITUTION	PROGRAMME	DIVISION
32.	Adane Clement Akwasi	KNUST	BSc. Chemistry	ECSED
33.	Attram Loretta Amakuor	Accra Technical University	HND. Science Laboratory Technology	ECSED
34.	Abubakar Abdul Jalil	Accra Technical University	HND. Science Laboratory Technology	ECSED
35.	Silvey Stella Enyonam	UCC	BSc. Laboratory Technology	ECSED
36.	Asiedu Deborah	UG	BSc. Administration	Finance
37.	Debrah Derrick Apeti	KNUST	BSc. Business Administration (Human Resource Management)	Administration
38.	Sabbah Leticia Korkor	UG	Bachelor of Arts	Finance
39.	Asimeng Sandra Sefah	UPSA	BSc. Accounting and Finance	Finance
40.	Iddrisu Abubakar	UDS	Bachelor of Commerce (Accounting)	Finance
41.	Tackey Kelvin Nii Amaah	UG	Bachelor of Science in Administration	Finance
42.	Tetteh-Quarshie Elizabeth	Koforidua Technical University	HND Accountancy	Finance
43.	Quansah Tracy Efua	Budapest Business Sch.	Bachelor in Commerce and Marketing	CD
44.	Baffoe Jessica	UCC	Bachelor of Arts, Communication Studies	CD
45.	Amevenku Benigna Dzidzor	KNUST	Bachelor of Science in Geological Engineering	GWGD
46.	Tsyorkor Mathais Mawuko	KNUST	BSc. Geophysics	GWGD

APPENDIX VI: LIST OF STAFF PUBLICATIONS

Journal Papers

1. Abbew, A. W., Amadu, A. A., Qiu, S., Champagne, P., Adebayo, I., Anifowose, P. O. and Ge, S. (2022). Understanding the influence of free nitrous acid on microalgal-bacterial consortium in wastewater treatment: a critical review. *Bioresource Technology*, 127916.
2. Abbew, A. W., Qiu, S., Amadu, A. A., Qasim, M. Z., Chen, Z., Wu, Z., and Ge, S. (2022). Insights into the multi-targeted effects of free nitrous acid on the microalgae Chlorella sorokiniana in wastewater. *Bioresource Technology*, *347*, 126389.
3. Addi, M., Gyasi-Agyei, Y., Obuobie, E. and Amekudzi, L.K. (2022). Evaluation of imputation techniques for infilling missing daily rainfall records on river basins in Ghana, *Hydrological Sciences Journal*, DOI: 10.1080/02626667.2022.2030868
4. Addo, S., Ameti, K. S., Sowah, W., Diyie, R. L., Duodu, C. P., and Asamoah, E. K. (2022). Semi-artificial method of induced breeding of the African catfish (Clarias gariepinus, Burchell, 1822) under varying broodstock ratios using Ovaprim®. *African Journal of Biotechnology*, 21(10), 504-509.
5. Addo, S., Boateng, C.M., Diyie, R.L., Duodu, C.P., Ferni, A.K., Williams, E.A., Amakye, A.O., Asamoah, O., Danso-Abbeam, H. and Nyarko, E. (2022). Occurrence of Microplastics in Wild Oysters (Crassostrea Tulipa) from the Gulf of Guinea and Their Potential Human Exposure. *Available at SSRN 4245548*.
6. Adjei, F.O., Obuobie, E., Adjei, K.A. and Odai, S.N. (2022). Evaluation of potential evapotranspiration assessment methods for hydrological modelling with SWAT in the Densu river basin in Ghana. *International Journal of Environmental Science and Technology*, Springer, Available from https://doi.org/10.1007/s13762-022-03945-y.
7. Afrifa, G.Y., Chegbeleh, L.P., Sakyi, P.A., Yidana, S.M., Loh, Y.A.S., Ansah Narh, T. and Manu, E. (2022). Quantifying nitrate pollution sources and natural background in an equatorial context: A case of the Densu Basin, Ghana. *Hydrological Sciences Journal*.
8. Ahiahonu, E. K., Anku, W. W., Roopnarain, A., Green, E., Govender, P. P., & Serepa-Dlamini, M. H. (2022). Bioresource potential of Tetradesmus obliquus UJEA_AD: critical evaluation of biosequestration rate, biochemical and fatty acid composition in BG11 media. *Journal of Chemical Technology & Biotechnology*, *97*(3), 689-697.
9. Ahiahonu, E. K., Anku, W. W., Roopnarain, A., Green, E., Serepa-Dlamini, M. H., & Govender, P. P. (2022). Exploring indigenous freshwater chlorophytes in integrated biophotovoltaic system for simultaneous wastewater treatment, heavy metal biosorption, CO_2 biofixation and biodiesel generation. *Bioelectrochemistry*, *147*, 108208.
10. Ahiahonu, Elvis K., William W. Anku, Ashira Roopnarain, Ezekiel Green, Penny P. Govender, and Mahloro H. Serepa-Dlamini. (2022) "Bioresource potential of Tetradesmus obliquus UJEA_AD: critical evaluation of biosequestration rate, biochemical and fatty acid composition in BG11 media." *Journal of Chemical Technology & Biotechnology* 97, no. 3, 689-697.
11. Ahmed, H. Zolfo, M.; Williams, A.; Ashubwe-Jalemba, J.; Tweya, H.; Adeapena, W.; Labi, A.-K.; Adomako, L.A.B.; Addico, G.N.D.; Banu, R.A.; Akrong O.A.; Quarcoo G.; Borbor S.; Osei – Atweneboana M. (2022) Antibiotic-Resistant Bacteria in Drinking Water from the Greater Accra Region, Ghana: A Cross-Sectional Study December 2021–March 2022. *Int. J. Environ. Res. Public Health*, 19, 12300. https://doi.org/10.3390/ijerph191912300

12. Akrong, M. O., Anning, A. K., Addico, G. N. D., Hogarh, J.N., deGraft-Johnson, K. A. A., Adu-Gyamfi, A., Ale, M., and Meyer, A. S. (2022) Biomass and carrageenan yields of Hypnea musciformis in relation to selected environmental variables in the coastal waters of Ghana. *J Appl Phycol*. https://doi.org/10.1007/s10811-022-02790-3
13. Akurugu, B.A., Obuobie, E., Yidana, S.M., Stisen, S., Seidenfaden, I.K. and Chegbeleh, L.P. (2022). Groundwater resources assessment in the Densu Basin: A review. *Journal of Hydrology: Regional Studies* 40 (2022) 101017, doi.org/10.1016/j.ejrh.2022.101017.
14. Ama, O. M., Aigbe, U. O., Anku, W. W., Osibote, O. A., and Pal, K. (2022). Degradation of Methylene Blue Dye and Bisphenol-A Using Expanded Graphene-Polypyrrole-Magnetite Nanocomposite. *Topics in Catalysis*, 1-10.
15. Araya, D., Podgorski, J., Kumi, M., Mainoo, P. A., and Berg, M. (2022). Fluoride contamination of groundwater resources in Ghana: Country-wide hazard modeling and estimated population at risk. *Water Research*, *212*, 118083.
16. Asuming-Brempong, E.K., Ayi, I., van der Puije, W., Gyan, B.A., Larbi, I.A., Ashong, Y., Frempong, N.A., Quartey, J.K., Otchere, J., Jones, F.M. and Wilson, S. (2022). Increased ShTAL1 IgE responses post-Praziquantel treatment may be associated with a reduced risk to re-infection in a Ghanaian S. haematobium-endemic community. *PLoS neglected tropical diseases*, *16*(3), p.e0010115.
17. Boateng, C. N., Mtethiwa, A., and Agyakwah, S. K. (2022). Drivers of adoption intensity of pond aquaculture : The case of Ghana. *Aquaculture*, *560*, 738597.
18. Diyie R.L., Aheto, W.D., Yankson, K. Armah, E. and Osei-Atweneboana M.Y. (2022). Development of Multiplex PCR Assay for Detection of Bacterial Pathogens in Cultured African Nile Tilapia (*O. niloticus*) and Catfish (Clarias Gariepinus) in Ghana. *Archives of Microbiology.* 204(7):394. doi:10.1007/s00203-022-03001-w.
19. Fatsi, P.S.K., Appiah, E.K., Ogasawara, C., Tettey, P.A., Hashem, S., Saito, H. and Kawai, K. (2022). 16S rRNA Gene Sequence Identification of Cultivable-Bacterioplankton Between Ambient Water and Gastrointestinal Tract (GIT) of Resident Teleost. *Indian Journal of Microbiology*, *62*(2), pp.187-194.
20. Gawusu, S., Zhang, X., Ahmed, A., Jamatutu, S. A., Mensah, E. D., Amadu, A. A., & Osei, F. A. J. (2022). Renewable energy sources from the perspective of blockchain integration: From theory to application. *Sustainable Energy Technologies and Assessments*, *52*, 102108.
21. Gawusu, S., Zhang, X., Jamatutu, S. A., Ahmed, A., Amadu, A. A., & Djam Miensah, E. (2022). The dynamics of green supply chain management within the framework of renewable energy. *International Journal of Energy Research*, *46*(2), 684-711.
22. Gebrechorkos, S.H., Pan, M., Lin, P., Anghileri, D., Forsythe, N., Pritchard, D.M.W., Fowler, H.J., Obuobie, E., Darko, D. and Sheffield, J. (2022). Variability and changes in hydrological drought in the Volta Basin, West Africa. *Journal of Hydrology*: Regional Studies 42, 101143, https://doi.org/10.1016/j.ejrh.2022.101143.
23. Hashem, S., Kawai, K., Fatsi, P. S. K., Kodama, A., Appiah, E. K., Ogasawara, C., and Saito, H. (2022). Genetic differences among the species of genus Aulonocara and related genera of Malawian cichlids. *Ecological Genetics and Genomics*, *23*, 100121.
24. Karikari, A. Y., Asmah, R., Anku, W. W., Amisah, S., Trevor, T., and Lindsay, R. (2022). Assessment of cage fish farm impacts on physico-chemical parameters of the Volta Lake in Ghana. *Journal of Fisheries and Coastal Management*, *3*(1), 22-22.
25. Kuriakose, J., Anderson, K., Darko, D., Obuobie, E., Larkin, A. and Addo, S. (2022). Implications of large hydro dams for decarbonising Ghana's energy consistent with Paris climate objectives. *Energy for Sustainable Development* 71 (2022) 433–446, doi.org/10.1016/j.esd.2022.10.011.

26. Loh, Y. S. A., Fynn, O. F., Manu, E., Afrifa, G. Y., Addai, M. O., Akurugu, B. A., and Yidana, S. M. (2022). Groundwater-surface water interactions: application of hydrochemical and stable isotope tracers to the lake bosumtwi area in Ghana. *Environmental Earth Sciences*, *81*(22), 518.
27. Magna, E. K., Koranteng, S. S., Donkor, A., and Gordon, C. (2022). Levels of Persistent Organochlorine Compounds in Nile Tilapia (*Oreochromis niloticus*) from Three Cage Aquaculture Farms on the Volta Basin of Ghana: Implications for Human Health. *Environmental Processes*, *9*(3), 1-21.
28. Magna, E. K., Koranteng, S. S., Donkor, A., and Gordon, C. (2022). Heavy Metal Pollution in the Surface Sediments from Cage Aquaculture Farms in the Volta Basin of Ghana: Source Identification and Ecological Risk Assessment. *Water, Air, & Soil Pollution*, *233*(10), 1-14.
29. Martinez Cesena, E. A., Zhou, Y., Melchor Gutierrez, J. N., Zhu, W., Panteli, M., Mutale, J., Mancarella, P., Tomlinson, J., Baisie, R., Obuobie, E., and Harou, J. J. (2022). Quantifying the Impacts of Modelling Assumptions on Accuracy and Computational Efficiency for Integrated Water-Energy System Simulations Under Uncertain Climate. *IEEE Transactions on Sustainable Energy*.
30. Morang'a, C.M., Ngoi, J.M., Gyamfi, J., Amuzu, D.S., Nuertey, B.D., Soglo, P.M., Appiah, V., Asante, I.A., Owusu-Oduro, P., Armoo, S. and Adu-Gyasi, D., (2022) Genetic diversity of SARS-CoV-2 infections in Ghana from 2020-2021. *Nature communications*, *13*(1), pp.1-11.
31. Morang'a, C.M., Ngoi, J.M., Gyamfi, J., Amuzu, D.S., Nuertey, B.D., Soglo, P.M., Appiah, V., Asante, I.A., Owusu-Oduro, P., Armoo, S. and Adu-Gyasi, D., (2022). Genetic diversity of SARS-CoV-2 infections in Ghana from 2020-2021. *Nature communications*, *13*(1), pp.1-11.
32. Nechifor, V., Basheer, M., Calzadilla, A., Obuobie, E. and Harou, J.J. (2022). Financing national scale energy projects in developing countries – An economy-wide evaluation of Ghana's Bui Dam. *Energy Economics* 111 (2022) 106065, https://doi.org/10.1016/j.eneco.2022.106065.
33. Obiri-Nyarko, F., Asugre, S. J., Asare, S. V., Duah, A. A., Karikari, A. Y., Kwiatkowska-Malina, J., and Malina, G. (2022). Hydrogeochemical Studies to Assess the Suitability of Groundwater for Drinking and Irrigation Purposes: The Upper East Region of Ghana Case Study. *Agriculture*, *12*(12), 1973.
34. Obiri-Nyarko, Franklin, Jolanta Kwiatkowska-Malina, Samuel Kwame Kumahor, and Grzegorz Malina. (2022). Evaluating low-cost permeable adsorptive barriers for the removal of benzene from groundwater : Laboratory experiments and numerical modelling. *Journal of Contaminant Hydrology* 250: 104054.
35. Odinakachukwu C. E., Adjei, K.A, Andam-Akorful, S.A., GyamfI, C., Darko, D., Odai, S.N., and Kwarteng, E.V.S (2022). *Environmental Processes* 9:59. https://doi.org/10.1007/s40710-022-00613-8
36. Okrah, C., Appiah-Adjei, E. K., and Agyekum, W. A. (2022). Assessment of aquifer potential of the Vea catchment in Ghana using Pumping test technique. *Pakistan Journal of Geology*, *6*(2), 53-59. http://doi.org/10.26480/pjg.02.2022.53.59
37. Onyango, S. O., Owiredu, S. A., Kim, K. I., and Yoo, S. L. (2022). A Quasi-Intelligent Maritime Route Extraction from AIS Data. *Sensors*, *22*(22), 8639.
38. Otun, K. O., Azeez, I. O., Ama, O. M., Anku, W. W., Aigbe, U. O., Ukhurebor, K. E., and Onyancha, R. B. (2022). Sensing the Presence of Inorganic Ions in Water: The Use of Electrochemical Sensors. In *Modified Nanomaterials for Environmental Applications* (pp. 65-89). Springer, Cham

39. Owiredu, S.A., Kim, K.I. and Kim, B.Y. (2022). Seafloor litter generated by coastal and offshore fisheries operations in the South Sea of Korea. *Marine Pollution Bulletin*, *182*, p.113942.
40. Prajapati, S.K., Ayanful-Torgby, R., Pava, Z., Barbeau, M.C., Acquah, F.K., Cudjoe, E., Kakaney, C., Amponsah, J.A., Obboh, E., Ahmed, A.E. and Abuaku, B.K. (2022). Author The transcriptome of circulating sexually committed Plasmodium falciparum ring stage parasites forecasts malaria transmission potential. *Nature Communications*, *13*(1), pp.1-1.
41. Quarcoo, G.; Boamah Adomako, L.A.; Abrahamyan, A.; Armoo, S.; Sylverken, A.A.; Addo, M.G.; Alaverdyan, S.; Jessani, N.S.; Harries, A.D.; Ahmed, H.; *et al.* (2022) What is in the Salad? *Escherichia coli* and Antibiotic Resistance in Lettuce Irrigated with Various Water Sources in Ghana. *Int. J. Environ. Res. Public Health*, 19, 12722. https://doi.org/10.3390/ijerph191912722
42. Ragasa, C., Amewu, S., Agyakwah, S. K., Mensah, E. T-D., and Asmah, R. (2022). Impact of aquaculture training on farmers' income: Cluster randomized controlled trial evidence in Ghana. *Agricultural Economics*, 1–16. https://doi.org/10.1111/agec.12754
43. Sun, S., Zhou, J., Li, Z., Wu, Y., Wang, H., Zheng, Q., Adu-Nti, F., Fan, J. and Tian, Y., (2022). Progranulin promotes hippocampal neurogenesis and alleviates anxiety-like behavior and cognitive impairment in adult mice subjected to cerebral ischemia. *CNS neuroscience & therapeutics*, *28*(5), pp.775-787.
44. Willen, L., Milton, P., Hamley, J. I., Walker, M., Osei-Atweneboana, M. Y., Volf, P., .and Courtenay, O. (2022). Demographic patterns of human antibody levels to Simulium damnosum sl saliva in onchocerciasis-endemic areas: An indicator of exposure to vector bites. *PLoS neglected tropical diseases*, *16*(1), e0010108.

Conference Papers

1. Abuntori, Z.N., Obeng Bekoe, E. Quarcoo, G., Adu-Boakye, M., Abdul-Latif, S. and Mensah, E.T.D. (2022). Application of Geo-accumulation index, and health risk evaluation of the lower White Volta sub- basin in Ghana. 15th Annual Interdisciplinary Conference, IIR, UDS, Tamale
2. Agyakwa, S.K., Asmah, R., Ragasa, C., Oyih, M.C., Mensah, E.T.D., Nkansa, M. and Amewu, S. Can Ghana's pond farmers match the productivity of their counterparts on Lake Volta? The Fish Site. https://thefishsite.com/articles/can-ghanas-pond-farmers-match-the-productivity-of-their-counterparts-on-lake 4th October, 2022
3. Agyakwa, S.K., Asmah, R., Ragasa, C., Oyih, M.C., Mensah, E.T.D., Nkansa, M. and Amewu, S. 378 fish farmers trained, gain improved income through Tilapia Seed Project: https://www.ghanaweb.com/GhanaHomePage/business/378-fish-farmers-trained-gain-improved-income-through-Tilapia-Seed-Project-1626707 20th September, 2022
4. Agyakwa, S.K., Asmah, R., Ragasa, C., Oyih, M.C., Mensah, E.T.D., Nkansa, M. and Amewu, S. Fish farm tracker app launched https://www.ghanaiantimes.com.gh/fish-farm-tracker-app-launched/
5. Anani, F. A., Agbeko, E., Atsakpo, P. D. K., Johnson-Ashun, M., Osei, L. K. and Donkor, K. K. (2022). Dugout farming of Nile tilapia, *Oreochromis niloticus* for school feeding programme: A case study in the Lower Manya Krobo District, Eastern Region, Ghana. Proceedings of 3rd CSIR RSA Scientific Conference. Accra, Ghana.
6. Bortey-Sam, N., Akoto, O., Ikenaka, Y., Nakayama, S. M. M., Baidoo, E., Asante, K. A. and Ishizuka, M. (2022)- Heavy metal(loid) exposure and occurrences of respiratory outcomes, lipid peroxidation and DNA damage in residents of a Ghanaian

industrial/commercial city. Proceedings of the 43rd SETAC Annual Conference held at Pittsburgh, PA, USA from 13th to 17th November. Page 514. Oral Presentation.

7. Climate Change Resilience, Adaptation and Sustainable rural transformation international Conference. Sub-theme 2: Adaptation to Global Climate Change. Oral presentation: Future Changes of Extreme Precipitation Indices over the Volta Basin using CMIP6 models.
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