CSIR-WATER RESEARCH INSTITUTE

2023
Annual Report

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CSIR-WATER RESEARCH INSTITUTE (CSIR-WRI)

Annual Report 2023

ACCRA, GHANA

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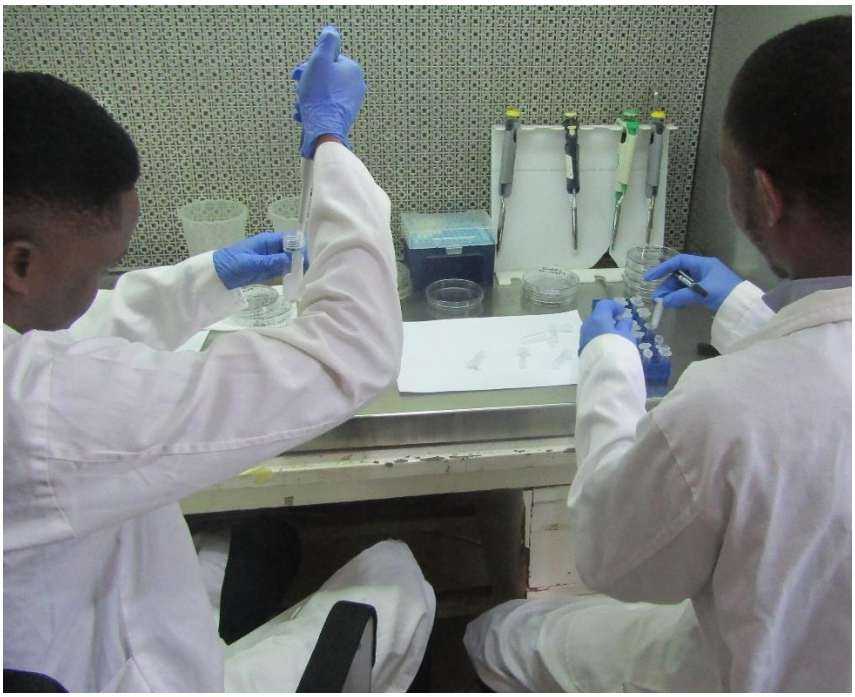
QUALITY WATER RESEARCH



FOR SUSTAINABLE NATIONAL DEVELOPMENT

CSIR-WATER RESEARCH INSTITUTE
ACCRA, GHANA

ACRONYMS

AFRIGIST	-	African Regional Institute for Geospatial Information Science and Technology
ARC	-	African Risk Capacity
ARDEC	-	Aquaculture Research and Development Centre
ASTII	-	African Science, Technology and Innovation Indicators
AMR	-	Antimicrobial Resistance
BPHRU	-	Biomedical and Public Health Research Unit
CC	-	Climate Change
CSIR	-	Council for Scientific and Industrial Research
CSIR-IRB	-	CSIR-Institutional Review Board
CWSA	-	Community Water and Sanitation Agency
DO	-	Dissolved Oxygen
EBBHD	-	Environmental Biology, Biotechnology and Health Division
ECSED	-	Environmental Chemistry and Sanitation Engineering Division
ERT	-	Electrical Resistivity Tomography
FAD	-	Fishery and Aquaculture Division
FAR-LeaF	-	Future Africa Research Leaders Fellowship
FDA	-	Food and Drugs Authority
FGD	-	Focus Group Discussion
GCF	-	Green Climate Fund
GFAASS	-	Ghana Forum for Agriculture Advisory Service and Support
GMET	-	Ghana Meteorological Agency
GSA	-	Ghana Science Association
GSM	-	Groundwater Simulation Model
GWCL	-	Ghana Water Company Limited
GWGD	-	Groundwater and Geoscience Division
HSD	-	Hydrological Services Department
IAB	-	Institute of Aquatic Biology
IDSS	-	Integrated Decision Support System
IECs	-	Institutional Ethics Committees
IPCP	-	International Panel on Chemical Pollution
IRB	-	Institutional Review Board
ISG	-	Immunological Society of Ghana
KNUST	-	Kwame Nkrumah University of Science and Technology
MDROs	-	Multidrug-Resistant Organisms
MESTI	-	Environment, Science, Technology, and Innovation
MMDAs	-	Metropolitan, Municipal and District Assemblies
NADMO	-	National Disaster Management Organization
NCC	-	National Coordinating Committee
NGRL	-	Newmont Golden Ridge Limited
NTDs	-	Neglected Tropical Diseases

OC	-	Organic Carbon
OM	-	Organic Matter
PURC	-	Public Utilities Regulatory Commission
RBS	-	Rapid Botanic Survey
RSA	-	Research Staff Association
SAR	-	Synthetic Aperture Radar
SDG	-	Sustainable Development Goal
SSPs	-	Socio-Economy Pathways
SOPs	-	Standard Operating Procedures
STHs	-	Soil Transmitted Helminthiases
SWAT	-	Soil and Water Assessment Tool
SWCCD	-	Surface Water and Climate Change Division
TWQR	-	Target Water Quality Range
UNEP	-	United Nation Environment Programme
UNESCO-IHP	-	United Nations Educational, Scientific and Cultural Organization - Intergovernmental Hydrological Programme
UTI	-	Urinary Tract Infection
WHO	-	World Health Organization
WRM	-	Water Resources Management
WRRI	-	Water Resources Research Institute
WSD	-	Water Storage Dam
WSSWG	-	Water and Sanitation Sector Working Group
TWG	-	Technical Working Group

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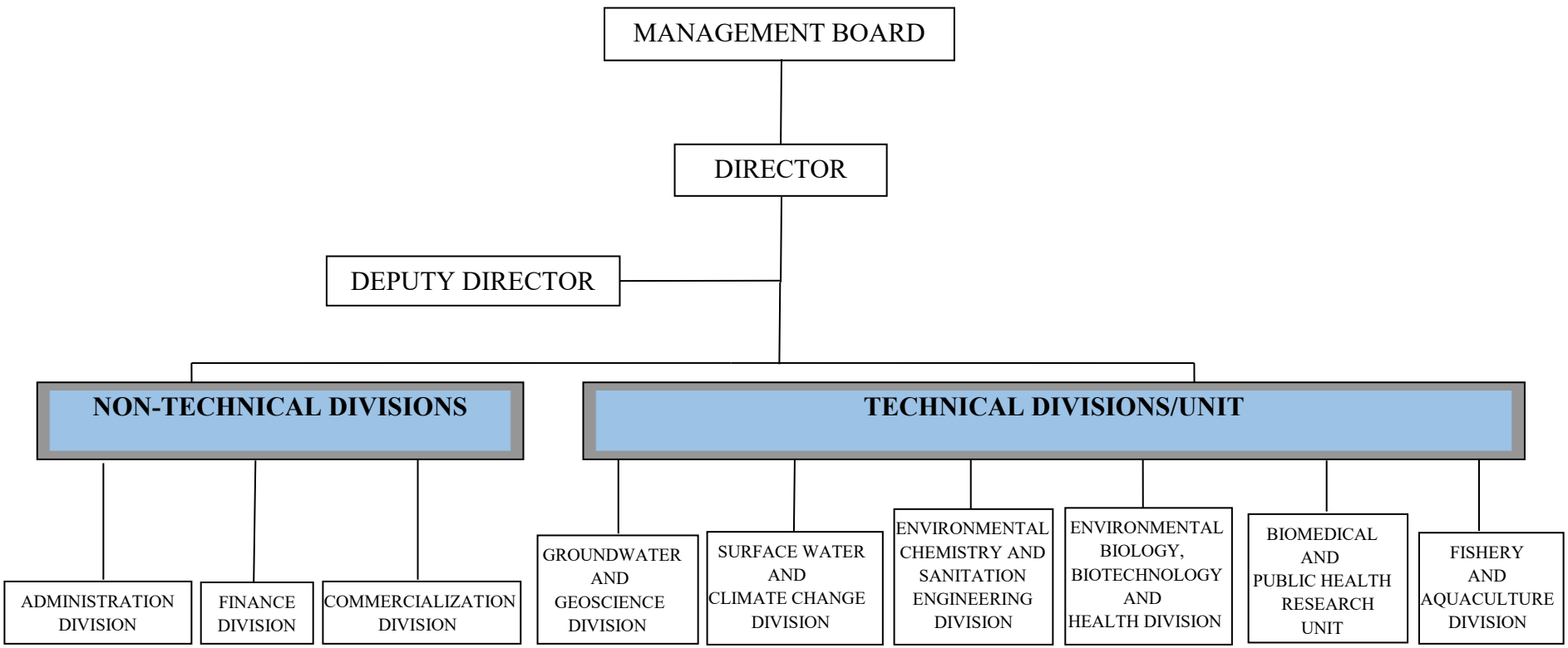
ORGANOGRAM


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

As one of the 13 research institutes of the Council for Scientific and Industrial Research (CSIR), the CSIR-Water Research Institute (CSIR-WRI) during the year 2023, took steps toward the realization of its vision of becoming a centre of excellence in the provision of scientific research into water and related resources as well as public health.

Mandated to conduct research into all aspects of water resources (both living and non-living), the Institute, in partnership with local and international collaborators, implemented over twenty (20) research projects. The focus was to provide scientific and technological information and services as well as strategies for the sustainable development, utilization, and management of water resources for the socio-economic advancement of the country.

This report highlights the Institute's research and development activities which focus on aspects of sustainable water resource management for socio-economic advancement.

The year 2023 saw the solidification of research in key research areas such as food security and poverty reduction, pollution and waste management, and biomedical and public health. These research areas, aside aligning with the Institute's mandate, further support the achievement of the United Nations Sustainable Development Goals (SDGs) with particular focus on SDG 1 (no poverty), SDG 2 (zero hunger), SDG 3 (good health and well-being), SDG 6 (clean water and sanitation), SDG 8 (decent work and economic growth), and SDG 13 (climate action).

In the area of biomedical and public health, the Institute continued with its water and wastewater epidemiology by conducting bio-medical research into communicable and non-communicable diseases. Efforts geared towards eradication of malaria were increased in the reporting year. Molecular screening for diarrhoea-causing microbes and Neglected Tropical Diseases (NTDs) studies such as Soil Transmitted Helminthiases (STHs) were considered. The Institute endeavoured to develop technologies and strategies towards the control and elimination of such diseases in contributing to a healthier population and workforce.

Throughout the year under review, fisheries and aquaculture initiatives were undertaken. Community cage fish farming initiated impacted the lives of especially youth and women by

equipping them with alternative livelihood skills which improved food security and nutrition in deprived communities.

Despite economic challenges and climate change related risks encountered during the year, the Institute made significant strides in reviving the Tilapia Breeding Program at the Aquaculture Research and Development Centre (ARDEC). The focus was to keep developing superior breed of the Nile tilapia (*Oreochromis niloticus*) which was fast growing, highly fecund, disease resistance, and had the ability to produce offspring with highly desirable traits. The program, with the potential to promote sustainable development and resilience in the aquaculture sector, will enhance Ghana's position in the global aquaculture market.

The Institute, in the reporting year, deepened its contribution towards the generation of demand-driven technologies by exploring the efficacy of oyster shells in removing nitrate and phosphate from drinking water and wastewater sources. The provision of scientific and technological information and services continued to be key in the Institute's activities with respect to the needs of stakeholders.

The critical role of sustainable groundwater in achieving the SDGs was also examined as a key element in the country's resilience to climate change. In support of the poor and vulnerable in society, the Institute continued to assess groundwater potential for potable and agricultural uses which served as a shield against ecosystem loss, and as a defence against human deprivation.

The Institute could not have achieved the above without the support of the Management Board, Internal Management Committee, donors, development partners, sponsors and collaborators. We are grateful to all for their hard work, dedication and bold steps toward the realization of our vision.

We acknowledge the collaborative efforts of all staff, comprising Senior Members, Senior and Junior staff, which contributed to a positive work environment and adherence to governance standards.

We also appreciate all those who have contributed to our success in diverse ways. Together we were stronger as a team without flaws in 2023. It is our hope that we continue to work even harder to uphold and defend the good image of the Institute to secure our successes.

We are grateful, that together, we have come this far.

EXECUTIVE SUMMARY

This report outlines research and development activities undertaken by the CSIR-Water Research Institute (CSIR-WRI) of the Council for Scientific and Industrial Research during the year 2023. The Institute is one of the 13 research 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 2023 Annual Report comprises three (3) sections: Introduction, Administration, and Research and Development Activities. The Introduction covers an overview of the establishment, vision statement, mission statement, objectives and core activities of the Research Divisions. The administrative report encompasses staff strength, appointments, promotion/upgrading, new recruitment, deaths as well as national service recruitment. The Research and Development activities are a compilation of research projects undertaken by the research staff, and commercialization of research and development activities through consultancy and advisory services.

The Institute, in partnership with local and international collaborators, implemented a total of twenty-seven (27) research projects during the year. These have been reported under three thematic areas:

i. Food Security and Poverty Reduction (9 projects)
ii. Climate Change, Environmental Management and Green Technology (11 projects)
iii. Biomedical and Public Health (7 projects)

A total of forty-three (43) journal papers, one (1) book, two (2) book chapters, twelve (12) conference papers, several technical reports, consultancy reports 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 Objectives and Core Activities of the Technical Divisions/Unit

1.6.1.1 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.

1.6.1.2 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 physical/chemical constituents, and their human and ecological health risks;
- Monitor pollution in coastal waters and lagoons in Ghana; and
- Assess the quality of boreholes for individuals and water meant for the production of sachet and bottled water to acquire Food and Drugs Authority (FDA) permit.

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.

The Division also collaborates with some partners outside Ghana and some of its Researchers serve as External Examiners for some universities in Ghana and outside Ghana.

1.6.1.3 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 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. The main objective is to ensure annual increase in domestic fish production through improved fish culture technologies and improved sustainable management strategies for inland and coastal fish and fisheries resources in Ghana. The specific objectives are to:

- improve the quality and variety of fish seed
- improve the quality and cost of fish nutrition
- make fish production cost-effective and viable
- make fish readily available and affordable
- minimize the negative environmental impacts
- Improve understanding of the state of fish and fisheries under natural conditions
- improve management interventions

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.

1.6.1.4 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 daily uses; 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
- Hydrogeochemical modelling

1.6.1.5 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.

1.6.1.6 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.

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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2.0 ADMINISTRATION

The Administration Division provided services and support to staff, Divisions and Outstations of the Institute to ensure effective and efficient work environment required for the achievement of the objectives of the Institute. The Division also implemented policies, regulations and rules of the Council and decisions taken at Management meetings to improve upon staff performance.

2.1 Management

Management Board worked assiduously with the Internal Management Committee (IMC) to promote research activities of the Institute and ensured that the Institute worked within set targets in its Key Performance Indicators (KPIs) while keeping to its vision. Membership of the Management Board and the IMC are given in Appendices I and II, respectively.

2.2 Staff Strength

Staff strength at the end of the year 2023 stood at 239. This was made up of 101 Senior Members, 95 Senior Staff and 43 Junior Staff. The list of Senior Members and Senior Staff and staff distribution are presented in Appendix III.

2.3 Statistics on Human Resource Activities

The number of appointments, promotion/upgrading, transfer, compulsory retirement and resignation are shown in Appendix IV.

2.4 Human Resources Development

Staff members 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 and in conformity with the policy of CSIR to provide relevant training for staff. The statistics are presented in Appendix V.

2.4.1 Short-Term Training Programmes Attended by Staff

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

- Royal Society of Chemistry, UK training course on Liquid Chromatography-Mass Spectrophotometry (LC-MS) at the Jomo Kenyatta University of Agriculture and Technology, Kenya from 13th to 17th November, 2023.
- Blue Carbon field data collection and analysis training organized by NOAA and Silvestrum Climate Associates, 31st October to 2nd November 2023, Accra.
- Blue Carbon 101 for coastal managers training organized by NOAA, 6th to 10th November 2023, Accra.
- Training on general aquaculture and aquatic animal health to support sustainable aquaculture in the Sub-Saharan Africa, 2nd to 9th September, 2023, WorldFish Center, Egypt.
- 2nd international spring school in global health, 27th to 31st March 2023, (online).
- 2023 women plus water lecture series on flood warnings and maps water models and tools in practice, 9th May 2023. (online).
- Training workshop on Integrated Decision Support System (IDSS) - feed the future innovation lab for small-scale irrigation organized by the Department of Earth Science, University of Ghana, 15th to 19th May, 2023, Accra.
- Training workshop on building a globally recognized research profile, organized by the Directorate of Research and Connectivity, Clifford University, Owerrinta Abia State, Nigeria, in collaboration with the University of Natural and Life Sciences (BOKU) Austria, 20th to 22nd November, 2023, (online).

- United Nation Environment Program (UNEP) training workshop on community-driven freshwater plastic monitoring, 11th to 12th September 2023, Accra.
- Training on monitoring water quality of inland lakes using remote sensing, 18th to 25th July, 2023.
- Training course on Coastal Management through the integrated sediment management approach, 22nd to 26th May, 2023.
- Crop mapping using Synthetic Aperture Radar (SAR) and optical remote sensing, 4th to 11th April, 2023.
- Summer school on air quality and pollution prevention in Ghana, organized by Clean Air Fund in collaboration with the Department of Meteorology and Climate Science, KNUST, Ghana and the University of Leeds, UK, 21st October to 4th November 2023, Kumasi.
- Training on connecting citizen science with remote sensing, organized by NASA's Applied Remote Sensing Training (ARSET) Program, 24th, 26th and 31st January 2023, (online).
- Training workshop on Land Degradation using Digital Earth Africa Tools, organized by African Regional Institute for Geospatial Information Science and Technology (AFRIGIST) in collaboration with Digital Earth Africa (DE Africa), 27th to 28th February 2023, (online).
- Fundamentals of machine learning for earth science, organized by NASA's Applied Remote Sensing Training (ARSET) Program, 20th and 27th April 2023, (online).
- Early career women scholars workshop 2023, organized by DAAD, University of Ghana and CEGENSA, 16th to 17th November, 2023, Accra.
- Training on climate change adaptation and mitigation in Africa (Region 3), organized by the Institute for Climate, Energy & Disaster Solutions, Australian National University, 28th April to 9th June 2023.
- Training on Copernicus user uptake in Africa via technical support in the field of disaster management and disaster risk reduction, organized by ZFL, University of Bonn, 29th to 30th March 2023.
- African Science, Technology and Innovation Indicators (ASTII) training workshop, organized by CSIR-STEPRI in collaboration with the African Union Development Agency of New Partnership for African Development (AUDA-NEPAD), 25th to 27th April 2023, Accra.
- EOS Data Analytics' webinar "All eyes on fields: EOSDA gets a U.S Patent for web-based productivity maps", organized by EOS Data Analytics, 31st July 2023, (online).
- EOS Data Analytics' webinar "Greenpeace and EOSDA – A road to sustainable future with space tech", organized by EOS Data Analytics, 17th October 2023, (online).

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 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:

- Stakeholder consultative meeting to rollout joint management plans and the harmonized regional frameworks for conserving aquatic biodiversity and environmental management for Kenya, Uganda and Tanzania, 23rd to 24th March 2023, Kampala, Uganda.
- Science engagement meeting, 25th October 2023, Kumasi.

- Expert consultation on the suitability of small reservoirs for aquaculture development, 31st October 2023, Accra.
- Ghana's water security: Rethinking the value of water, 28th to 29th November 2023, Accra.
- One-day steering committee meeting of experts of fish feed formulation, 17th November 2023, Fisheries Commission, Accra.
- A workshop on alternative feed formulation for on-farm fish feed production using local raw materials to support commercial fish farming in Ghana, 30th October to 2nd November 2023, R and B Farms, Swedru.
- A two-day intensive workshop for key departmental officers and faculty members of the CSIR College of Science and Technology, 25th to 26th October 2023, CSIR-Food Research Institute, Accra.
- Stakeholder workshop: Piloting aquaculture in small reservoirs in the North-East Region, Ghana, 7th November 2023, Walewale.
- 15 Years of impact at Saha Global, 15th November 2023, Tamale.
- Workshop of the "local knowledge diffusion node of the TEMBO Africa Project, 15th November 2023, Tamale.
- OCPP biodiversity theme workshop: Understanding the needs and priorities for Marine Spatial Planning (MSP) and Marine Protected Areas (MPAs), 15th to 16th February 2023, Accra.
- Launch of e-learning platform - CSIR Farm Academy, 13th December, 2023, Accra.
- Blue food partnership Ghana initiative networking event, 22nd September 2023, Accra.
- An early career personal development workshop, 24th to 25th July 2023, Accra.
- An international workshop on antimicrobial discovery and biobanking, 10th to 12th October 2023, Accra.
- Science Engagement Days 2023 - Equitable partnerships in development research projects, 27th to 29th March 2023, Arusha, Tanzania.
- CREAM shared-socio economic pathway workshop national stakeholders, 8th to 9th February 2023, Koforidua.
- Sensitization workshop for CSIR researchers engaged with the Jospong Group, 18th to 19th May 2023, Gomoa Fetteh.
- UNESCO workshop on underwater cultural heritage, 28th to 30th August 2023, Accra.
- Dissemination workshop on understanding the agricultural research and development system in Ghana: What implication for projects related to value chain and employment issues? 19th September 2023, Accra.
- Natural capital accounting: Land and ecosystem extent and ecosystem services sub-working groups meeting, 26th to 29th September 2023, Accra.
- Seminar on Ghana's water security: Rethinking water availability, 1st November 2023, Accra.
- Seminar on Ghana's water security: Rethinking the quality of water, 14th November 2023, Accra.
- Seminar on Ghana's water security: Rethinking water management, 23rd November 2023, Accra.
- Seminar on Ghana's water security: Rethinking water and life, 29th November 2023, Accra.
- 33rd Biennial Conference of the Ghana Science Association, 5th September 2023, Accra.
- 2nd National Coordinating Committee (NCC) on drinking water quality management meeting, 17th October 2023, Accra.

- Ghana water quality study II stakeholders update meeting, 14th December 2023, Accra.
- WASH sector performance review meeting, 9th to 10th November 2023, Accra.
- Water and Sanitation Sector Working Group (WSSWG) meeting, 27th June and 5th October 2023, Accra.
- 7th Green and Sustainable Chemistry Conference, 22nd to 24th May 2023, Dresden, Germany.
- National Technical Committee on water quality at the Ghana Standards Authority, 15th March 2023, Accra.
- Vaccine research and development workshop, 22nd June 2023, Accra.
- Co-creation workshop on "piloting national nature strategy for Ghana - introducing the framework", 29th August 2023, (online).
- Co-creation workshop on “framework for a CBD-aligned national nature strategy: Applying the framework to the Ghanaian context”, 13th September, 2023, Accra.
- Annual ethics lecture 2023; 26th October 2023, Accra.
- Planning and results sharing meetings of the project: Sustainable management of wetlands and floods for enhancing food security and ecosystem resilience in West Africa (GDZHIAO), 19th to 23rd June 2023, Banjul, The Gambia.
- Annual planning and stakeholder dissemination workshop of the project: Building climate-resilience into basin water management (CREAM), 7th to 9th November 2023, Accra.
- Science engagement meeting for knowledge exchange and dissemination of results from 3 Danida-funded projects (VOLTRES, RELAB and CREAT) on climate resilience and sustainability of African lake ecosystems and their fisheries, 24th to 25th October 2023, Kumasi.
- First meeting of Ghana committee for UNESCO-IHP, 30th March 2023, Accra.
- Investing in farmer-led irrigation development in Sub-Saharan Africa: Business, development, and research practices, 26th to 27th April 2023, Accra.
- Mini-national workshop to review draft regional strategy for flood and drought risk reduction and management in the Volta Basin, 27th April 2023, Accra.
- Workshop on ‘Feed the future innovation laboratory for small-scale irrigation, 23rd to 25th May 2023, Addis Ababa, Ethiopia.
- Green Climate Fund (GCF) proposal formulation on mangroves and coastal resilience, 2nd June 2023, Accra.
- Water and Development Partnership Programme -Joint Sounding Board and Committee meeting, 23rd August 2023, (online).
- Second meeting of Ghana committee for UNESCO-IHP, 30th August 2023, Accra.
- Review of climate-smart agriculture and food security action plan, 16th to 17th August 2023.
- Two (2) day stakeholder consultative workshop on WASH sector resilience study in Ghana, 27th to 28th April, 2023.
- Training programme on patent registration and intellectual property, 19th December 2023, Accra.
- Workshop to review the draft Volta Basin Charter, 22nd August 2023, Accra.
- Workshop on flood nowcasting in Ghana, 2nd to 3rd February 2023, Koforidua.
- Workshop on African Risk Capacity (ARC) - Drought risk modelling and customization for Ghana, 27th to 30th March 2023, Accra.
- 18th Meteorological virtual seminar series – Ghana on future changes in extreme precipitation events over the Volta Basin, 27th April 2023, (online).

- Workshop on enhancing food security: The role of Ghanaian scientists, 18th to 19th May 2023.
- World Food Day youth dialogue,17th October 2023, Accra.
- Inception workshop on customized and integrated climate services for improved resilience and sustainable socio-economic development in West Africa, 18th to 19th December 2023.
- Third meeting of the Technical Working Group (TWG) on invasive species (IS) management in Ghana, 26th July 2023, Accra.
- Workshop on water quality in the Volta River Basin, 14th September 2023, Accra.
- Consultation workshop on degree of implementation of integrated water resources management (Sustainable Development Goal Indicator 6.5.1) monitoring and reporting and national validation in Ghana, 11th September 2023, Accra.
- Consultation meeting on Ghana's circular economy (GCE) and bridging the financial gap, 5th September 2023, Accra.
- Future Africa Research Leaders Fellowship (FAR-LeaF) workshop on "transdisciplinary research", 17th to 21st August 2023, Pretoria, South Africa.
- PRE-COP 28 stakeholder meeting under the theme: "Road to COP 28-Harmonizing science and policy perspectives towards Ghana's climate priorities and resilience building to support global efforts", 14th December 2023, Accra.
- Workshop to review a draft regional strategy for flood and drought risk reduction and management in the Volta Basin, 27th April 2023, Accra.
- Workshop to assess the progressive management pathway for AMR in Ghana, 7th to 10th March 2023, Accra.
- Third meeting of the Technical Working Group (TWG) Ghana AMR Surveillance, 18th September 2023, Accra.
- Legionella Action Group meeting, 6th July and 31st October 2023, (online).
- Fourth meeting of the Technical Working Group (TWG) Ghana AMR Surveillance, 31st October 2023, Accra.
- USAID EpiC Global Health Security (GHS) project kick off meeting, 19th December 2023, Accra.

2.6 Employee Relations

2.6.1 Retirements and Service Recognition

The 2023 Retiree and Service Recognition Awards took place during the end-of-year party held on 19th December, 2023. Staff who were honoured for their contributions to the Institute are shown in Table 2.1.

Table 2.1: List of Retirees in 2023.

No.	Name(s)	Years Served
1	Dr. Gloria N. D. Addico	31 years
2	Dr. Anthony Y. Karikari	33 years
3	Mrs. Patience D. K. Atsakpo	35 years
4	Mrs. Claudia Bentum	35 years
5	Mr. Oswald K. Nyimebaare	30 years
6	Mr. Godwin Amegbe	39 years
7	Mr. Edem K. Ayegbe	33 years
8	Mr. Emmanuel O. Ayim	19 years
9	Mr. Cephas Dzah	18 years
10	Ms. Joycelin J. Osibo	39 years
11	Mr. Lawrence Seshie	24 years
12	Mr. Anthony Arko	35 years
13	Mr. Samuel A. Antwi	38 years

2.7 National Service and Industrial Attachment

The Institute supported tertiary institutions towards training of students as part of its corporate social responsibility and national capacity building activities. The durations of the training programmes were eleven (11) months for National Service and between four (4) and twelve (12) weeks for industrial attachment. The details are presented in Appendix VI.

2.8 Visitors to the Institute

Some institutions/organizations visited the Institute during the year 2023. The details are shown in Table 2.2.

Table 2.2: Institutions who visited the Institute in 2023.

No.	Institution	Date of Visit
1	Aggrey Memorial A.M.E Zion	03-November-2023
2	Rotary Club, Accra	11-September-2023
3	Biological Science Student Association, University of Cape Coast	31-March-2023
4	Media Foundation for West Africa Climate Change	27-January-2023

2.9 Membership of Committees and Boards

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

- Fisheries Commission Board
- CSIR Strategic Plan Implementation Committee
- CSIR-Water Research Institute Interim Management Committee
- International Panel on Chemical Pollution (IPCP)
- CSIR-Water Research Institute Editorial Committee
- CSIR-Water Research Institute Open Day Organizing Committee
- CSIR-Research Staff Association (CSIR-RSA)
- Ghana Forum for Agriculture Advisory Service and Support (GFAASS)
- World Aquaculture Society- African Chapter, West Africa Region, Regional Advisory Committee
- Immunological Society of Ghana (ISG)
- Ghana Science Association
- Technical Committee on Environmental Protection Standards on Effluent Quality.
- Ghana Standards Authority Adhoc Committee to set Boron standard in drinking water in Ghana

- LANSORT Vaccine Development Group
- Ghana Biomedical Conference
- European Academy of Allergy and Clinical Immunology (EAACI)
- CSIR-RSA-Southern Zone Investment Committee
- Ghana UNESCO-IHP Committee
- CSIR-WRI Intellectual Property Right Committee
- CSIR-WRI Facility Management Committee
- GhIE-Research and Awards Committee
- GhIE-Welfare Committee
- CSIR-RSA Digital Communication Committee
- CSIR-WRI Editorial Committee
- CSIR-WRI Intellectual Property Right Committee
- National Technical Committee for Drinking Water Quality.
- Water Resources Information Platform committee
- Ghana Natural Capital Accounting (NCA) Ecosystem Services Technical Sub-Working Group
- Ghana National Platform for the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES)

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 VII.

2.11 Open Day and Seminars in 2023

2.11.1 Open Day

An Open Day was organised with a total of 270 people participating. These comprised of exhibitors, research presentation participants and the general public. The event was held on the premises of the Institute on 28th and 29th November 2023 on the theme 'Ghana's Water Security: Rethinking the Value of Water'.

The Open Day celebration was to welcome stakeholders and the general public to be acquainted with the activities of the institute. Series of seminars on the premises of the Institute and online via Zoom on 1st, 14th and 23rd November, 2023 were held prior to the main event. There was also a stakeholder engagement forum, an interaction with the media and exhibitions of various water technologies and made-in-Ghana products and services. It was organized and facilitated by the CSIR-WRI and sponsored by CSIR-Building and Road Research Institute, CSIR-Food Research Institute, SIRCOOL Bottled Water Company Ltd. and JOISSAM Co. Ltd.

This event saw the participation of the major key stakeholders, research and academia, and public and private institutions. Some pictures during the Open Day exhibition are shown in Figure 2.1.

Figure 2.1: Some pictures during the Open Day exhibition.

2.11.2 Seminars

The seminars consisted of presentations and discussions on the theme, Ghana's Water Security: Rethinking the Value of Water and sub-themes such as Rethinking Water Availability, Rethinking the Quality of Water, Rethinking Water Management and Rethinking Water and Life. Some pictures during the seminars are shown in Figure 2.2 and details of the seminar presentations are shown in Table 2.3.

Figure 2.2: Some pictures during the seminars.

Table 2.3: Internal Seminar Presentations During 2023.

Date	Presenters/ Speakers	Topics
1st November, 2023	Dr. Barnabas Amisigo	Surface water availability, quality and sustainable use
1st November, 2023	Dr. William Atuobi Agyekum	Groundwater availability, quality and sustainable use
14th November, 2023	Dr. Anthony Yaw Karikari	Protecting the quality of Ghana's waters through pollution control and regulation
14th November, 2023	Rev. Dr. Gloria N. D. Addico	Enhancing the quality of Aquatic life in Ghana's waters: Implications for water management
23rd November, 2023	Mr. Ben Ampomah	Improving Water Governance for Socio-economic benefits
28th November, 2023	Professor Chris Gordon	Ghana's Water Security: Rethinking the Value of Water.
29th November, 2023	Prof. Mike Yaw Osei-Atweneboana	Water and Human Health
29th November, 2023	Prof. Alfred A. Obeng-Yeboah	Water Ecosystem Services and Human Wellbeing: Implications for Water Management

2.12 CSIR-WRI Commercial Fish Farm

The CSIR-WRI commercial fish farm (Figure 2.3) was established with the objective to generate income, promote sustainable aquaculture development and enhance local fish production and sustain livelihoods. The commercial fish farm began operations in July 2023 with three (3) 13 m^3 capacity tarpaulin tanks. Tanks 1, 2 and 3 were stocked with 700, 1150 and 1610 catfish fingerlings, respectively. The number of tanks were increased to six (6) in September 2023. This comprised five (5) circular tanks, and one (1) rectangular tank. Currently, there are a total of ten (10) production tanks comprising three (3) large rectangular tanks, two (2) smaller tanks, and five (5) circular tanks, each holding an average of 800 fish. Three batches of catfish have been harvested since inception. Customers had the option of purchasing the fish fresh, frozen, smoked or live. The sizes of the harvested fish ranged from 800 g to 1.2 Kg.

Activities undertaken during the year included preparation of tanks and stocking; fish sampling (involves weighing and measurement of fish length); grading or sorting of fish; feeding of fish with pelletized feed three times daily; water quality monitoring; water exchange (involves discharging the water frequently to improve the water quality, minimise fish mortality and also reduce pathogenic effect); and fish harvesting either through repeat netting or partially emptying the tank's water through an outlet point. Some of the activities are shown in Figures 2.4 and 2.5.

Figure 2.3: CSIR-WRI commercial fish farm.

Figure 2.4: Feeding fishes with pelletized feed.

Figure 2.5: Monitoring water quality at the commercial fish farm site.

Impact of the CSIR-WRI Commercial Fish Farm on National Economy

Fish farmers and individuals buy the fingerlings and juveniles for culturing thereby bridging the unemployment gap. Also, households and individuals purchased the Table-size fish which are a source of animal protein, thereby improving nutrition and food security.

2.13 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:

- Production and supply of tilapia fingerlings (Client: Fish Farmers)
- Use of SWAT to model water flow regulation and sediment retention in the Pra and Volta Basins (Client: World Bank)
- Water quality analyses (Clients: Saha Global, TAMA Foundation, Water Resources Commission, Savannah Cement, Eastern Corridor)
- Quarterly assessment of final effluent quality (Client: GIHOC Pharmaceuticals)
- Monthly assessment of final effluent quality (Client: Accra Brewery Limited)
- Monthly assessment of final effluent quality (Client: Standard Chartered Bank)
- Half-yearly assessment of physico-chemical and bacteriological quality of boreholes and tap water from selected communities (Client: Oyibi Area Water and Sanitation Scheme)
- Surface water ecological studies and monitoring at the Akyem mine (Client: Newmont Golden Ridge Limited)
- Quarterly assessment of effluent quality (Client: West Hills Mall Limited)
- Assessment of water quality for drinking and irrigation (Client: Food Systems Resilience)
- Quarterly assessment of water and sludge samples (Client: West African Fish Limited)
- Monthly assessment of effluent quality (Client: Tema Lube Oil Co. Ltd.)
- Quarterly assessment of effluent quality (Client: Movenpick Ambassador Hotel)
- Assessment of wastewater quality (Client: Cocoa Processing Company)
- Assessment of product water and effluent quality (Client: Befesa *Desalination* Developments *Ghana* (Abengoa)
- Assessment of water quality (Client: Environmental Services Limited)
- Aquaculture feasibility studies, Maferenya, Republic of Guinea (Client: Salifu ILIASU, ECOWAS Bureau de la Représentation Permanentede la CEDEAO en Guinée)
- Environmental monitoring of activity area (Client: Kama Industries)
- Drinking water quality assessment of water treatment system (Client: VALCO Company Limited)
- Independent sampling and testing of GWCL distribution network in 4 regions (Ashanti, Western, Eastern and Greater Accra) (Client: Public Utility Regulatory Authority (PURC)

2.14 Capacity Building/Human Resource Development

2.14.1 Training Offered by Staff to Individuals and Groups

The Institute offered several training programmes via various modules to individuals, groups, Non-governmental Organizations, and students of the Universities and Technical Universities. Amongst them were:

- Training of over 50 beneficiaries in fish nutrition and feeds at the National Aquaculture Training Centre of the Fisheries Commission, Amrahia-Accra.
- Training of over twenty (20) practicing and prospective fish farmers at ARDEC, Akosombo
- Part-time teaching of MPhil students of the CSIR College of Science and Technology, Department of Fisheries Science and Aquaculture, a course in fish nutrition and feeds.
- Hands-on training for 26 participants on cage fish farming for four communities in the North-East Region of Ghana as part of the resilient aquatic food systems project.
- Training of internship students and national service personnel from UDS, UENR, KNUST, UG and various technical universities on fish farming activities at ARDEC.
- Quarterly training on fish production (tilapia and catfish grow out)
- Training of technical officers to carry out in-silico screening of aptamers against Schistosoma circulating cathodic antigen (CCA)
- Training of technicians and interns on immunological techniques
- Part-time lecturing in immunology at the Accra College of Medicine (ACM), East Legon, Accra.

2.14.2 Contribution to Training Programmes (External Examiner, Supervision and Co-Supervision of Masters and PhD Thesis)

- Assessment of a Ph.D. student's proposal (Hydro-ecological and economic modelling of hydrological services in the Somone Watershed, Senegal) and examined orally as part of a Ph.D. comprehensive examination, June 2023: Moustapha Wele (PG6990821), Regional Water and Environmental Sanitation Center, Kumasi (RWESCK), Kwame Nkrumah University of Science & Technology (KNUST)
- Assessment of a Ph.D. student's proposal (Assessment of Anthropogenic and Climate Impacts on Tropical Wetland Ecosystem, Ghana) and examined orally as part of Ph.D. comprehensive examination: Mandy Edinam Dzomeku (PG6991021), RWESCK, KNUST
- Assessment of a Ph.D. student's proposal (Assessment of current risks related to climate change and anthropogenic activities affecting water resources and their management: the case of the Bia transboundary watershed) and examined orally as part of Ph.D. comprehensive examination: Kouame Amoin Marie Andrée (PG6990721), RWESCK, KNUST
- Examination of MPhil student thesis: Modelling the impact of climate change on the hydrologic response of the Pra River Basin, by Jeremiah Onumah (student number: 10440193), Earth Science Department, University of Ghana.
- Supervision of Ms. Yaa Asabea Agadzi (student number: WRI/AQCU/20/09/001), MPhil student enrolled at the CSIR College of Science and Technology, thesis title - Occurrence of microplastics in water, sediment, culutured and wild fish in the Lower Volta Basin of Ghana (2023).
- Supervision of Ms. Esi Esuon Biney, a PhD student enrolled at the Civil Engineering of the Kwame Nkrumah University of Science and Technology; thesis title – Integrated ecological approach to water quality assessment of the Barekese Reservoir for efficient and sustainable management (2022 - 2024).
- Supervision of Bismark Akurugu, a PhD student on the CREAM project and enrolled at the Earth Science Department of the University of Ghana; thesis title – Aquifer characterization and numerical modelling for groundwater resources assessment in the Densu Basin (2019-2024).

- Supervision of Martin Addi, a PhD student on the CREAM project; enrolled at the Department of Meteorology and Climate Science, Kwame Nkrumah University of Science and Technology; thesis title – Improving multiple ensembles climate change projections over Pra and Densu river basins for hydrological impact modeling (2019-2024).
- Supervision of Simeon Odametey, a PhD student on the CREAM project; enrolled at IESS, University of Ghana; thesis title – Evaluating the dynamics of water related ecosystem services in the Densu River Basin (2019-2024).
- Supervision of Mark Osei-Owusu, a PhD student on the CREAM project; enrolled at the Civil Engineering Department of Kwame Nkrumah University of Science and Technology; thesis title – Impacts of changes in climate and land-use/-cover on hydrology of the Pra River Basin (2019-2024).
- Supervision of Franz Alex Gaisie-Essilfie, a PhD student on the CREAM project; enrolled at the Civil Engineering Department of Kwame Nkrumah University of Science and Technology; thesis title – Machine learning-based model for prediction of land-use/land-cover changes in the Densu Basin, Ghana (2020-2024).
- Supervision of Samuel Kyei-Manuh, a PhD student on the CREAM project; enrolled at the Department of Meteorology and Climate Science, Kwame Nkrumah University of Science and Technology; thesis title – Water resource modelling in the Pra Basin from a multi-objective perspective (2020-2024).
- Supervision of Frederick Logah, PhD student at Kwame Nkrumah University of Science and Technology (KNUST); thesis title – Integrated flood risk assessment of the Black Volta Basin, Ghana (graduated in March 2023).
- Supervision of S'mangele Johanna Buthelezi, a student at Management College of South Africa, Department of Public Administration; thesis title: Evaluating the access to Drinking Water and Sanitation Services in the Mpukunyoni area of the Mtubatuba Municipality.
- Supervision of Yoland Bronwynn Dempers, a student at Management College of South Africa, Department of Public Administration; thesis title: Assessing the Effectiveness of Youth Training and Development Programmes: Case of the Premier's Advancement of Youth Programme in Western Cape.
- Supervision of Tabisa Gwele, a student at Management College of South Africa, Department of Public Administration; thesis title: Assessing the Effectiveness of Occupational Health and Safety Policies under Covid-19 Pandemic: A Case of the College of Emergency Care under the Department of Health in the Western Cape.
- Supervision of a PhD student thesis title: Water resources management: A catalyst for water yield sustainability in the Densu River Basin, Ghana) by Ebenezer B. Mac-Tetteh, Institute of Development and Technology Management, Cape Coast.

2.15 Review of Manuscripts/Journals

- Reviewed a manuscript for the Sustainable Water Resources Management (SWAM) journal. Title: Hydrological analysis of stream flow characteristics in the Awetu River, Ethiopia. (MANUSCRIPT NUMBER: SWAM-D-23-00354)
- Reviewed a manuscript for the American Journal of Tropical Medicine & Hygiene. Title: Suboptimal bacteriological quality of household water in municipal Ibadan, Nigeria.
- Reviewed a manuscript for the Environmental Sciences Europe. Title: Effect of some physicochemical parameters on the decay rate of enteric bacteria isolated from a surface water (Springer Nature).

3.0 RESEARCH AND DEVELOPMENT ACTIVITIES

3.1 FOOD SECURITY AND POVERTY REDUCTION

3.1.1 FISHERIES AND AQUACULTURE

3.1.1.1 Resilient Aquatic Food Systems Initiative

(Research Team: Dr Ruby Asmah - Principal investigator, Dr Emmanuel Mensah, Dr Miriam Ameworwor, Mr Acheampong Addo, Ms Adelina Akuamoah Boateng)
Collaborating Agencies: International Water Management Institute, Fisheries Commission

Introduction
Fish is a major protein source in Ghana. The resilient aquatic food systems project is a community enhancement program which is expected to enhance food security and create sustainable employment for indigenes of the communities particularly women and youth in selected communities in the Northeast Region. It was initiated in 2022 and is expected to end in 2024.

Objective
The objective of the project is to enhance fish production through the culture of freshwater tilapia in selected community reservoirs in the Northeast region of Ghana.

Activities undertaken
In the reporting year, activities undertaken included training of selected youth which included women from Nalerigu, Langbinsi, Tombu and Nansoni in fish farming. In addition, water quality monitoring and fish sampling in the reservoirs were conducted in August, September, October and November 2023. Several project team meetings were also undertaken.

Key results achieved so far
The project team successfully trained 30 youth including women from the project communities in fish farming. The intensive training program which spanned 3 days included power point presentations and practical sessions in the field (Figure 3.1.1). The training was held at Sans Hotel in Nalerigu from 27th to 29th March 2023.

Recommendation
Water quality is very important in the success of fish farming and therefore there is a need for continued monitoring of the reservoirs. Additional aquaculture training sessions are needed for the community groups to solidify their understanding of fish farming.

Impact of the study on the national economy
The project is impacting the lives of youth and women in communities in the Northeast Region, equipping them for alternative livelihood and sources of income besides crop farming. Fish harvested from the project will improve food security and nutrition in deprived communities and create business opportunities for fish sellers and processors.

Figure 3.1.1: Training sessions at Nalerigu.

3.1.1.2 Ecological state of selected small reservoirs in the Northeast Region

(Research Team: Dr. Ruby Asmah – Principal Investigator, Dr. Emmanuel Mensah, Dr. Miriam Yayra Ameworwor, Acheampong Addo, Adelina Akuamoah-Boateng and Michael Agbeti)

Collaborating Agencies: CGIAR, WorldFish, International Water Management Institute (IWMI), and Fisheries Commission

Introduction

The Northeast Region of Ghana is endowed with many small and large reservoirs which serve as sources of water for domestic, livestock, and irrigation purposes. To effectively harness the benefit from these reservoir systems to create more jobs, provide food through enhanced fish production, and alleviate poverty, community cage fish farming was initiated through the Resilience Aquatic Food Systems Project in four communities in the Northeast Region of Ghana. The ecological state of the reservoirs was assessed before the commencement and during the cage fish production.

Objective

The study aimed to assess the ecological state and suitability of small reservoirs for cage aquaculture in Northeast Region.

Activities undertaken

During the period under review, water quality and plankton community assessment were carried out in four reservoirs namely Langbinsi, Nalerigu, Nansoni, and Tombu in the North East Region of Ghana. Fish stock assessment of the four reservoirs was also conducted. The sampling was conducted between February and November 2023.

Key results achieved so far

Dissolved oxygen (DO) from February before production started, and from August to November as production progressed ranged between 2.16 ± 0.71 to 6.69 ± 0.85 mg/l at Langbinsi, 3.65 ± 3.18 to 6.22 ± 0.99 mg/l at Tombu, 0.79 ± 1.42 to 5.93 ± 1.27 mg/l at Nalerigu and 5.26 ± 2.90 to 5.52 ± 1.06 mg/l at Nansoni. DO concentration was generally high in February and November 2023. The lowest DO concentration was recorded at the bottom of the reservoirs (Figure 3.1.2). The surface water dissolved oxygen levels to about 4m depth were suitable for cage aquaculture.

High turbidity values were recorded in the Nalerigu and Langbinsi reservoirs during the rainy season. This resulted in high fish mortalities in the two reservoirs. The two reservoirs were also found to have low ionic contents resulting in low conductivity values (Figure 3.1.3). Average weights of fish in the reservoirs ranged from 50 to 110g.

Nalerigu accounted for 32.5% of the total plankton abundance recorded, followed by Nansoni with 31.6%. The least plankton abundance of 13.6% was recorded in Langbinsi. Blue-green algae, green algae, diatoms, dinoflagellates, and chrysophytes occurred in all four reservoirs (Figure 3.1.4). *Microcystis* was the dominant blue-green algae genera.

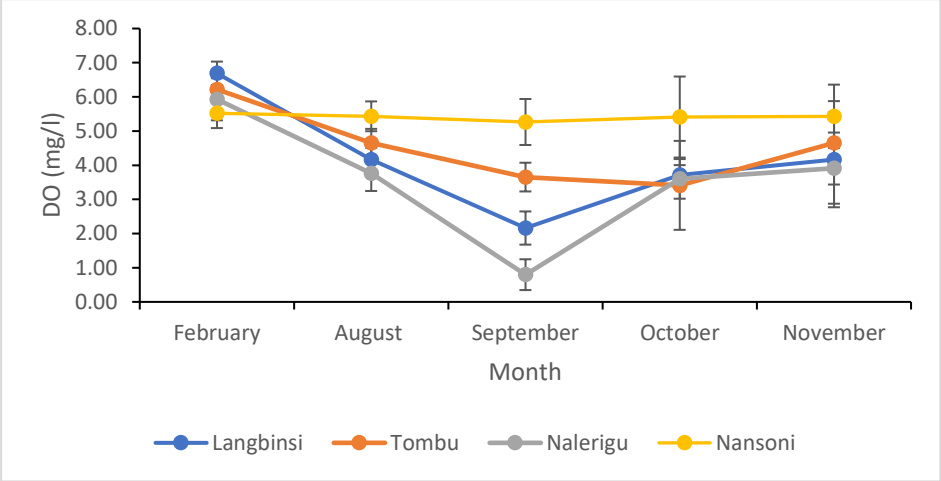


Figure 3.1.2: Variations in DO concentrations in four reservoirs in the North East Region of Ghana.

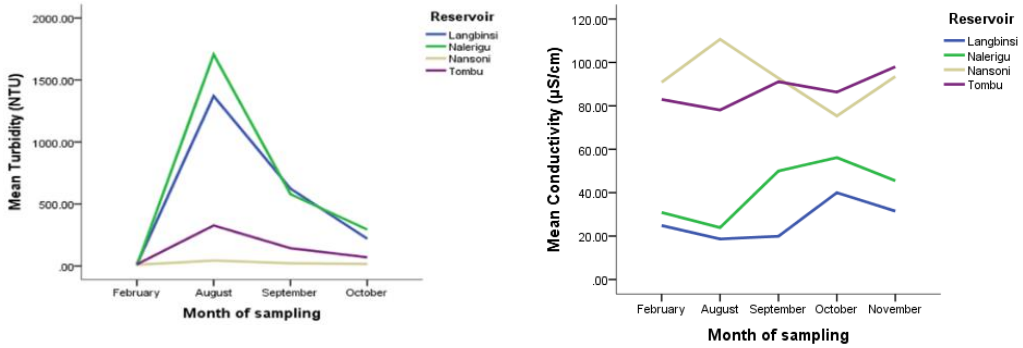


Figure 3.1.3: Some water quality results from the study.

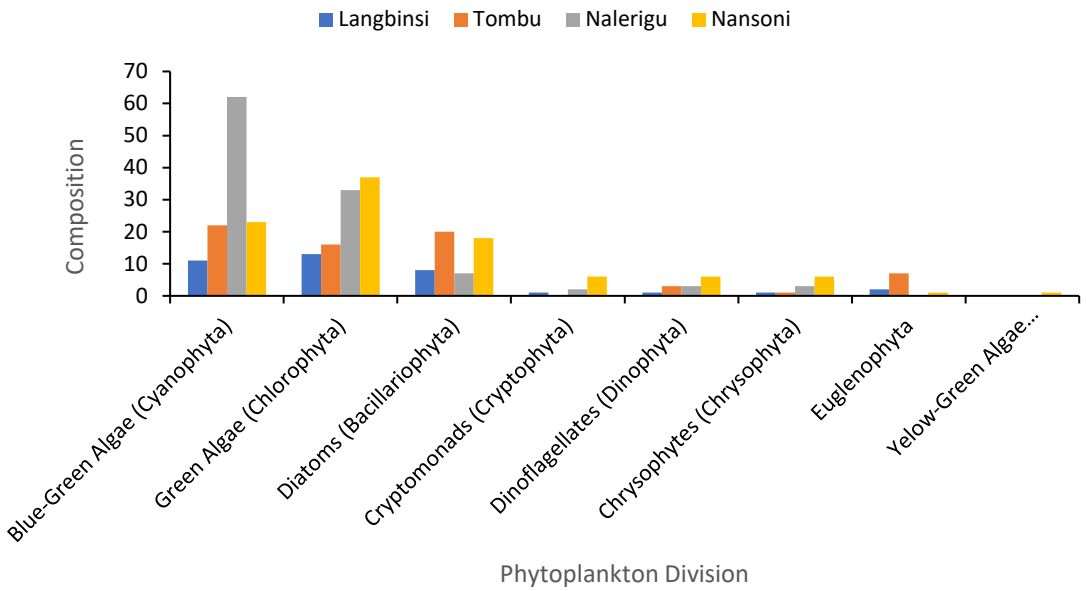


Figure 3.1.4: Composition of phytoplankton assemblage in four reservoirs in northern Ghana.

A total of 351 individual fish made up of 16 species from 8 families were sampled. Fish samples from the Langbinsi reservoir were dominated by *Coptodon zilli* (51.82%). *Pollimyrus isidori* (82.47%) (Figure 3.1.5) from the family Mormyridae was dominant at Nalerigu. *Petrocephalus bane* (28.36%) and *Siluranodon auritus* (48.35%) respectively, dominated the catch at Nansoni and Tombu reservoirs. The Nansoni reservoir was the most diverse and the richest in species (2.09 and 2.85, respectively). Nalerigu reservoir was the least diverse (0.6) (Table 3.1.1).

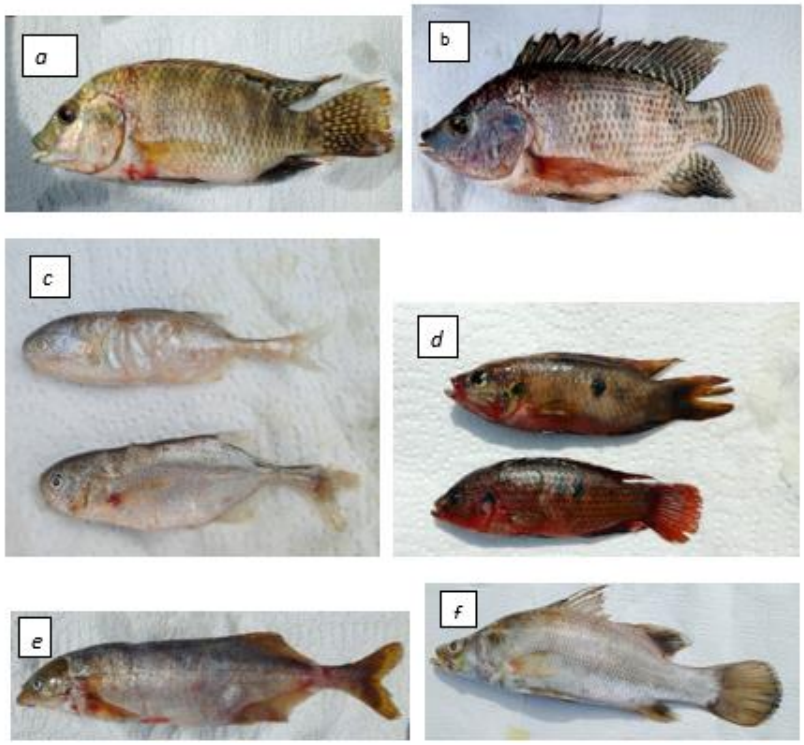


Figure 3.1.5: Some fish species encountered in the reservoirs (a) *Coptodon silli* (b) *Oreochromis niloticus* (c) *Pollimyrus isidori* (d) *Hemichromis bimaculatus* (e) *Marcusenius abadii* (f) *Lates niloticus.*

Table 3.1.1: Ecological indices of the fish communities in the reservoirs during the study in 2023.

Diversity Index	Langbinsi	Nalerigu	Nansoni	Tombu
Shannon diversity	1.01	0.64	2.09	1.42
Pielou index	0.3	0.13	0.49	0.31
Margalef index	0.6	0.65	2.85	1.55

Conclusion

The dissolved oxygen concentrations of the reservoirs were suitable for cage fish production, except in September 2023 when DO concentrations in Langbinsi and Nalerigu were at lethal levels. *Microcystis* algae is a low DO-tolerating algae and its high occurrence in the Nalerigu reservoir confirmed the observed DO levels in that reservoir. All four reservoirs supported fisheries. Family Cichlidae was important to the fisheries of Langbinsi and Tombu, and family Mormyridae was important to the fisheries of Nansoni and Nalerigu reservoirs.

Recommendation

There are several reservoirs in the North Regions that are being underutilised. The study has proven the suitability of these reservoirs for fish farming. With funds, the job can be replicated in several of these reservoirs for job creation and nutrition.

Impact of the study on the national economy

The outcome of the project will enhance health through food security and improved nutrition for communities in the northeast region. It is also providing an alternative source of livelihood for the youth and women engaged in the farming activities.

3.1.1.3 Evaluation of On-Station Developed and Two Commercial Tilapia Starter Feeds for Nile Tilapia, *Oreochromis niloticus*, Fingerling Production

(Research Team: Dr. Francis A. Anani – Principal Investigator, Patience D. K. Atsakpo, Kelvin Donkor, Felix Ayarika, Mercy Johnson–Ashun, Evans T. Dankwa, Abede Kotoku, Agbeko Vudugah, Stephen Amanor, Adjei Enoch and Terkpetey Abraham)

Introduction

Production of fingerlings of the major fish species, Nile tilapia, *Oreochromis niloticus*, culture in Ghana is carried out in earthen ponds, concrete/plastic/tarpaulin tanks or net hapas. The brand choice of starter feeds used by tilapia hatchery operators to produce the fingerlings is influenced by cost, availability and fish growth performance. A study was carried out to evaluate an on-station developed tilapia starter feed (ARDECFeed) and two (2) commonly used commercial ones (Koudijs and Raanan) for Nile tilapia fingerling production. The pricing of the developed feed took into account the cost of all production inputs, namely ingredients, labour, power and transportation. The project was initiated and ended in the reporting year.

Objective

The objective was to investigate growth performance and cost-effectiveness of using on-station developed and two commercial tilapia starter feeds to produce Nile tilapia, *O. niloticus* fingerlings.

Activities undertaken

In the year under review, the following activities were undertaken:

i. Feeding trials of mono sex Nile tilapia fry, of initial mean weight 0.06 ± 0.01 g in 9 fine mesh netting hapas, each of dimensions 5.0 x 2.0 x 1.2 m (8.0 m^3 effective volume) at a stocking density of 500 fry hapa-1 using the various starter feeds for a period of 9 weeks;
ii. Weekly monitoring of water quality parameters (ammonia, nitrate, nitrite, dissolved oxygen, temperature, pH and phosphate), fish survival and growth;
iii. Summarizing (using descriptive statistics) and analysing data on production cost, fingerlings produced and the return on production using Microsoft Excel software (2017 version); and
iv. Carrying out the cost and return analyses to assess the cost-effectiveness of the 3 starter feeds in tilapia fingerling production.

Key results achieved so far

Among the results achieved were:

i. Final mean weight attained by the nursed Nile tilapia fry fed with the various feeds were 17.53 ± 8.77, 17.34 ± 9.12 and 17.84 ± 7.86 g for ARDECFeed, Koudijs and Raanan, respectively, and there were no significant differences (ANOVA, $p > 0.05$) among them;
ii. Water quality parameters recorded at the inlets and outlets of the pond, as well as within the experimental hapas of each feed type were similar and they fell within acceptable range;
iii. It was least expensive to use ARDECFeed to produce a kg of tilapia fingerlings. Koudijs's was most expensive; and
iv. Recorded profit indices were 11.29, 9.55 and 9.80 for ARDECFeed, Koudijs and Raanan, respectively.

Conclusion

Measured growth performance indicators showed that all the tilapia starter feeds were of good quality, and that of ARDECFeed was the most economical whilst that of Koudijs was the least economical. None of the 3 feeds impacted water quality negatively.

Recommendation

Cost of ARDECFeed can be reduced reasonably if the ingredients are sourced at farm gate prices instead of from retailers.

3.1.1.4 Genetic Improvement and Revival of the Selective Breeding Program at ARDEC

(Research Team: Dr. Ebenezer Koranteng Appiah – Principal Investigator, Dr. Emmanuel Koboja Magna, Dr. Patrick Senam Fatsi, Mercy Johnson-Ashun, Lily Osei Konadu)

Introduction

The Tilapia Breeding Program at ARDEC was established in 1999, aimed at developing a superior breed of the Nile tilapia (*Oreochromis niloticus*) which was fast growing, highly fecund, disease resistance, and the ability to produce offspring with highly desirable traits. The program achieved its intended purpose and significantly boosted aquaculture development in the country. However, in 2012, following the evaluation of the latest dataset sent to WorldFish, it was reported back to us that there was a problem of inbreeding among the selected family lines. This highlighted the need to re-evaluate and revise the selection lines.

Objectives

The objectives were to:

1. evaluate the level of inbreeding among the selected family lines of Nile tilapia in the ARDEC breeding program;
2. develop and implement a new breeding strategy that minimizes inbreeding and enhances the genetic diversity of Nile tilapia; and
3. establish a new base population of Nile tilapia that is free from inbreeding, for use as parent stock in future breeding cycles.

Activities undertaken

The following activities were undertaken during the reporting period:

1. ***Screened fish samples***: All fish samples used in the tilapia breeding program in 2012 were screened to track the various pedigree or family lines.
2. ***Validated fish species***: The identified fish species were validated with their respective fish IDs using the dataset submitted to WorldFish in 2012.
3. ***Paired families***: Individual families were paired to produce the base population for the first filial generation.

Key results achieved so far

1. ***Recovery of generation 11 broodstock families:*** The last batch of broodstock families used in the tilapia breeding program at ARDEC in 2012 was successfully retrieved. A total of 264 individuals were obtained, comprising 174 males and 90 females. Among these, only 60 individuals were identified as having tags after scanning with an electronic transponder tag scanner.
2. ***Validated fish species***: The identity and family pedigree of the identified fish were confirmed using the previously reported dataset.
3. ***Paired families***: The first filial generation of the paired families has been successfully produced.

Conclusion

Reviving the Tilapia Breeding Program at ARDEC presents a significant opportunity to restore its status as a leading center for tilapia breeding and contribute substantially to sustainable aquaculture practices. By addressing current challenges, implementing strategic improvements, and fostering collaboration, ARDEC can establish a robust program that benefits both the local community and the aquaculture industry. This revitalized program is expected to enhance genetic diversity, improve fish stock quality, and support the growth of a resilient aquaculture sector in Ghana. With continued dedication and innovation, ARDEC aims to set new standards in tilapia breeding and sustainability for the future.

Recommendation

Given the progress made so far, it is imperative to seek the expertise of Dr. Felix Attipoe, whose extensive experience in fish genetics and breeding can provide valuable guidance. His expertise will be crucial in expanding the family lines, ensuring genetic diversity, and enhancing the overall success of the Tilapia Breeding Program at ARDEC.

Impact of the study on the national economy

Reviving the tilapia breeding program in Ghana can have a profound impact on the country's economy. Increased production and availability of tilapia, a popular and affordable source of protein, can significantly contribute to food security and improved nutrition, especially in rural areas. Additionally, a thriving aquaculture industry can create numerous employment

opportunities, stimulate economic growth in the fisheries sector, and support the development of related industries such as feed production and fish processing. Furthermore, an expanded tilapia breeding program can enhance Ghana's position in the global aquaculture market, leading to increased export opportunities and foreign exchange earnings. This comprehensive approach not only bolsters the national economy but also promotes sustainable development and resilience in the aquaculture sector.

3.1.1.5 Determinants and Framework for Implementing Sustainable Climate-Smart Aquaculture Insurance System for Fish Farmers: Evidence from Ghana

(Research Team: Dr Emmanuel Mensah – Principal Investigator, Nicholas O. Mensah, Jeffery K. Asare, Emmanuel T.D. Mensah, Ernest Christlieb Amrago, Frank Osei-Tutu, Anthony Donkor)

Collaborating Agencies: Dept. of Agribusiness Management and Consumer Studies, UENR, Sunyani; Dept. of Applied Agriculture, Central University of Punjab, India

Introduction

In Ghana, an estimated 2.2 million people rely on aquaculture and the fishing industry for a living. However, the growth of aquaculture can be limited due to climate change effects such as floods, droughts and cyclones, which harm aquaculture systems. The associated risk could be transferred to third parties by means of insurance. However, the adoption of agricultural insurance can be used as a strategy to reduce both the ex-ante and ex-post effects of climate change on agricultural production. Although the impact of climate change is detrimental, findings emanating from this study which was initiated in 2022 and ended in the reporting year provides an opportunity for insurance practitioners, academics and researchers to come out with climate-smart agricultural insurance products and covers that are fit for purpose to help fish farmers cope with the income shock that climate change related risks may bring.

Objective

The objective was to determine farmers' preferred climate-smart insurance products, factors influencing participation and enrolment strategies, and analyse the factors influencing their mode of participation in climate-smart aquaculture insurance.

Activities undertaken

Structured questionnaire, which included both open ended and closed ended questions, was used for data collection through face-to-face interviews with 140 fish farmers in the Eastern Region of Ghana. Focused group discussions were conducted with leaders of fish farmers' associations and 30 selected fish farmers who had over five years' experience to elicit their knowledge and awareness on insurance. This also helped to attain qualitative information that supplemented the quantitative data. Data on demographic characteristics of fish farmers, mode of participation, climate, environmental, anthropogenic risk factors and enrolment strategies in climate-smart aquaculture insurance were analysed via descriptive statistics.

Key results achieved so far

The result indicated that 88% farmers were males, whereas 12% were females. On average, 95% of the respondents had formal education, implying that most farmers can understand basic insurance concepts and packages, which will aid them in informed decision-making. Moreover, 42% fish farmers preferred insurance agents enrolled them on aquaculture insurance. However, 4% fish farmers preferred multi-channel enrolment. A plausible explanation for this observation is that fish farmers perceive insurance agents and their employees as the most appropriate people to explain insurance products and cover to them. With respect to farmers' time of payment, 66% preferred semi-annually, 7% preferred quarterly while 27% preferred

annually (Table 3.1.2). This may be a reflection and alignment of their payments to their production and cash conversion cycles.

Table 3.1.2: Aquaculture insurance preference, implementation and enrolment strategies.

INSURANCE	FREQUENCY (N)	PERCENTAGE (%)
Mode of Participation		
Individual	135	96
Group	5	4
Total	**140**	**100**
Basis of indemnity		
Market value	5	4
Cost of production	10	7
Damage degree	125	89
Total	**140**	**100**
Insurance preferences		
Climate induced Aquaculture Stock Mortality	127	91
Insurance		
Climate induced Consequential loss Insurance	10	7
Insurance		
Insurance Cover for Diseases only	3	2
Total	**140**	**100**
Enrolment Strategies		
Insurance agents	59	42
Directly form insurers	20	14
Extension officers	18	13
Microfinance officers	12	9
Ministry for food and Agriculture	11	8
Single Channel	14	10
Multi-Channel	6	4
Total	**140**	**100**
Payment time		
Quarterly	10	7
Semi annually	92	66
Annually	38	27
Total	**140**	**100**

Conclusion

It is indicative from the results that farmer association, farm income, credit access, climate related peril and anthropogenic peril had a positive influence in assessing insurance. In contrast, years of education negatively influenced climate-smart aquaculture insurance participation. Moreover, the production system had a negative relationship with the mode of participation.

Recommendation

From the study, climate-induced perils (environmental and anthropogenic) were paramount in providing sustainable climate-smart policies and cover for farmers. Stakeholders from the academia, research institutions, regulators and other agricultural insurance companies can start a conversation based on this study to conduct research to determine the appropriate threshold of climate-related perils. This will help agricultural insurance practitioners develop climate-smart aquaculture insurance with appropriate conditions and claim payment methodology.

Impact of the study on the national economy
This study has implications for both theory and practice. For farmers, the findings will help them to apprehend their preferred climate-smart aquaculture insurance types and their preferred enrolment strategies. For policy makers, the study gives insights on several factors that influence farmers' preference for aquaculture insurance products and further provides insights as to how to design, draft and administer climate-smart aquaculture insurance among farmers. To insurance providers and others, these findings will serve as a blueprint as it gives clear directives and a comprehensive framework on how to design for farmers.

3.1.1.6 Rapid Assessment of Water Quality to Support Safe Aquaculture in Ghana – Utilizing Bacteria to Quantify Ecological Health

(Research Team: Dr. Etornyo Agbeko – Principal Investigator, Dr. Rhoda Lims Diyie, Andrew Joseph, Eric Kretsi, Prof. Simon Jackson)
Collaborating Agencies: Centre for Environment, Fisheries and Aquaculture Science (Cefas) and Modendotech Ltd., UK

Introduction
Aquaculture, using fresh or marine water, is dependent upon good water quality to sustain optimal fish growth and ecological health. Water quality is a critical factor when culturing any aquatic organism. Fish disease and anthropogenic pollution are major threats to sustainable fish production and consumption. This is expected to worsen with increasing effects of climate change, growing human population and changing land use. Optimal water quality needs vary by species and must be monitored to ensure growth and survival. The project was initiated and terminated in the reporting year.

Objective
The general objective was to facilitate the deployment and use of Bacterisk+ kits at selected aquaculture sites in Ghana to rapidly assess water quality and compare with traditional culture results.

Activities undertaken
Water and sediment samples were collected from eight water bodies, at eleven different sites along the coastal shoreline of Ghana. One site for inland aquaculture was also selected for this study. Surface water samples were collected from the Volta Lake in Eastern region (freshwater), estuaries and lagoons (Brackish water) along the Ghanaian coastline, that is from the Volta to Western regions. The site selection also targeted areas that support commercial shellfisheries bivalves, gastropods, and crustaceans. Water samples were analyzed in the field using rapid diagnosis kits called Bacterisk+ for microbial numeration. Results from the Bacterisk+ assay are expressed in 'endotoxin risk' (ER) units, which is an arbitrary scale derived from the colour change of the reagents in the end-point assay. Results were interpreted using the Bacterisk+ interpretation guide which gives the water quality classification as well as the endotoxin risk ranges.

Key results achieved so far
***Fisheries and physico-chemical water quality at sampling sites*:** The West African mangrove oysters (*Crassostrea tulipa*), West African mud creeper/periwinkle (*Tympanotonus fuscatus*) and whelk (*Pugilina morio*) were the most important species by harvest found across the eleven (four from the Eastern, two from Volta, one from Greater Accra, two from Central and two from Western region of Ghana) study sites. The sanitation of coastal aquatic systems and their catchment areas visited were generally poor and the water bodies suffered greatly from

anthropogenic activities, with the exception of a site along the Western stretch (Amanzule River) and sites along the Volta Lake which were relatively good, i.e., W2, V1 and V2 (Table 3.1.3).

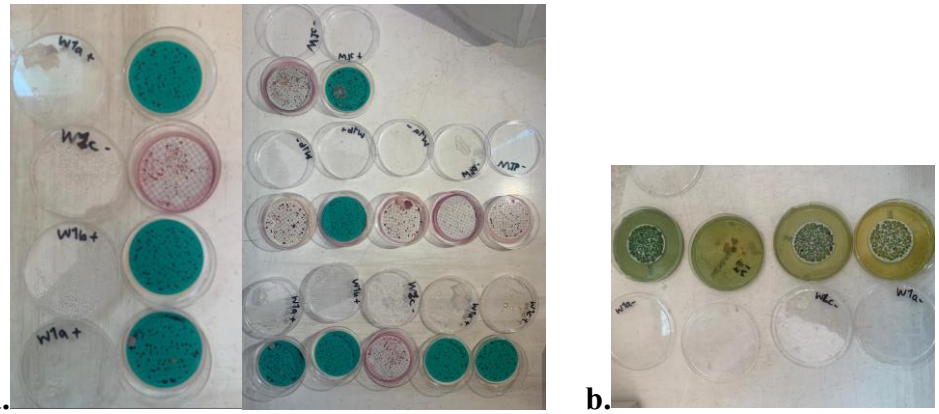
Table 3.1.3: Mean Values of the Water Quality Parameters from the Various Site.

	E1	E2	E3	E4	V1	V2	G1	C1	C2	W1	W2
Temp.	29.53	30.30	35.53	29.53	30.3	32.17	29.70	30.40	30.50	27.80	33.2
DO	4.40	8.63	5.23	4.37	9.87	5.17	8.37	7.80	8.47	6.23	7.95
pH	7.18	7.67	10.90	7.25	8.21	7.37	7.22	8.37	7.43	6.85	7.90
TDS	36.37	40.13	30.80	36.60	8.94	4.13	37.67	22.07	4.11	42.97	16.55
Sal.	0.03	0.04	0.02	0.04	10.82	4.69	0.04	30.87	1.33	0.04	21.85
EC	72.67	80.03	70.50	73.17	17.81	8.24	74.87	43.13	2.49	57.13	33.1

NB: All values in respective SI units

Microbial Water Quality (Bacterisk+ kit)

In comparison to the classification range for coastal bathing waters, on the Bacterisk+ endotoxin risk interpretation guide, the mean values obtained for water samples from sites 1, 2, 3, 4, 7, 9 and 10 could be classified as of sufficient or better water quality, with low endotoxin risk as they recorded values below 6900. However, water quality of samples from sites 5 and 6 were within the poor water quality classification range with medium endotoxins risk as their mean values were between 6900 and 10000. Water samples from sites 8 and 11 could as well be classified under poor water quality with high endotoxin risk as their values exceeded 10,000. Generally, recorded values from sites 4, 9 and 10 from the Eastern, Central and Western regions, respectively, indicated very good water quality as the values were far below 1000. These results were compared with traditional culture methods (Figure 3.1.9). Thus, the assay for endotoxin may be a useful technique for rapidly determining bacterial biomass and quality of water.



a. **b.**

Figure 3.1.9: (a) Enterococci Colony Forming Units (CFU) evaluated as red, pink, or reddish-brown colonies with a diameter of 0.5–2 mm, and E. coli CFU, evaluated as dark blue to violet colonies; (b) Positive Results of *V. cholerae* isolates and *V. parahaemolyticus* colonies.

Conclusion

The study proved the use of the Bacterisk+ kit as a user friendly and self-taught protocol, capable of generating valuable data within 30 mins, thus could help in the assessment of water quality (pathogen enumeration) for ecological health in prompt decision making. The use of Bacterisk+ kits at selected aquaculture sites in Ghana as validated through this study, was rapid enough to assess water quality by quantifying levels of gram-negative endotoxins associated with anthropogenic pollution and possible aquatic disease.

Recommendation
Monitoring to generate enough data from Bacterisk+ that can adequately help in establishing the linkages to ecosystem function and services, thus giving baseline information on sites that could be used for mariculture, fish farming diversification, and improved food safety and security is recommended. Continuous improvement in some aspects of the Bacterisk+ kits/assay is needed for higher accuracy**.**

Impact of the study on the national economy
The project gave the opportunity to build the capacity of most aquaculture stakeholders including some Fisheries Commission officers in Ghana, veterinarians, research scientists, technical officers from laboratories and fish farms, fish farmers, some academicians, among others.

3.1.1.7 Assessment of the Current Status of Antimicrobial Use and Antimicrobial Resistance in Ghanaian Aquaculture Farms and their Public Health Impact

(Research Team: Rhoda Lims Diyie – Principal investigator, Karyn Ewurama Quansah, Judith Wayo, Frank Aboagye, Nawal Moro Buri, Mario Chrisk, Hawa Ahmed, Lady Boamah Adomako, Emmanuel Armah, Gloria Addico, Mike Osei-Atweneboana, Ruby Asmah)

Introduction
Antimicrobial Resistance (AMR) occurs when bacteria, viruses, fungi, and parasites undergo genetic changes over time, rendering them unresponsive to antimicrobials-medicines designed to prevent and treat infections caused by pathogens (Levy, 1999). Aquaculture systems are identified as major hotspots for the entry of antimicrobials into the environment due to their extensive use (Kümmerer, 2009). While the knowledge of antimicrobial resistance patterns of pathogens isolated from aquaculture farms in Ghana, as well as the emergence and potential spread of genes responsible for resistance, is largely unknown, it is crucial due to its direct impact on fish and public health. The project started in 2023 and is expected to end in 2024.

Objectives
The project aims to investigate antibiotic usage in Ghana, examining the patterns and distribution of AMR and antimicrobial resistance genes (AMG), as well as residues in tilapia and catfish farms. Additionally, the study seeks to establish the scientific basis for increasing awareness of the risks associated with the spread of multi-drug resistant bacteria.

Activities undertaken
In the year under review, fish, water, and sediment samples were collected from selected aquaculture farms in the Greater Accra and Eastern regions of Ghana. The samples were obtained from the upstream, midstream, and downstream of the Volta Lake. Two disease pathogens, *Aeromonas hydrophila* and *Streptococcus agalactiae,* selected for their high prevalence in Ghanaian aquaculture farms (Diyie et al., 2022), were isolated from all samples obtained from cages and ponds. Prevalence rates of *Aeromonas hydrophila* and *Streptococcus agalactiae* were determined using standard protocols. The antimicrobial susceptibility patterns of the isolated pathogens were assessed through the Kirby Bauer disc diffusion test method, following the guidelines provided by the Clinical Laboratory Standards Institute (CLSI). Additionally, the double disc synergy test was employed for detecting Extended Spectrum Beta-lactamase (ESBL) producers. A structured questionnaire was also administered to gather information on antibiotic use across all studied farms and the data processed using Microsoft Excel and the Statistical Package for Social Scientists (SPSS) software.

Key results achieved so far

Bacteria loads in water, sediment and fish samples from fish farms: Generally, Aeromonas bacteria loads in the fish were lower than those of sediment and water samples ($p < 0.05$). Water samples recorded the highest load of Aeromonas bacteria which is a typical occurrence as pathogen loads in culture media are often higher than those in fish. For water samples, the highest Aeromonas bacteria load of 1 × 10^5 CFU/mL was recorded at Farm 1, while loads of 7 × 10^4 CFU/mL and 2 × 10^2 CFU/mL were recorded at Farms 2 and 3, respectively. Gut and fish swab analyses of fish samples from Farm 2 had the highest Aeromonas load of 6 × 10^2 CFU/g and 11 × 10^2 CFU/g, respectively. Fish samples from Farm 3 had 3 × 10^4 CFU/g and 2 × 10^4 CFU/g for fish gut and swab analysis, respectively. The least Aeromonas bacteria load for fish was obtained from Farm 1. For sediment collected under the fishponds, the highest Aeromonas bacteria load of 4 × 10^2 CFU/mL was recorded at Farm 2, followed by Farm 3 with 8 CFU/mL, and Farm 1 with the least Aeromonas load of 0 CFU/mL.

***Distribution of Aeromonas spp and their antibiotic resistance profile*:** From questionnaire analysis, 70% of farmers reluctantly disclosed the use of antibiotics on farms for varied purposes, whiles 30% did not use them at all. A total of 58 bacteria isolates were identified and tested against five antibiotics namely: Cefotaxime, Tetracycline, Levofloxacin, Sulphamethoxazole and Cefotaxime/Clavulanic acid. A total of 43.10 % of the isolates were found to be resistant to some of the antibiotics tested. The highest percentage of resistance was recorded from fish samples with 71.43 % of isolates (N=22) resistant to Sulphamethoxazole, and 28.57 % being susceptible to all the other antibiotics tested. For water samples, 37.5% (N=16) were resistant to Sulphamethoxazole. The lowest percentage resistance of 15.79% (N=20) was recorded in sediment samples.

All the samples analyzed (N=53) showed presence of antimicrobial resistance genes (AMG) at varying prevalence rates with respect to the three primers used so far. The highest resistance was recorded by primer CTX-M 825, followed by MA and then CTM-X- 914, thus, confirming the presence of various molecular determinants of antibiotic resistance in bacteria on aquaculture farms (Figure 3.1.6).

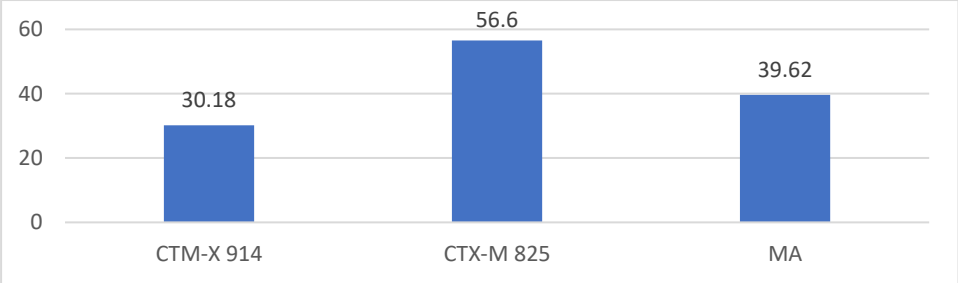


Figure 3.1.6: Prevalence patterns of AMG with respect to the three ESBL specific primers used.

Further investigations on the antibiotic residues of Amoxycilin trihydrate, Amprolium hydrochloride, Chloramphenicol, Chlorotetracycline hydrochloride, Ciprofloxacin hydrochloride, Clopidol, Danofloxacin mesylate, Metronidazole, Oxytetracycline hydrochloride tested in all fish samples from 12 farms in Accra and along the Volta Lake, however recorded values of <0.01mg/kg, far below the limits of quantification by Codex MRLs for fish muscles. This implies that antibiotics residues may currently not be a threat to fish consumers in Ghana.

Conclusion
In this study, antibiotic usage in aquaculture farms in Ghana was conclusively verified. The presence of *Aeromonas spp.* as a disease-causing pathogen was also confirmed, albeit at varying concentrations across different farms. The investigation further revealed the prevalence of multidrug-resistant bacteria and resistance genes in water, sediment, and fish samples from aquaculture farms. Despite the elevated resistance levels, the veterinary drug residues in tilapia and catfish from various farms were consistently below quantifiable levels, suggesting a low likelihood of adverse impacts of residues on humans through fish consumption.

Recommendation
The use of antibiotics on aquaculture farms should be strictly regulated to effectively minimize antibiotic-resistant bacteria and genes, along with their transmission to humans.

Impact of the study on the national economy
This project is pivotal for promoting responsible practices, safeguarding public health, ensuring environmental sustainability, and fostering economic development in the aquaculture sector. It aligns with global efforts to address the challenges posed by AMR and contributes to the long-term viability of the industry.

3.1.1.8 Assessment of Commercial Production of All-Male Nile Tilapia, *Oreochromis niloticus*, for Food Fish Safety Towards One-Health (Phase 1)

(Research Team: Dr. Etornyo Agbeko – Principal Investigator, Diyie R. L.; Johnson-Ashun, M.; Osei, L.K.; Kretsi; E.; Birikorang, S.; Kpodo Z.C.)

Introduction
The Tilapiine are among the most cultured, consumed (rich-proteins) and economically valuable freshwater food fish globally. Commercial farming of tilapia warrants all-male (monosex) production through fry treatment using synthetic androgen (hormone) receptors such as 17-alpha Methyltestosterone (17 α-MT). Various debates range on the impact of this hormone/steroid on the Tilapia, the aqua culturist, the ecosystem and the fish consumer's health. This is part of the concept leading to the One-Health or Farm-to-Fork approach. The project started in 2022 and ended in 2023.

Objective
The objective was to review the recent status and trajectory effects of 17 α-MT hormone for all-male Nile tilapia production using the One-Health approach.

Activities undertaken
A total of 180 fry of Nile Tilapia (*Oreochromis niloticus*) with average weight 0.08 ± 0.01g were randomly selected and evenly distributed (30 fry per hapa) in replicates. Weekly sampling of fry to juvenile stage was observed in hapa-in-Concrete ponds (1x3 m) of mesh netting size of 0.64 m^2. The experimental control tank was designated as $NH_{1,2,3\ (control)}$ without any hormone and treatment tank: $H_{1,2,3\ (MT\ hormone)}$. Fish growth performance and water quality monitoring and analysis were conducted. Field observations, inferences and expert opinion were used for validation of the study.

Key results achieved so far
All water quality variables observed for hormonal treatment and non-treatment were within acceptable ranges for tilapia production except in hormonal treatment that had lower dissolved

oxygen (DO:1.8-2.5 mg/l) and higher total dissolved solids (TDS: 116-119.33). The use of muscularization hormones promoted fish growth as corroborated in Figure 3.1.7. The elevated immunity levels exhibited by the hormonal treated tilapia is shown in Figure 3.1.8.

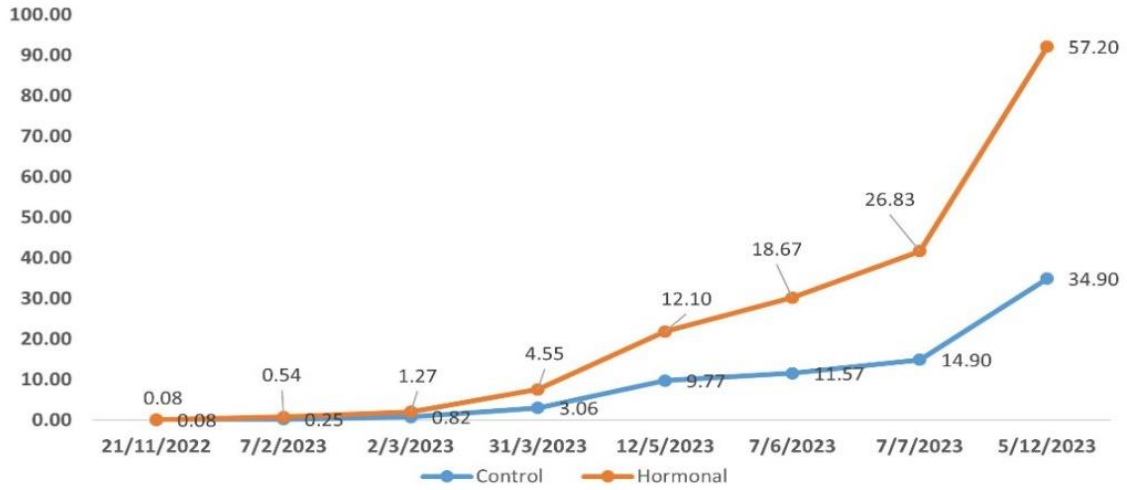


Figure 3.1.7: Fish growth (mean body weight, g) trend for hormonal (treated) and control (non-hormonal) tilapia under sustenance feeding in experimental tank culture system.

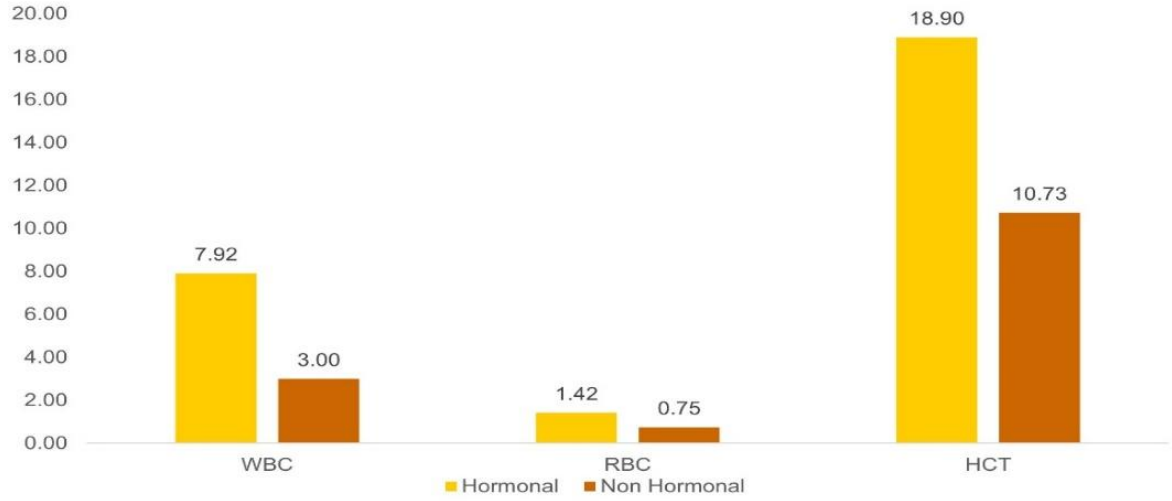


Figure 3.1.8: Mean values of haematological analysis for hormonal and non-hormonal tilapia.

Conclusion

The use of 17α- Methyl testosterone (MT) hormone in tilapia production enhanced fish growth. Preliminary indications are that MT hormonal Tilapia could elevate fish health, although Non-hormonal Tilapia would support aquatic ecosystem health than the hormonal tilapia production. Hormonal treated tilapia consumption impact on human was not established in this study.

Recommendation

Development of standards for 17α- MT application and traceability are needed for tilapia food safety. Precautionary use of 17 α-MT at a recommended dose of 60 mg/kg feed with adherence

to safety protocols for sustainable commercial production of all male tilapia alongside confirmatory impacts studies will be pragmatic. Research into alternative bio sources is recommended.

Impact of the study on the national economy
Broader dialogue and funding for research on tilapia safety for informed policy direction via One-Health approach could enhance consumer confidence for higher patronage of tilapia for increase revenue generation.

3.1.1.9 Assessment of Persistent Organic Pollutant (POP) Contamination in Fish and Sediment from the Lower Volta Basin in Ghana

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

Introduction
The TWAS-SG-NAPI/UNESCO, a two-year grant, funded by The World Academy of Arts and Sciences, The German Ministry of Education and Research (BMBF), and UNESCO, aims to equip and strengthen early career researchers in Science and Technology, through the provision of funding to establish their research expertise areas in their respective home countries. The aim of the project was to fill knowledge gaps in the distribution and quantitation of persistent organic pollutants (POPs) contamination in fish from the Lower Volta Basin in Ghana. The project started in 2022, and is expected to end in 2024.

Objectives
The objectives were to:

i. determine concentrations of POPs and other toxic organic pollutants concentration in farmed and wild fish and sediment from the Lower Volta Basin;
ii. estimate the risk of human exposure from consumption of POP-contaminated freshwater fish;
iii. enhance the capacity of MPhil students, and researchers on how to monitor and interpret toxic contaminant data of fish; and
iv. improve community awareness on the prevalence and impact of organic pollutants in the environment; community literacy on environmental health issues and their relation with consumption of POP-contaminated fish.

Activities undertaken
Major activities undertaken during the period under review were fish and sediment samples collection in the dry and wet seasons from three (3) predominant fish farming communities (Kpong, Ada Sogakope, and Asikuma Labolabo) along the Lower Volta Basin. Sediment and edible tissues were extracted using the quick, easy, cheap, effective, rugged and safe extraction model (QuEChERS), with acetonitrile as extraction solvent. The extracts were subjected to a Gas Chromatography-Mass Spectrometry (GC-MS) and Liquid Chromatography-Mass Spectrometry (LC-MS/MS) analysis. The POP data collected was analysed using principal component analysis. The risk of human uptake and accumulation of POPs from fish was assessed using the health index which takes into account the estimated daily intake of the residual concentration of POPs, and also the acceptable daily intake of pesticide residues (Akoto *et al*., 2013).

Key results achieved so far

Concentrations (limit of detection - LOD = 10 µg/kg) of various organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) were below the LOD, except for 2 analytes for which the highest mean concentration of organophosphate pesticides (OPs) observed were Chlorpyrifos (27.85 µg/kg) in the tissues, and Atrazine (14.59 µg/kg) in the liver of farmed fish from Ada-Sogakope during the dry season. Based on concentrations detected, the Estimated Daily Intake (EDI) of all OCPs, PCBs, and OPs for children and adults who consume both farmed and wild fish from examined sites, were significantly below the Acceptable Daily Intake (ADI) or Reference Dose (RfD) values. Subsequently, the Human Risk Index (HRI) for OCPs, PCBs, and OPs in children and adults consuming fish gills and edible tissues, was less than the threshold value of one (1). This indicated a high probability of low exposure risk to humans with respect to POP contaminants from the Lower Volta Basin, although high fish consumption from the Lower Volta Basin could potentially result in increased/harmful exposure. Concentrations of various OPs analysed in water and sediment samples were below the limit of detection (LOD = 10 µg/kg) for both seasons. The highest mean concentration of OPs observed in sediment samples were Chlorpyrifos for samples from Ada-Sogakope in the wet season (20.00 µg/kg) and dry season (14.20 µg/kg).

Impact of the study on the national economy

Results from the project will allow for strengthening of regulations on the use of Chlorpyrifos and other OPs in agriculture, aquaculture, industrial and household settings, to help minimize release into the environment and bioaccumulation in freshwater fish in Ghana.

3.2 CLIMATE CHANGE, ENVIRONMENTAL MANAGEMENT AND GREEN TECHNOLOGY

3.2.1 POLLUTION AND WASTE MANAGEMENT

3.2.1.1 Removal of Nitrate and Phosphate from Drinking and Wastewater using Oyster Shells

(Research Team: Dr. Franklin Obiri-Nyarko - Principal Investigator, Mr. Jude Ofei Quansah, Mrs. Sandra V. Asare, Dr Anthony Yaw Karikari, and Dr. Collins Okrah)

Introduction

The persistent increase in nutrient levels in aquatic environments, driven by rapid industrialization and human activities such as the discharge of untreated wastewater into water bodies, poses significant threat to both human and ecosystem health. Drinking water containing high levels of nitrate can result in adverse effects, including methemoglobinemia, commonly known as "blue baby syndrome," in infants. Consequently, the removal of phosphate and nitrate from drinking water sources has become a focal point of interest for researchers. An innovative approach involves the utilization of oyster shells to extract nitrate and phosphate from drinking water. This method falls under the category of biological treatment, known as bioremediation or biofiltration. Oyster shells, primarily composed of calcium carbonate, act as a substrate for diverse microorganisms. This facilitates the conversion of nitrate (NO_3^-) and phosphate (PO_4^{3-}) into less harmful forms. Accordingly, this study aims to explore the efficacy of oyster shells in removing nitrate and phosphate from contaminated water within this specific context. The project was initiated in the reporting year and is expected to end in 2025.

Objectives

The objectives were to:

i. assess the efficacy of oyster shells in removing phosphate and nitrate from water through batch experiments;
ii. determine the optimal conditions for the efficient removal of nitrate and phosphate using oyster shells; and
iii. evaluate the reusability of oyster shells for the removal of phosphate and nitrate.

Activities undertaken

During the period under review, oyster shells, procured from a local seafood market in the southern part of the Greater Accra Region, underwent a preparation process. Initially, the shells were washed with distilled water to eliminate impurities and air-dried at room temperature. Subsequently, the dried shells were ground and sieved using a standard soil sieve (75 µm). The activated oyster shells were thermally treated at 600°C for 4 hours and stored in a desiccator to prevent contamination. Batch experiments were conducted by reacting 1.0 g of oyster shell with 50 mL of a phosphate standard solution (10 mg/L) in a 50 mL conical tube at room temperature (25 °C) with an agitation speed of 150 rpm in a shaking incubator, unless specified otherwise. Kinetic analyses involved varying the reaction time from 30 minutes to 420 minutes. Equilibrium batch experiments utilized initial phosphate concentrations of 10 − 50 mg/L with a reaction period of 1 hour. For thermodynamic adsorption procedures, 1.0 g of oyster shell was reacted with 50 mL phosphate solutions at temperatures of 15, 25, and 35 °C for 1 hour. Following each reaction, a vacuum pump (FB 70155, Fisher band) facilitated the filtration of oyster shells from solutions. Residual concentrations were analyzed using a UV-Visible spectrophotometer (HACH DR 6000).

Key results achieved so far

The results obtained thus far from the experiments revealed a notable characteristic in the adsorption behaviour of phosphate on oyster shells. Equilibrium was attained within three hours of the adsorption experiment. As the experiment progressed, a distinct shift in the adsorption rate became evident, manifesting a deceleration. This slowdown in the adsorption rate was carefully examined, and our analysis suggested that it can be attributed to the saturation of favourable active sites on the oyster shells. These active sites, initially available in abundance, played a crucial role in facilitating the rapid adsorption of phosphate during the initial phase. As the process unfolded, the saturation of these sites led to a gradual reduction in the adsorption rate, marking the transition to a slower equilibrium phase.

Conclusion

The results obtained so far indicated that oyster shells are effective and economical adsorbents for removing phosphate from aqueous solutions. On-going studies are focusing on nitrate removal and other practical aspects. These further investigations are expected to deepen our understanding of the complex dynamics involved in phosphate and nitrate adsorption on oyster shells.

Impact of the study on the national economy

i. Successful removal of phosphate and nitrate from water sources can lead to improved water quality and a reduction in waterborne diseases. This, in turn, can contribute to a healthier population and workforce, potentially reducing healthcare costs and improving overall productivity.
ii. It could also lead to the development of new knowledge and skills in the field of water treatment. This could create opportunities for technology transfer, capacity building, and the growth of a knowledge-based economy.

3.2.1.2 Sustainable Lagoon Water Quality, Land use and Governance

(Research Team: Dr Marian Amu-Mensah – Principal Investigator, Martha Agyeman-Duku, Lady Boamah-Adomako, Hawa Ahmed, Mario Danban Chrisk, Gertrude Nortey, Dr Gloria Addico, Prof. Isaac Hodgson - Coordinator)

Introduction

The quality, benefits, and protection of lagoons and other water bodies are highly dependent on how rules and regulations are formulated and implemented towards its sustainability, which necessitates key stakeholders as drivers of water management efficiency. Lagoons are a vital type of wetland in the ecosystem because they provide dynamic natural settings for complex creatures and support socio-economic activities and human nutrition. However, lagoons have been severely impacted by human activities, which have resulted in a reduction in lagoon quality and, in certain cases, its total disappearance. Hence, the need to gather information from the interactions with the lagoons, is essential to the lagoon's sustainable development. The project began in 2022 and was completed in the reporting year.

Objective

The objectives were to:

i. identify and examine significant and valuable institutional systems in wetland conservation and identify sustainable governance systems;
ii. evaluate major threats and challenges in wetland governance;
iii. evaluate the pollution and sedimentation levels in the studied lagoons;
iv. provide orientations for the needed wetland ecosystem conservation; and

v. provide recommendations and guidelines for wetland conservation policy.

Activities undertaken

During the year under review, the study areas namely: Sakumo I and II lagoons, Mokwe Lagoon and Songor Lagoon were sampled. At Sakumo I, data was collected at areas such as Lakeside Bortianor, Tetegu, Oblogo Bawe, Ayigbe Town Tsokome, and Faana communities along the Densu Delta. At Sakumo II, data was collected from areas such as Sakumono Wuolei and Sakumono Galleilia. At Mokwe Lagoon, data was collected from the Regional Maritime University - Nungua, Nungua Maamie, Nungua Methodist and Manayekpo. At Songor Lagoon, communities such as Lolonya and Kportitsekope were selected.

Water, sediment, macroinvertebrate, phytoplankton and macrophytes samples were collected and analyzed using standard methods. The water and sediment samples were analysed for physico-chemical properties, as well as heavy metals such as Fe, Mn, Cu, Pb, Cd, and Zn. Furthermore, the water samples were analysed bacteriologically for Streptococcus spp, Aeromonas spp, Staphylococcus, Pseudomonas, Vibrio, and *E. coli*. The phytoplankton samples were identified using the manual of algal species from Laboratoire D'Ichtyologie Museum National D'Histoire Naturelle, Paris (1958) and a Phytoplankton Manual (2017) compiled by the Hydrobotany section of the Institute. For the identification of macrophytes, a modified Rapid Botanic Survey (RBS) protocol and associated analytical approaches developed and described by Hawthorne and Abu-Juam (1995) and Hawthorne (1996) was adopted for the survey of both aquatic macrophytes and terrestrial plants.

In addition, a survey was conducted using mixed-methods approach to interview 462 respondents to collect primary data. An in-depth interview was also conducted with four formal and four informal leaders associated with the governance of the lagoons. Satellite imagery was also taken to determine land use pattern.

Key results achieved so far

Fostering collaboration between the official government management sector and the unofficial traditional sector was a primary obstacle. The age level of respondents did not show how involved they were in decision-making. However, a MANOVA test indicated that gender had a significant impact on decision-making, with men scoring higher (M = 6.228) than women (M = 5.808). Furthermore, because of their direct connection to the community and its resources, the traditional authority was chosen as the favoured owner of the lagoons (Table 3.2.1).

Table 3.2.1: Factor analysis of wetland governance and demographics.

Wetland Governance	**Components**		**Cronbach Alpha**	**Communalities**
	1	2	**α**	
Which people are involved in decision-making (W2)	0.937			0.383
Who controls activities around the Lagoon (W5)		0.714		0.904
Ownership of Lagoon (W7)		0.568		0.796
Are you involved in decision-making (W8)		0.464		0.868
Variance%	44.077	18.011		62.088
KMO and Bartlett's Test				
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.845		
Bartlett's Test of Sphericity	Chi-Square	1851.781		
	Df	28		
	Sig.	0		

The Sakumo I and II lagoons, Mokwe, and Songor lagoons have been significantly affected by human activities, which have disrupted their surface flow and structure. The lagoons had been subjected to growing ecological dangers and contamination due to the discharge of fish waste, residential wastewater, and rubbish near the waterbody, all of which eventually end up in the lagoons during the rainy season. As a result, bad water quality has been reported, with a mean count of faecal coliforms of 3350 cfu/100 ml, ranging from 1100 to 4500 cfu/100 ml. The *E. coli* count for Sakumo I ranged from 700 to 800 cfu/100 ml. Furthermore, the taxa of phytoplankton that were identified were Chlorophyceae (green algae), Bacillariophyceae (diatoms), and Cyanobacteria (blue-green algae), with indications of high level of pollution. Physico-chemical parameters such as conductivity, salinity, chloride, sodium and potassium were above recommended limits while dissolved oxygen concentrations were mostly below the recommended USEPA limit of 5mg/l that is needed to adequately support aquatic organism.

At Sakumo II, relatively low macroinvertebrate populations were found, indicating overuse of the lagoons. A total of 100 individuals belonging to seven (7) taxa and two (2) orders (Gastropoda and Pelecypoda) were found during the survey. The diversity index (H') for Sakumo II was 1.265. However, both Sakumo I and Mokwe lagoons did not record any community assemblage (Table 3.2.2). Ultimately, the research findings indicated that in cases where ownership is ambiguous, lagoons or water resources ultimately become the property of no one, making sustainable conservation impossible.

Table 3.2.2: Relative abundance of macroinvertebrates at three of the four sites.

	Sakumo I	**Sakumo II**	**Mokwe**
Taxa (S)	0	7	0
Individuals	0	100	0
Shannon (H')	0	1.265	0

Conclusion

It was concluded that changes to the landscape and decreased hydrologic connectivity caused by human activities increased turbidity, which in turn decreased macroinvertebrate diversity. The identification of these factors in tributaries is vital for developing a strategy for habitat restoration to conserve the entire ecosystem.

Recommendations

The following recommendations were given:

i. A comprehensive strategy for governance and management is needed to improve the functions of the lagoon ecosystems. This approach must take into account both the functioning of the sea ecosystem, the lagoon water and nutrient cycles**.**
ii. The current governance framework for lagoons and other waterbodies should be bound to accommodate the existing rules, regulations, systems, and structures. This will ensure ecological and socio-environmental sustainability while pursuing sustainable lagoon governance, which will benefit all parties involved, particularly the nearby communities.

Impact of the study on the national economy

In essence, the study contributes to the body of literature from Ghana and around Africa to have a thorough grasp of the body of knowledge already available on lagoon resources and the role that indigenous knowledge plays in the management of waterbodies. It is anticipated to

bolster the understanding of water resources required in the light of ecological decline of wetlands.

3.2.1.3 Assessment of Groundwater Potential for Palm Plantation at Ewusiejoe, Western Region

(Research Team: Dr. Obed Fiifi Fynn – Principal Investigator, Dr. Collins Okrah, Mr. Eric Darko, Mr. Samuel K. Debrah)

Introduction

Norpalm Ghana Limited is a Ghanaian-owned oil palm company located at Ewusiejoe in the Western Region of Ghana. The company produces palm oil in commercial quantities for both domestic and industrial purposes. The processing requires large volumes of water to run the steam boilers. The major source of water supply to the factory was the Butre River, which over the past years has been heavily polluted, resulting in a high cost of treatment before use and a high cost of production. CSIR-WRI was consulted to provide a lasting solution through the exploration and development of groundwater resources.

Objective

The objective was to conduct geophysical site investigation, pumping test, and hydro-chemical analysis of borehole water samples.

Activities undertaken

A six-hour pumping test and three-hour recovery measurement were conducted on three boreholes. In-situ measurements of some physico-chemical parameters such as pH, TDS, temperature, and hydraulic conductivity were undertaken and water samples were collected and preserved under the right conditions for further hydro-chemical analysis at the CSIR WRI-laboratory. A geophysical site investigation was conducted along several traverse lines oriented parallel and orthogonal to the main drainage (Butre River) in the project area. The roll-along technique of ABEM Terrameter equipment was used for the survey. The Schlumberger and dipole-dipole arrays in forward and reverse modes were applied to obtain the electrical resistivity tomography (ERT) of the subsurface to guide the interpretation of subsurface anomalies and characterize the aquifers. Additionally, the groundwater detector (River G) was also employed to locate a reasonable number of potential points. The aquifer horizon was determined as well as the salinity level to assess the suitability of the groundwater for both agricultural and industrial purposes. Sounding was later conducted on these potential water points to determine the depth of the water table as well as the thickness of the aquifer.

Key results achieved so far

The quality of the groundwater for both domestic and industrial purposes was satisfactory for potable use. The outcome of the pumping test revealed that existing water outlets can provide a total discharge of 9360 liters per hour at a safe yield while producing a total of 11769 liters per hour when optimally utilized. A total of 7200 liters per hour can be obtained in the event that the wells have to be pumped continuously for 24 hours. Averagely, a total of 9443 liters per hour of water is attainable, leaving a deficit of 15557 liters per hour. Geophysical analysis conducted within the study area revealed two (2) potential points for the drilling, construction, and development of large volumes of groundwater with generally good quality for industrial purposes. Based on the technique employed, it can be agreed that large volumes of water are expected to be reached at depths between 225 and 280 meters below sea level, with about 85% degree of success.

Conclusion
A pumping test conducted on three (3) boreholes on site revealed that a total amount of 9360 litres per hour is attainable from the existing water outlets under safe yield conditions. This means an additional 15640 litres of water is required to meet production demand. The groundwater was established to be of good quality for both industrial and domestic purposes. The geophysical site investigation for the drilling of additional borehole revealed two potential points with a promising degree of success. It was observed that existing boreholes were tapping water from the unconfined shallow aquifer. Even though the area is underlain by competent Birimian rocks, associated with poor groundwater occurrence in the aquifers, the state-of-the-art device (River G Water Detector), which can detect large volumes of water underground, revealed the groundwater potential expected at depths from 225 to 280 meters in the study area. Thus, very prolific aquifers can be tapped to augment the water demands for palm oil production.

Recommendation
Pumping of the existing wells should be done at the current safe yields of the individual boreholes. The two additional boreholes should be drilled to augment the existing ones, and periodic groundwater quality and quantity monitoring should be conducted using water level logger for sustainable groundwater management. A deep well should be drilled to 240 m depth to tap the large fresh groundwater.

Impact of the study on the national economy
Aquifers storing large volumes of groundwater was delineated to make water supply available to NORPALM Ghana Limited. This was to potentially increase production of palm seedlings and palm oil to improve the supply chain for farmers and palm oil consumers and to meet demand for palm seedlings for cultivation. Eventually, it would improve job creation for the youth and enhance the gross domestic product (GDP) of the country at large.

3.2.1.4 Trends in Dissolved Oxygen Levels in Major Rivers in the Southwestern, Coastal and Volta Rivers Systems of Ghana: Implications for Aquatic Life

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

Introduction
Continuous monitoring of the quality of water bodies across the country is of utmost importance due to the multifaceted impact on the environment, public health, and socio-economic factors. Dissolved Oxygen (DO) is probably the most important parameter related to water quality and biological habitat in aquatic environments (Corey and Hondzo, 2009), and is a key indicator of water quality (AtlasScientific, 2022). Fish and other aquatic organisms need DO to survive. Therefore, without adequate amounts of DO in water bodies, aquatic life cannot survive. Continuous monitoring of DO variations in water bodies is therefore crucial for the protection and management of the aquatic ecosystem. The project started in 2023 and is expected to end in 2030.

Objective
The objective was to analyze trends in dissolved oxygen levels in major rivers in the dry and wet seasons to assess the implications on aquatic life.

Activities undertaken

A total of forty-one (41) water sampling stations were visited in the Southwestern Rivers Systems, Coastal Rivers Systems and the Volta Rivers Systems in the months of February and July 2023. Water samples from major rivers such the Pra, Ankobra, Volta, etc. were collected for analyses of various physico-chemical water quality parameters. Water samples for physico-chemical analyses were collected into clean 1L plastic sampling bottles. Samples for DO determination were collected separately into 300 ml plain glass bottles and 1 ml each of Winkler I and Winkler II Reagents added to each bottle to bind the DO (precipitate DO from solution). Each bottle was stoppered carefully to exclude air bubbles and mixed by inverting the bottle a few times. All samples were kept on ice in a chest and transported to the laboratory. In the laboratory, 2 ml conc. H_2SO_4 was added to each DO bottle to dissolve the precipitate after which 200 ml of the solution was titrated with M/40 $Na_2S_2O_3$ using starch as indicator. The DO concentration was then calculated from the equation:

1 ml M/40 $Na_2S_2O_3$ = 1 mg DO/L (APHA, 2017)

Key results achieved so far

For the protection of aquatic life and aquatic ecosystems in Ghana, the WRC has established a guideline for DO in surface waters. The guideline or TWQR (Target Water Quality Range) stipulates that for the protection of all life stages of aquatic biota, 80 % - 120 % of DO saturation should be the norm for all aquatic ecosystems (WRC, 2003; Atlas Scientific, 2022).

The results indicated that in the dry season (February), Potroase and Mangoase on River Densu; Osino on River Birim; Dominase on River Ankobra; Dunkwa-On-Offin and Adiembra on River Offin; Lake Bosomtwe, Aframso on River Afram; Daboya on White Volta, and Kpong on the Main Volta had DO saturation below 80%, at 24.3 % of the stations. Potroase and Mangoase had low values of 35.1% and 46.5%, respectively.

In the wet season (July), Potroase, Mangoase and Nsawam on River Densu; Osino on River Birim; Sefwi-Wiawso on River Tano; Dunkwa-On-Offin, Adiembra and Barekese Reservoir on River Offin; Lake Bosomtwe; Dadieso on River Bia; Aframso on River Afram; had % DO saturation below 80%, comprising 26.8 % of the stations. Osino, Sefwi-Wiawso and Barekese had low values of 47.7 %, 46.3% and 49.1%, respectively, in the wet season.

Potroase and Mangoase, Osino, Dunkwa-On-Offin, Adiembra, Lake Bosomtwe and Aframso were the stations that had % DO saturations below the TWQR (80%) in both dry and wet seasons. The % DO saturation was observed to be slightly higher in most places in the dry season compared to the wet season. However, the paired-two-samples t-test showed no significant difference between the % DO saturations of the waters in February and July 2023 (df =40, p-value = 0.11, one-tail).

Similarly, the t-test showed no significant difference between the % DO saturations of each river system in February and July. The ANOVA (Single Factor) also showed no significant difference between the % DO saturations of the group of the 3 river systems in February and July (df =40, p-value = 0.60, ANOVA). This again confirms that there was no significant difference between the % DO saturations in February and July. The % DO saturation of the rivers in February 2023 and July 2023 is shown in Figure 3.2.1.

Conclusion

No significant difference of % DO saturations between the seasons were observed. In the dry season 24.3 % of stations had % DO saturations below the recommended threshold (80%), while in the wet season 26.8 % of stations had % DO saturations below the threshold. Seasonal studies of dissolved oxygen levels are important for the assessment of water quality, management and protection of the aquatic ecosystem.

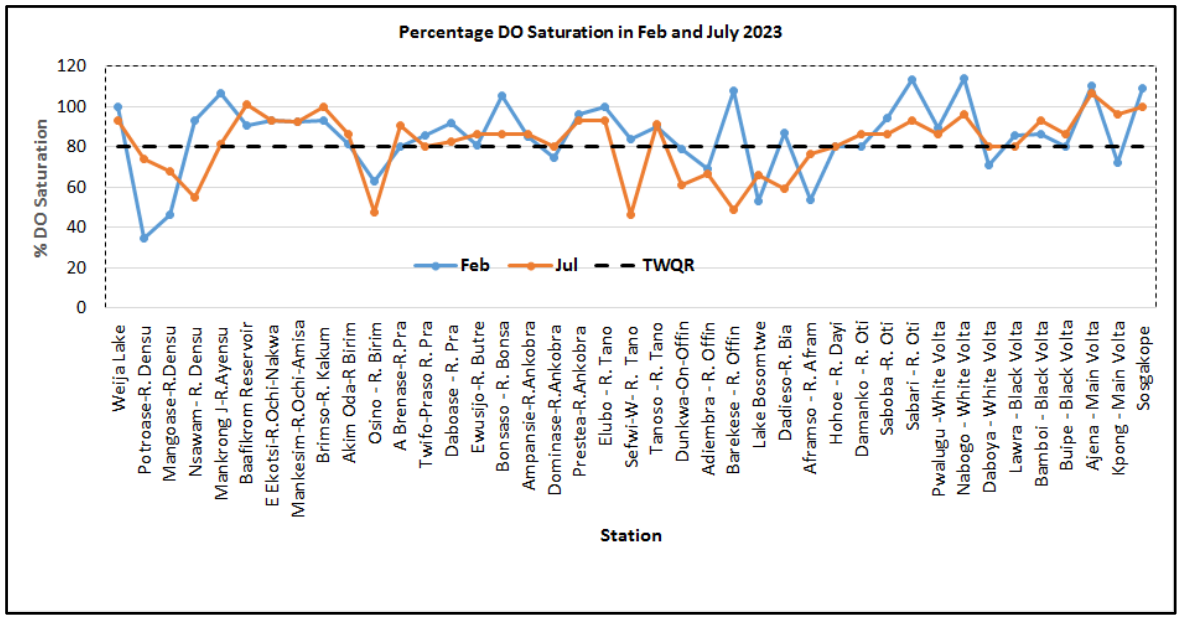


Figure 3.2.1: Percentage DO saturation in the rivers during the months of February and July 2023.

Recommendation

It was recommended that measures such as reduction in human activities close to these water sources should be enforced to minimize pollution inputs into the rivers. This is because Potroase which is close to the source of the Densu River that supplies large communities downstream (Nsawam, Accra) with drinking water had low % DO saturations below the threshold in the dry and wet seasons. This is of concern for both drinking water and aquatic life. Similarly, the low % DO saturation observed in the Barekese Reservoir during the wet season is a cause for concern because it is the source of water supply to a large population of the city of Kumasi.

Impact of the study on the national economy

Studying seasonal variations in dissolved oxygen levels is essential for understanding the dynamics of aquatic ecosystems. It will enable better management practices, help in the assessment of general water quality in the country, and contribute to the conservation of biodiversity in rivers, lakes, and other aquatic environments. In particular, it will aid the WRC in the effective management of Ghana's water resources.

3.2.1.5 Independent Sampling and Analysis of Drinking Water in Ashanti, Western, Eastern and Accra West Regions

(Research Team: Dr. Kwadwo Ansong Asante – Principal Investigator, Dr. Mark Osa Akrong, Mr. Humphrey Darko, Mrs. Regina Ama Banu, Dr. Anthony Yaw Karikari, Dr. George Tetteh Mensah, Prof. Mike Yaw Osei-Atweneboana)

Introduction

The Public Utilities Regulatory Commission (PURC) is mandated under Section 3 (c) of Public Utilities Regulatory Commission Act, 1997 (Act 538) as part of their functions, to "initiate and conduct investigations into standards of quality of service given to consumers". The Commission periodically undertakes independent investigation into urban drinking water quality in selected operational regions of the Ghana Water Company Limited (GWCL). Hence, the Institute was requested to carry out two rounds of independent sampling (Dry and Wet Seasons) and analysis of drinking water in selected water sampling points from four (4) of the Regions GWCL operates, namely Ashanti, Western, Eastern and Accra West. The project commenced in 2022 and ended in 2023.

Objective

The objective was to undertake independent investigation into the quality of urban drinking water produced by the Ghana Water Company Limited (GWCL) in their operational regions of the country by carrying out two rounds of independent sampling and analysis of drinking water in selected water sampling points from 4 of the Regions GWCL operates, namely Ashanti, Western, Eastern and Accra West.

Activities undertaken

The dry season sampling began in October, 2022 and wet season sampling commenced in May, 2023. Analyses for both samplings were completed and a final report was submitted to PURC in December, 2023.

Key results achieved so far

Based on the physico-chemical analyses of the water samples collected from the various districts in the 4 regions during the wet season, water treated and distributed by the Ghana Water Company Limited (GWCL) is predominantly good and suitable for potable use except in a few districts such as Mampong and isolated sampling points in some districts of Ashanti Region; Axim-Elubo Zone 6 and a few sampling points at Sekondi Zone 5 (Western Region); and Tafo, Nsawam Districts (Eastern Region) where Iron/Manganese continues to be an issue and GWCL must step up efforts to reduce the levels to acceptable standards. At Tepa District (Ashanti Region) as well as parts of Tafo, Kade, Akim Oda and Nsawam Districts (Eastern Region) where the source of water is borehole, there was a little improvement in the pH values at Tepa, Tafo and Nsawam Districts compared to the dry season. Compared to the dry season, there was a remarkable improvement in Residual Chlorine levels in 10 districts from the Ashanti Region; Kade and Kwahu Districts in the Eastern Region; Axim-Elubo Zone 6 and Sekondi Zone 5 Districts in the Western Region as well as Dansoman North, Dansoman South and Sowutuom Districts in Accra West Region. The bacteriological quality of most of the samples from the Eastern Region and especially Accra West Region was unsatisfactory, rendering them unsuitable for human consumption. Some of the samples contained low Residual Chlorine and this could compromise the quality. During the sampling exercise, the teams observed pipelines going through drains at Akrofrom and Kenyasi (Ashanti Region) and Shama (Western Region). This bad practice could introduce foreign materials into the water distribution lines and impact on the quality.

Out of the total of 443 samples from the Ashanti Region, 294 representing 66.4% were observed to be bacteriologically safe. These water samples conformed to the Ghana Standards/WHO Guidelines for drinking water. Thus, 149 samples (33.6%) were unsafe bacteriologically for drinking purpose. Furthermore, out of the 443 samples collected and analysed, 27 samples representing 16% were contaminated with *E. coli* bacteria. Seasonally, there was a marginal improvement in the water quality at some of the sampling points in the wet season (294/443; 66.1%) compared to the dry season (268/443; 61.2%).

Out of the 397 water samples from the Eastern Region, 155 water samples representing 39% were bacteriologically safe for potable use during the wet season. In the dry season, however, a markedly higher (242/356; 68%) quantity of water samples were bacteriologically safe for potable use. Also, 89% of the wet season samples as well as 85% of dry season samples did not contain *E. coli*. Seasonally, there was deterioration in water quality in the wet season juxtaposed to the dry season.

From the Western Region, out of the total of 142 samples, 91 samples representing 64.1% were found to be bacteriologically safe. Thus, these water samples satisfied the WHO Guidelines/Ghana Standards for drinking water. However, 51 samples (35.9%) were unsafe bacteriologically for drinking purpose. Furthermore, out of the 142 samples collected and analysed, 7 samples (4.9%) were contaminated with *E. coli* bacteria. Seasonally, there was a slight improvement in the water quality at most of the sampling points in the wet season (91/142; 64.1%) than the dry season (72/147; 53.7%).

In the wet season, 293 water samples obtained from Accra West were relatively less than what was collected in the dry season (348 samples) due to the interruptions by rainfall during the sampling period. Of the 293 analysed samples, only 12% were bacteriologically safe per the WHO Guidelines/Ghana Standards and thus, 88% were bacteriologically unsafe. In the dry season, 29% of the 348 samples were bacteriologically safe. There is therefore the need for critical intervention to remedy the sources of such contamination in the Accra West distribution systems. The presence of *E. coli* in the water samples was however less in both seasons; 61 out of 293 in the wet season and 12 out of 348 in the dry season. During the wet season however, such positive presence was found across almost all districts (10 out of 12) compared to what pertained in the dry season (3 out of 12). There is therefore an urgent need for corrective action to prevent *E. coli* presence from these sampling points especially during wet seasons.

Conclusion

As observed in the dry season, some standpipes or environs were not clean at the time of sampling. Typically, some tap walls had algal growth and floors were muddy and dirty. Also, the environs of some taps needed to be cleared of weeds and owners were advised to do so and discouraged from keeping animal pens close to taps. Such unhealthy environment or practice could lead to the consumption of contaminated water. Albeit most of the pipe owners claimed they periodically clean the taps, the environment did not depict so, and therefore the sampling teams continued to educate them on the essence of cleaning the taps regularly with soap and alcohol (since some of the sampling points are by the roadside), to ensure the water is safe for consumption.

The general complaint from consumers about the irregular supply or rationing of water by GWCL persisted during the 2nd round of sampling (wet season). Depending on the area, some residents claimed the taps could be closed for days and when the water supply was restored, the water became turbid for some time or was accompanied with bad odour. In anticipation of

water not being supplied by GWCL, consumers kept water in containers which were not clean in our view, and this could compromise the quality.

Recommendation
GWCL must continue to ensure that the booster stations sustain the water quality with its chlorine dosage periodically as in some of the samples collected, Residual Chlorine levels were too low or not present at all and this could account for the poor bacteriological quality of some of the samples. Also, the road leading to the Bogoso Treatment Plant on the mountain needs attention because it was in a deplorable state and the research team had to park their vehicle and walk to the plant to collect the samples.

Impact of the study on the national economy
As Ghanaians consume water produced by GWCL in one way or another, it is imperative that the produced water is wholesome and safe as clean and safe water is fundamental to poverty reduction, sustainable development, human survival, health, and ecosystem wellbeing.

3.2.1.6 Building Climate Resilience into River Basin Management (CREAM)

(Research Team: Ing. Dr. Emmanuel Obuobie – Principal Investigator, Dr. Emmanuel Obeng Bekoe, Dr. Francis Amevenku, Dr. Sylvester Afram Boadi, Dr. Prosper Bazaanah, Dr. Barnabas Amisigo, Ing. Gabriel Appiah, Ing. Frank Oblim, Ing. Patricia Granaham, 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 six-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 socio-economic 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. The project commenced in 2019 and is expected to end in 2025.

Objectives
The scientific objectives were to:

i. improve the data basis for high-resolution, bias-corrected climate change (CC) projections for use in impact studies and to analyze trends in extreme climate events in the two study basins;
ii. further develop and test methodologies for integrating climate change scenarios (Representative Concentration Pathways – RCPs), 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 directly into river basin management;
iv. develop an interdisciplinary framework for supporting stakeholder dialogue and negotiations in Water Resources Management (WRM);
v. analyze stakeholder constraints to effective water governance and develop strategies to introduce innovative, effective policies and measures and enhance resilience; and
vi. enhance the capacity of researchers, PhD students and stakeholders on how to incorporate climate resilience into water management.

Activities undertaken
Major activities undertaken in 2023 were:

Project co-ordination/leadership: The CREAM team at CSIR-WRI led and coordinated efforts of project partners in the implementation of the planned project activities for 2023. This included providing guidance to implementation of the different work packages (WP) in collaboration with the WP leads; and building relationships, corporation and understanding between WPs. In addition, the CSIR-WRI team led the preparation of the project's technical and financial reports that were submitted to and approved by the funding agency.

***Field data collection and maintenance of hydro-meteorological equipment*:** The project team conducted four rounds of field visits to the Pra and Densu river basins for regular monitoring of climate, stream/river water levels, groundwater levels, and sediment at multiple locations in the two basins. Data collected included rainfall, minimum and maximum temperatures, relative humidity, river water levels, suspended sediment concerntrations in rivers and groundwater. In addition to the data collected, repair and maintenance works were carried out on all the equipment installed by the project in the two basins. Seventy-eight sediment samples were collected from 13 locations in both basins in the reporting year. The samples were analyzed for sediment concentrations and the results were used as input data for calibration of the SWAT model for the two basins.

***Quantification of Shared Socio-economic Pathways (SSPs)*:** In the reporting year, the CREAM research team in Ghana, together with the team in Aarhus University, conducted a workshop for national stakeholders in February 2023, to co-develop qualitative narratives on selected SSPs (SSP1- sustainability world; SSP3-regional rivary world; and SSP5-fossil-fueled economy) for five key sectors (energy, water and wastewater, agriculture, tourism and environment) of the country and the study basins. Together with the basin-scale narratives that were co-developed with stakeholders of the Pra and Densu basins in 2022, the qualitative narratives were developed into quantitative future projections under the three SSPs. The SSP projections are being used as inputs to simulation models and analytical analysis of the impacts of choice of development pathways and changes in land cover and climate on water resources in the two study basins.

***Working sessions, data analysis and modelling*:** In the reporting year, the project made significant progress regarding data analysis and model simulations. The six project workpackages held extended working sessions and conducted rigorous data analysis and model simulations. The climate workpackage for example conducted bias correction analysis on 38 climate projections from 15 of the regional climate models used in the CORDEX-Africa Experiment for three IPCC scenarios (RCP2.6, 4.5 and 8.5). The resulting bias corrected data was used by the Hydrology workpackage to analyse the impact of climate change on streamflows in the Pra and Densu River Basins. In addition, the Hydrology workpackage completed calibration of the Soil and Water Assessment Tool (SWAT), MIKESHE and Groundwater Simulation Model (GSM) for the Pra and Densu River Basins. Furthermore, the system modelling and optimization workpackage of the CREAM project made some advances with their basin water allocation model (WEAP) which was initially set up in 2022, by coupling the model to a generic optimization algorithm and conducting a preliminary simulation runs. The optimization setup is undergoing further refinment.

***Annual planning meeting 2023*:** The CSIR project team organized the 2023 annual planning meetings of the CREAM project from 7th to 9th November 2023 at the conference room of the

CSIR Head Office. The meeting brought together all the 9 project partners to discuss progress made in 2023 and drafted workplans for the 2024 year. The meeting was also used to share some results with stakeholders for feedback. Presentations were made by senior sceintists and the project's PhD students. The meetings provided opportunity for face-to-face engagements and knowledge exchange between the Ghanaian team and project partners from Denmark and Australia.

***Publications and draft manuscripts*:** The research team published one journal article, submited one manuscript for publication and revised one other manuscript.

Key results achieved so far

Key results achieved included:

i. Archived data on climate, hydrology, hydrogeology, land-use/-cover, ecosystem, governance and socio-economics, for the Pra and Densu basins;
ii. Functional and well-maintained hydro-meteorological monitoring networks;
iii. Published journal articles and submitted manuscripts;
iv. Hydrological and groundwater models (SWAT/MIKE SHE/GSM) adapted to Pra and Densu basins.

Impact of the study on the national economy

The project will develop innovative tools that can 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).

3.2.1.7 Sustainable Wetland and Flood Management for Strengthening Food Security and Ecosystem Resilience in West Africa (GDZHIAO)

(Research Team: Dr. Emmanuel Obuobie – Principal Investigator, Dr. Sylvester Aframe Boadi, Dr. Prosper Bazaanah & Franz Alex Essilfie-Gaisie)

Collaborating Agencies: Centre de Suivi Ecologique (Senigal), Centre for Space Science and Technology Education (CSSTE, Nigeria), Institut Supérieur d'Etudes Spatiales et Télécomunications (Burkina Faso); Volta Basin Authority (Burkina Faso), Centre Universitaire de Recherche et Application en Teledetection (Cote D'Ivoire), Institut Géographique du Burkina (Burkina Faso), Department of Parks and Wildlife Management (The Gambia), Center for Remote Sensing and Geographic Information Services (Ghana), Direction nationale des eaux et forêts (Mali), Centre National de Surveillance et d'Observation Environnementales (Guinée), Direction de la Faune, Chasse et des Aires Protégées (Niger), Direction des Parcs Nationaux (Senegal), Space For Humanity Foundation (Nigeria), (INE, Benin)

Introduction

The GDZHIAO project aims at assisting decision-makers and stakeholders manage wetlands and floods in West Africa by providing tools, innovative approaches and earth observational data for effective monitoring and managing wetlands and floods at several scales. This includes supporting disaster management organizations to harmonize and develop legislative and regulatory framework for managing wetlands and floods. The CSIR-WRI team on the project works specifically on flooding issues. The project began in 2022 and is expected to end in 2026.

Objective

Specific objectives of the CSIR-WRI component were:

i. identify and map past and on-going initiatives and programmes related to floods in Ghana;
ii. appraise existing policies on flood management to identify areas of weaknesses that should be strengthened;
iii. develop and simulate flood contingency plans for 2 districts in Ghana, jointly with the National Disaster Management Organization (NADMO) and in collaboration with relevant stakeholders;
iv. strengthen the capacity of NADMO and other disaster management organizations to enhance community participation in the planning and management of floods; and
v. consolidate and operationalize the flood services for the Black Volta Basin in Ghana based on flood forecast systems from other project partners (INE/CSSTE).

Activities undertaken

Activities undertaken in the reporting year included:

***Selection of districts for contingency planning*:** The CSIR-WRI project team held two meetings with the NADMO team to familiarize the NADMO team with the GDZHIOA project and to identify 2 districts in the Black Volta Basin in the Upper West Region for which flood contingency plans will be developed. The meetings were also used to discuss preparations needed prior to commencing the development of the contingency plans.

***Preparation of concept note*:** The CSIR team, in collaboration with the NADMO team, prepared a concept note that will guide the development of the flood contingency plans. The concept note covers, among other things, the scope of the contingency plans, the key stakeholders to involve in the development process and the related resources required to conduct the exercise.

***Participation in global project annual exchange meeting*:** The lead of the CSIR-WRI team participated in the GDZIAO annual exchange meeting which took place in Banjul, The Gambia, from 19th to 23th June 2023, where he presented progress made in the implementation of activities in Ghana as well as activities planned for the rest of 2023.

***Mapping of flood projects, programmes and initiatives in Ghana*:** The CSIR-WRI project team started mapping flood projects, programmes and initiatives in Ghana. This consists of identifying and collecting geo-referenced information on all past flood projects in Ghana, archiving of same in pre-designed excel file, and developing a spatial database to house the data. So far, data on 38 projects, programmes and initiatives have been collected and archived. The data covers information such as name of project, period of implementation, status of project, city/town of implementation, name of river basin, country, coordinates of location, implementing body, contact of lead implementer, partner institutions, funding source(s), funding amount, project objectives and weblink to the project.

Key results achieved so far

Results achieved in the reporting period included:

(i) Two districts (Lawra and Jirapa) identified for developing and simulating flood contingency plans.
(ii) Concept note to guide the development and simulation of flood contingency plans developed, in collaboration with NADMO.

(iii) Data on flood projects, programmes and initiatives in Ghana collected and archived.

Impact of the study on the national economy
The project will develop innovative tools and approaches and couple that with earth observation data for effective monitoring of wetland and flood at multiple scales. These will be co-developed with disaster management organizations (e.g., NADMO, GMET and HSD) and will be integrated into existing national systems to enhance flood and wetland management in the country.

3.2.1.8 Community Participation in Governance and Sustainability of Rural Water and Sanitation Systems in the Savannah Region, Ghana (FAR-LEAF)

(Research Team: Dr Prosper Bazaanah – Principal Investigator, Ing. Dr. Emmanuel Oboubie; Dr Sylvester Afram Boadi; Ing.Frank Oblim; Ing. Patricia Granaham and Mario Danban)
Collaborating Agencies: Future Africa Institute, University of Pretoria, Carnegie Corporation, and Central Gonja District Assembly

Introduction
Water and sanitation are critical to the health, livelihood, and well-being of everyone. Hence, the governance of water and systems must be a shared responsibility between state agencies and citizens. Participatory and effective governance systems are no longer based on top-down or hierarchically arranged structures, but rather bottom-up and multi-level participation, where decision-making on social amenities includes not only state agencies, but also civil society and citizens in general. In Ghana, rural parts of the country continue to struggle over access to critical social amenities like water and sanitation. This is due, in part, to lack of facilities, governance, and maintenance culture of existing facilities. In the early 90s, a top-down decentralized governance structure was introduced, leading to the establishment of the MMDAs to promote local development including efforts at making water and sanitation facilities and services accessible to all persons. In performing their mandate, the MMDAs collaborate with other agencies like the CWSA, aiming to improve water and sanitation delivery in rural communities. In 1994, community ownership and management model (COMM) was introduced as a bottom-up strategy to infuse innovation, attract funding, and professionals in the community water and sanitation sector. However, the sector still has drawbacks that remain unresolved. Studies have found that most amenities located in deprived areas are not in use due to funding deficits and failures to maintain the systems. Central Gonja District exemplifies this struggle, with state-funded facilities at risk due to maintenance lapses. Despite being state-funded, there has been no attempt to investigate the effectiveness of governance structures established to maintain and sustain the systems at the community level. This study assesses community participation in governance and sustainability of drinking water and sanitation systems in the Central Gonja District. The project started in 2022 and is expected to end in 2024.

Objective
The objective of the study was to assess community participation in governance and sustainability of drinking water and sanitation systems at the Central Gonja District. The specific objectives were to:

i. analyze the community residents' perceptions on the performance of community-based sanitation and water governance structures in rural settlements of the area;
ii. assess how the engagement of stakeholders in water governance decisions affects the sustainability of rural community water and sanitation systems; and

iii. co-develop strategies for enhancing participatory governance and sustainability of rural water and sanitation amenities in the district.

Activities undertaken

The study was piloted at the Bilsikura community. A mixed research method, involving qualitative and quantitative approaches was used in the pilot phase of the data collection exercise. The piloting exercise entailed a small-scale study to pretest the household questionnaires, interview and Focus Group Discussion (FGD) guides. Due to gender sensitivities, and prevailing patriarchal systems, the FGDs were organized on gender bases, allowing for active participation of women. The total sample size for the pilot phase was 74, composed of 50 household heads, 12 expert interviews, and 12 FGD participants. A systematic sampling approach was used to select household respondents from every second household for questionnaire administration. Two FGDs comprised of 6 memberships were held, one each for males and females, respectively. FGD and interview participants were purposively selected while local interpreters were hired to translate the questions from English into the local language (Gonja) and to ensure discussants understand the issues being discussed in their own local dialect. Trained research assistants were hired to support the implementation of the research activities. Ethical clearance was obtained from the CSIR-Institutional Review Board (CSIR-IRB). A thematic approach was followed in the analysis of the qualitative data, while SPSS was used for the analysis and presentation of quantitative data.

Key results achieved so far

The main economic activities in the Bilsikura area include farming, trading, artisanship and catering. The people accessed variety of water sources, including surface water *[rivers, lakes, dams, and rainwater]*, which accounted for 82% of household usage, and groundwater systems (boreholes and dugout-wells) accounting for 18%. Open defecation remains a pressing concern, with almost 60% engaged in the practice due to the lack of public toilet systems. Solid waste is either burnt or disposed in open fields, causing pollution and ill-health. The Assembly's structures at the community level were perceived to be ineffective in addressing the needs of the community. The participants perceived that low state funding, lack of engagement of the people, low technical knowledge, logistical capacities, ineffective leadership, and lack of accountability threatened the effective functioning of water and sanitation governance structures in the community. Community members took self-initiatives to safeguard and maintain their drinking water sources, including the creation of neighborhood watchdogs (10%), reliance on taboos (6%), community funding initiatives (28%), and fencing of dugouts (60%) to keep livestock and wildlife away from drinking sources.

Key strategies proposed for enhancing water and sanitation governance included stakeholder engagement, training and empowerment of the people, and improvement in communication channels of the Assembly. Involving all parties in decision-making and investing in capacity-building initiatives could empower decision structures and individuals to actively participate in water and sanitation systems, ensuring long-term sustainability while addressing community needs and concerns.

Conclusion

The results highlighted that the Bilsikura community faces challenges in water and sanitation amenities, marked by reliance on surface water sources and prevalence of open defecation. Pollution and health risks persist due to improper waste disposal practices. The weakness of the local governance structures in securing funds and engaging the community members

exacerbates the situation. To improve governance and sustain these systems, stakeholder engagement, funding, and capacity-building initiatives should be strengthened.

Recommendation
The District Assembly should prioritize investment in water and waste management infrastructure and public toilet systems to reduce open defecation, prevent burning, and promote community health and well-being. Initiatives like capacity-building and training should be introduced to empower governance structures at the community level to actively manage and maintain water and sanitation systems, ensuring their long-term sustainability. Following the lessons from the pilot phase of the project, the next phase focuses on upscaling the activities, which entails the implementation of the main research activities in the study area.

Impact of the study on the national economy
Safe drinking water and basic sanitation are core to every economy. The lack of these basic facilities affects our health, livelihoods, and the well-being of communities. Therefore, strengthening capacities and adequately resourcing local structures are crucial steps in achieving the country's vision of ensuring water and sanitation for all. The ineffectiveness of the Assembly's structures highlights the need for a comprehensive approach to delivering systems that reflect the needs and interests of community members. The key lessons for sustaining the sector are context-dependent, including recognizing the limitations of existing governance structures and addressing gaps in funding, technical knowledge, leadership, and community engagement in decision-making.

3.2.1.9 Assessment of Heavy Metal Concentrations in Soils in South East Ghana

(Research Team: Dr. Franklin Obiri-Nyarko – Principal Investigator, Dr. Anthony A. Duah, Mrs. Sandra V. Asare, Dr. Anthony Yaw Karikari, Mr. Jude Ofei Quansah, Mr. Samuel K. Debrah)

Introduction
Heavy metals are significant environmental pollutants due to their persistence in the environment, their toxicity, and their ability to bioaccumulate in living organisms. These metals do not degrade over time and can remain in the environment for long periods, posing a continuous threat to both the ecology and human health. Once released into the environment, heavy metals can migrate through soil profiles and reach the groundwater, contaminating drinking water sources and affecting agricultural productivity.

In southeast Ghana, rapid industrialization is contributing to the increased release of heavy metals into the environment. Factories, mining activities, and improper disposal of electronic waste are some of the primary sources of these pollutants. Given the potential of heavy metals to disrupt ecosystems and cause human health problems, it is crucial to assess and monitor their levels in the environment. Accurate data on the concentration and distribution of heavy metals in soils can inform mitigation strategies and regulatory policies to protect public health and the environment. Accordingly, this research aimed to determine the levels of heavy metals in urban soils in southeast Ghana, with a specific focus on lead, copper, cobalt and zinc.

Objectives
The objectives were to:

i. determine the concentrations of heavy metals, specifically lead, copper, cobalt and zinc in the soils of Tema;

ii. map the spatial distribution of heavy metals contamination to identify areas with elevated levels;
iii. investigate potential sources of the heavy metals;
iv. examine the physical and chemical properties of soils that influence the retention and mobility of heavy metals;
v. assess the potential ecological and human health risks associated with the identified levels of heavy metals; and
vi. provide recommendations for mitigating heavy metals contamination and improving soil and environmental quality in the study area.

Activities undertaken

During the period under review, soil samples were collected with an auger from the study area, following the guidelines of ISO standard 10,381 (ISO/TC190, 2005). The samples were placed in clearly labelled zip lock bags and transported in ice chests to the CSIR-WRI sediment and analytical chemistry laboratories for analysis. The heavy metals content of the samples was analyzed using an Innov-X Alpha Portable XRF analyzer. Prior to analysis, the samples were thoroughly mixed to ensure a uniform composition and air-dried to reduce moisture content to below 10%. The soil samples were also analyzed for their physico-chemical properties, including pH, organic carbon (OC), and soil separates (sand, silt, and clay). The OC content of the soils was quantified using the loss-on-ignition (LOI) method at 450°C for 4 hours, followed by conversion to organic matter (OM) using the van Bemmelen factor of 1.724.

Key results achieved so far

The analysed physico-chemical properties of the studied soils are shown in Figure 3.2.2. Clay content exhibited a wide variability, ranging from 0.2% to 13.1% (mean 5.1 ± 4.0%), and the silt fraction ranged from 0.2% to 11.7% (mean 4.0 ± 2.6%). The predominance of the sand fraction (75.5% to 99.6%, mean 91.0 ± 5.3%) indicated that the study area is a sandy to sandy-loam terrain. The pH (H_2O) of the soils ranged from 6.8 to 8.2 (mean 7.7 ± 0.4), indicating a neutral to slightly alkaline environment. The OC content ranged from 1.3% to 9.7% (mean 3.8 ± 2.3%), showcasing clear diversity in the distribution of organic carbon within the study area. As shown in Figure 3.2.2, areas characterized by high sand content tended to exhibit lower clay content and vice versa, illustrating an inverse relationship between these two soil components. Silt displayed a distinct trend, with elevated content mainly localized in the southern part of the study area. Furthermore, there was an observation of heightened OC levels and alkaline pH values in the central to southern part of the study area. The factors contributing to these trends might include variations in land use, vegetation cover, or specific geological characteristics influencing soil composition

Conclusion

Considering the predominant presence of sand fraction in the soils, there exists the possibility of heightened migration of heavy metals from the surface to deeper layers or adjacent environments. We are currently analyzing data on heavy metals content to assess their levels in the soil, identify their sources, and explore their relationship with the soil's physico-chemical properties.

Impact of the study on the national economy

The findings can support the development and implementation of more effective environmental regulations and policies which can prevent further contamination and protect natural resources.

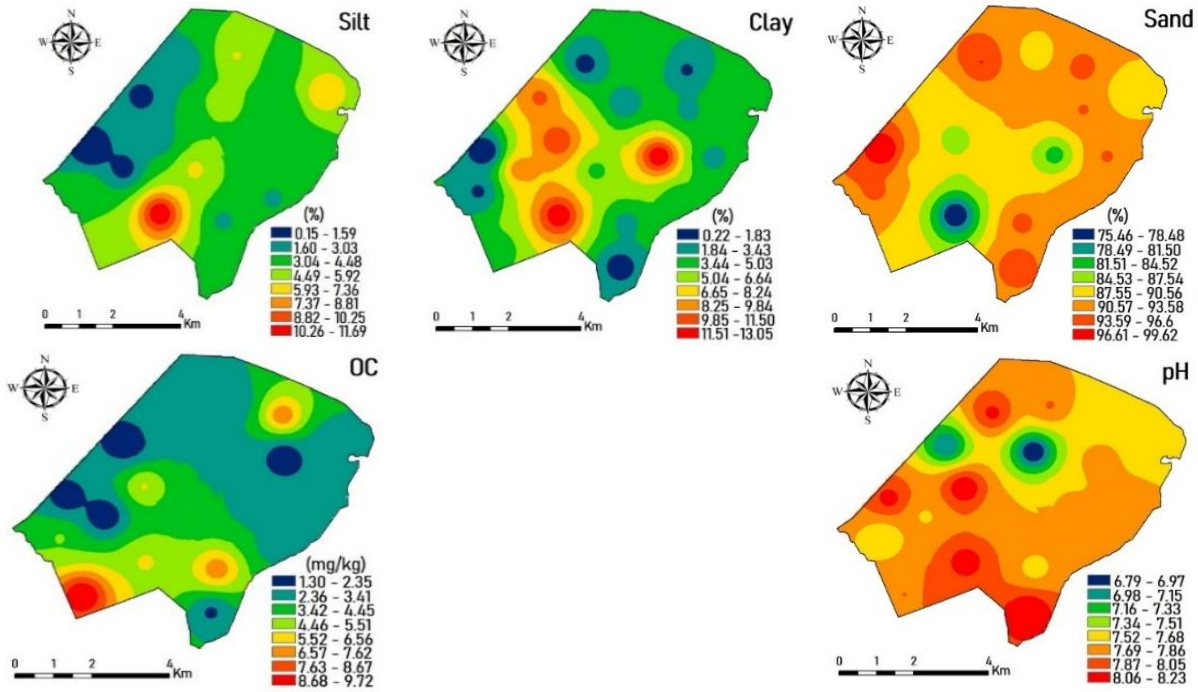


Figure 3.2.2: Spatial distribution maps of the physico-chemical properties of the soils in the study area.

3.2.1.10 Assessment of Groundwater Resources of the Volta Region

(Research Team: Ing. Ralph Tagoe – Principal Investigator, Dr. Anthony A. Duah, Mrs. Sandra V. Asare, and Dr. Collins Okrah)

Collaborating Agency: Community Water and Sanitation Agency (CWSA)

Introduction

The Groundwater Assessment of Ghana was initiated in 1992 to cover all regions in the country. The aim was to provide information on groundwater availability, suitability, and sustainability for domestic, agriculture and small-scale industries application in thematic maps. This current project began in 2021 and is expected to end in 2024.

Objective

The specific objective was to develop spatial distribution single-parameter groundwater characteristics, develop a composite hydro-geological map for the region, and assess the future trends of groundwater resource.

Activities undertaken

We have developed groundwater-use maps that include borehole location, study area, district, settlements and several hydrogeological parameters such as yield, static water level, geology and depth. Groundwater-use quality maps developed included concentrations for chloride, fluoride, sodium, iron, conductivity, manganese, and turbidity. These thematic groundwater-use maps will support mapping the groundwater occurrence in the various geological formations. They will also ensure quality assurance checks on the available borehole data.

Key results achieved so far

Geologically, the region is underlain by different rock formations, including Buem, Dahomeyan, Quarternary, Tertiary, Togo and Voltaian supergroup rocks. Among the dominant rocks are phyllites, sandstones, siltstones, granites, gneisses, mudstones, quartzites, and shale.

The water table ranges from 1m to 19 m. However, some areas in the Ketu District have deeper water tables, reaching 20 and 40 m below ground level. Conversely, Kadjebi, Hohoe, Kpando, and Nkwanta Districts have shallower water tables below 9 m. Borehole depths in the region vary between a shallow depth of 2 and 20 m at Keta and Adidome Districts and a deeper depth of 60 – 80 m at Akatsi, Sogakope, Kadjebi, and Ketu Districts. These suggest the presence of both shallow and deeper aquifer systems within the region.

The study found that turbidity values were less than 5 NTU, satisfying the World Health Organization (WHO) Guideline and the Ghana Standard for drinking water. However, higher turbidity values between 150 and 450 NTU were recorded in areas around Adidome, Sogakope, and Nkwanta. The total hardness levels were mostly less than 500 mg/L at Nkwanta, Jasikan, Hohoe, Kpandu, and Ketu, which fell within the WHO Guideline and Ghana Standard for drinking water. However, other areas (Ho, Akatsi, Adidome, Keta, Krachi, and Kajebi) recorded total hardness values between 500 mg/L and 1500 mg/L, which clearly indicate unacceptable levels for drinking water.

The chloride levels of groundwater resources were less than 250 mg/L, acceptable for drinking water. However, isolated areas in the downstream, particularly around Adidome and Sogakope, recorded chloride values above 250 mg/L. The total iron level was 0.2 mg/L, which is within the WHO and Ghana requirements of less than 0.3 mg/L. Therefore, the levels of iron in the groundwater resources across the Volta region are satisfactory. Fluoride concentrations in the groundwater were mostly less than 1.5 mg/L at Krachi, Kadjebi, Sogakope, parts of Jasikan, and Keta, adhering to the acceptable WHO guideline and Ghana Standard value. However, Hohoe, Akatsi, Adidome, and parts of Keta and Jasikan showed fluoride concentrations ranging from 1.5 to 45 mg/L, exceeding the recommended level (Figure 3.2.3).

Conclusion

The Volta Region is characterized by various rock formations, including Buem, Dahomeyan, Quarternary, Tertiary, Togo, and the Voltaian supergroup. The water table ranges from 1 m to 19 m, with shallower water tables in some districts. Borehole depths vary, indicating both shallow and deeper aquifer systems. Turbidity values below 5 NTU satisfy the WHO Guideline and the Ghana Standard for drinking water. Total hardness levels were mostly below 500 mg/L, satisfying the WHO Guideline and Ghana Standard. Chloride levels were below 250 mg/L, with total iron level of 0.2 mg/L. Fluoride concentrations were below the recommended limit of 1.5 mg/L.

Recommendation

Policymakers and water managers can use the hydrogeological characteristics to guide water use efficiency in the region.

Impact of the study on the national economy

The assessment of groundwater resources in the Volta Region of Ghana has the potential to positively influence the national economy. By assessing the availability, quantity, quality, and sustainability of groundwater, this study can generate key economic benefits. To begin with, improving the water supply for domestic use will enhance health outcomes by providing clean and safe drinking water thereby reducing the incidence of waterborne diseases. Productivity will increase and the cost of healthcare will be reduced due to a reduction in waterborne diseases. Overall economic growth would occur due to the general well-being of the people.

Secondly, access to reliable groundwater data would positively affect the agricultural sector. Farmers can use groundwater for irrigation thereby increasing crop yields. The finances of farmers would improve thereby stimulating economic growth. The country would benefit from increased exports and a reduction in food imports.

Thirdly, ensuring a sustainable and quality groundwater supply has the potential to drive investment in the region. Manufacturing industries that rely on this precious resource for their operations would thrive thereby creating more jobs for the residents and in effect improving the socio-economic well-being.

The production of digital groundwater-use maps would facilitate regular updates and sustainable resource management. Accurate and up-to-date data would inform the decision-making process of policymakers which would help in preventing overexploitation and ensuring the sustainable use of the groundwater resources for economic growth.

Another significant impact is infrastructure development. The study can lead to the construction of new wells, boreholes, and water distribution systems, providing jobs and long-lasting economic benefits by supporting various sectors and improving the quality of life of the residents.

The combined effects of these benefits would contribute to the robustness and resilience of the economy of the Volta Region and Ghana as a whole.

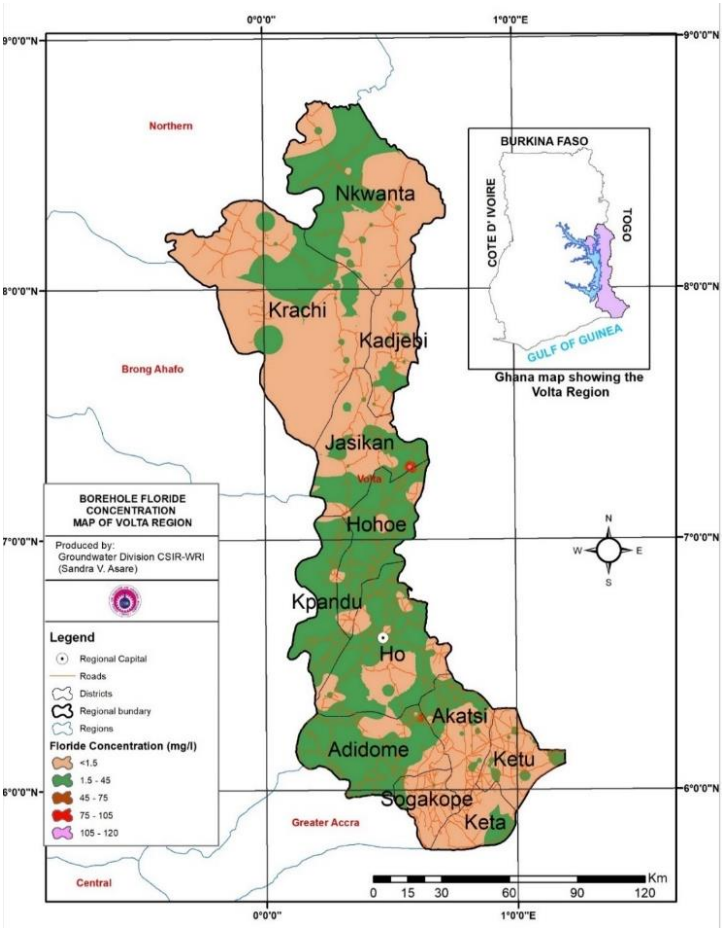


Figure 3.2.3: Borehole fluoride concentration map of the Volta Region.

3.2.1.11 Occurrence of Microplastics (MPs) in Water, Sediment, Cultured and Wild Fish in the Lower Volta Basin of Ghana

(Research Team: Dr. Pennante Naa Ayikailey Bruce-Vanderpuije- Principal Investigator, Dr. Ruby Asmah, Miss Yaa Asabea Agadzi and Ishmael Norvimagbe)

Collaborating Agency: Institute of Coastal Environmental Chemistry, Hereon Zentrum, Geestatcht, Germany.

Introduction

In Ghana, fish is one of the country's cheapest animal protein sources (17%). The Volta Lake, located on the Lower Volta Basin, a part of the Volta Basin- a transboundary basin shared by six riparian West African countries, hosts approximately 143 fish species. Approximately, 60 cage farms (≥2,278 cages) operate on the Lake. By means of major tributaries such as the Black and White Volta, Oti River, and majority of rivers flowing into the Volta Lake, possibilities of microplastics (MPs) waste inputs from households/industrial effluent discharges potentially contaminate the Lower Volta Basin, and its fishes. Despite the growing evidence of MPs, and their presence in fish, large populations in urban and rural communities depend on fish (tilapia) from the Lake. Our working hypothesis was that the presence of aquaculture/cage farms at the study areas potentially increase concentrations of MPs in river/lake sediment, water, and/or fish from cage sites, in comparison to wild sites. This necessitates MPs research into wild and cage environments of freshwater sources in Ghana, as cage farming informs on the impact of plastic infrastructural setups on fishes in the Lower Volta Basin. Additionally, the absence of MPs characterization techniques observed from Ghanaian studies (60% utilized visual identification- naked eye/optical microscope, and/or selective fluorescent MPs staining techniques) presented limitations of misidentification/biases in the absence of spectroscopy, microscopy and/or combustion techniques. This makes it impossible to understand the types of plastics dominantly in use, their residence in our waterways and impact on fish, and the potential for human exposure on fish consumption.

Objectives

The objectives were to:

i. characterize (polymer type, size) and quantify MPs in fish, sediment and surface water from selected sites: Ada Sogakope, Kpong, and Asikuma cage and wild fishing sites of the Lower Volta Basin, using the Laser Direct Infrared (LDIR) spectroscopy, and Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) as complementary tools;
ii. determine the spatial distribution of MPs in fish, sediment and surface water from selected sites; and
iii. determine/compute potential exposure risks to humans, based on fish consumption.

Activities undertaken

Activities undertaken included:

***Sampling*:** Sediment, surface water, and fish samples were collected from the study area in the wet and dry seasons.

***Extraction*:** Fish MPs extraction was based on modifications of optimized analytical methods of studies of Karami, *et al*. (2017) and Enders, *et al*. (2017). These studies focused on high plastic polymer recoveries, high biota digestion efficiency, low polymeric molecular alterations and low polymer degradation (colour changes- chemical corrosiveness), using combinations of acids, bases and oxidants. The extraction method was validated using in-house fragmented model MPs from PET centrifuge tubes, PE plastic bags/plastic water

bottles, PVC, PP tubing, and PS foams. Using an optimized alkaline digestion protocol, for every 1g of fish sample, 5mL of 30% KOH:NaClO.

Microplastic extraction from sediment, water, and commercial feed were based on density separation methods of Karlsson, *et al*. (2017), Zobkov, *et al*. (2020), and Liu, *et al*. (2021) using a combination of a weak acid, salt, base, and/or an oxidant (Karlsson, *et al*., 2017; Liu, *et al*., 2021; Zobkov, *et al*., 2020). Sediment samples were oven-dried at 60 ˚C, and sonicated in supersaturated NaCl solution to isolate microplastics from sediments.

Membrane filtered surface water was rinsed with potassium hydroxide solution (10 % KOH was made with distilled water) at a sample solution ratio of 1:3 to digest any organic matter, and filtered through a 10-13 µm (retention range) filter paper/membrane (Liu, *et al*., 2021). MPs (dried residues) were picked with forceps).

***Characterization*:** Microplastics extracted from fish, sediment, and water were observed under a digital stereomicroscope with image analyses system camera for possible identification. Colour, size, shape and number of microplastics identified in each sample was recorded. Spectroscopic analyses were conducted with an ATR-FTIR spectrometer, and an LDIR. Using an ALPHA I in combination with a germanium and diamond crystal, MPs were analysed to determine the chemical identity of the polymer.

Key results achieved so far

Results achieved in the year under review were:

i. MPs pollution varied in fish (670 MPs items g^{-1} fish ww; 3.9%) which ingested a low proportion, in sediment (16,250 MPs items kg^{-1} sediment dw; 95.4%) which served as a sink for a large proportion of MPs, and in water (111 MPs items L^{-1} water; 0.65%).
ii. The contributions were dominantly influenced by seasonal variations and mode of fish production. Fish health was not influenced by MPs ingestion, as the growth and condition factors were isometric and good.
iii. MPs abundance was approximately two-fold higher in fish in the wet season of 2022, yet higher in sediment in the dry season.
iv. Based on fish production, wild demersals ingested more MPs than cultured fish (*Oreochromis niloticus*), indicating additional MPs sources other than aquaculture.
v. Utilizing complementary techniques of ATR-FTIR and LDIR, the characterization and quantitation of 10% of the total potential MPs enabled aquaculture source apportionment.
vi. Results from human exposure risk assessment, on consumption of MPs-contaminated freshwater fish showed EAI concentrations below the recommended EUMOFA (range: 518 and 3078 particles) guideline.

Impact of the study on the national economy

This is the first study to elucidate the occurrence and abundance of MPs in cultured tilapia (*Oreochromis niloticus*), and selected wild fish species (*Chrysichthys nigrodigitatus, Chrysichthys auratus, Tilapia guineensis, Tilapia zilli, Mormyrus spp., Synodontis vellifer, Synodontis schall, Parachanna obscura, Auchenoglanis occidentalis, Brycinus brevis,* and *Malapterurus electricus*), sediment, and water in the Lower Volta Basin in Ghana. With respect to fish species analysed, this study provided baseline information on MPs in *Chrysichthys auratus, Tilapia guineensis, Mormyrus spp., Synodontis vellifer, Auchenoglanis occidentalis, Brycinus brevis,* and *Malapterurus electricus*. These local fish species were investigated for MPs in a freshwater system for the first time in Ghana. Results from this study will contribute

to knowledge on human exposure to MPs in Ghana, and serve as a baseline for other riparian countries of the Volta Basin.

3.3 BIOMEDICAL AND PUBLIC HEALTH

3.3.1 BIOMEDICAL, BIOSAFETY AND ETHICS

3.3.1.1 Towards the Elimination of NTDs: Application of Cost-Effective and Sensitive Molecular Environmental Surveillance Tools – A Pilot Study

(Research Team: Dr. Samuel Armoo – Principal Investigator, Juliet Hodgson, Gideon Twieku, Gerard Quarcoo, Emmanuel Armah, Prof. Mike Yaw Osei-Atweneboana)

Introduction

Neglected Tropical Diseases (NTDs) comprise a group of infectious diseases which is mostly prevalent in the tropical regions and affects about 1.7 billion people worldwide. The most prevalent NTD is Soil Transmitted Helminthiases (STHs) which are a group of intestinal nematodes that include *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworm species such as *Necator americanus* and *Ancylostoma duodenale*. In Ghana, majority of wastewater from homes and factories are expended into drains and nearby water bodies and reused by farmers for irrigation, thereby increasing the risk of transmission of pathogens to consumers. Measurement of microbial DNA/RNA in wastewater can give an indication of the presence of infections in a population, and can be leveraged for the preliminary investigation of potential disease hotspots.

Objective

The objective was to use wastewater surveillance as a cost-effective and sensitive environmental surveillance tool for STHs.

Activities undertaken

The study was conducted along the Nima Creek which serves as the main irrigating water source for about thirty registered urban farmers in the Greater Accra Region. A total of 32 samples from 8 sites along the Nima Creek were collected, kept on ice and transferred to the laboratory at Biomedical and Public Health Research Unit of CSIR-Water Research Institute for processing and DNA extraction. Screening for the presence of *A. lumbricoides*, *N. americanus*, *A. duodenale* and *T. trichiura* was performed using a High-Resolution Melt (HRM) dissociation assay. All real-time PCR assays were performed using the SsoAdvanced universal SYBR green supermix (2X) (Bio-Rad, USA). Each PCR reaction (total volume of 10 µL) contained 5 µL of the supermix, 0.2 µM of each pathogen specific primer pair, 2 µL each of template DNA and sterile nuclease free water.

Key results achieved so far

The most common STH was *A. lumbricoides*, which was detected in 17 (53.2%) out of the 32 samples. This was followed by *A. duodenale* (31.2%), *T. trichiura* (21.9%) and *N. americanus* (12.5%) (Figure 3.3.4). Out of the 32 samples, 9 (28.1%) tested positive for all 4 STHs, 3 (9.4%) tested positive for 3 STHs, 9 (28.1%) tested positive for 2 STHs, and 11 (34.4%) tested positive for a single STH. All 8 sampling sites harbored at least one of the four STHs investigated. Two sampling sites (SSC and SSF) harbored all four STHs and were downstream of the Nima creek. At site SSA, which was upstream, only *T. trichiura* was detected. *Both A. lumbricoides* and *A. duodenale* were detected in all sampling sites apart from SSA (Figure 3.3.5).

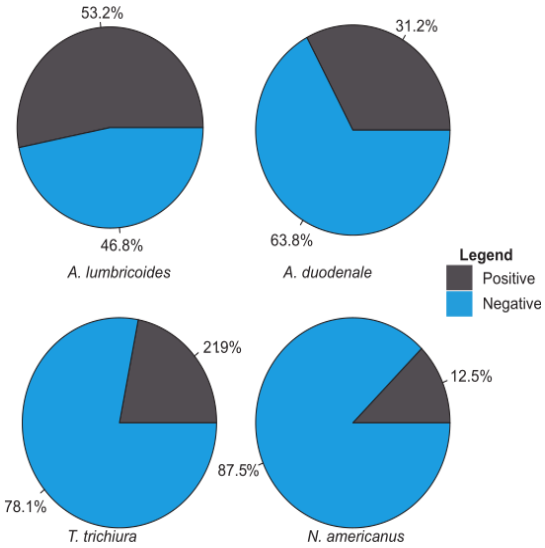


Figure 3.3.4: Overall prevalence of STH from 32 environmental samples.

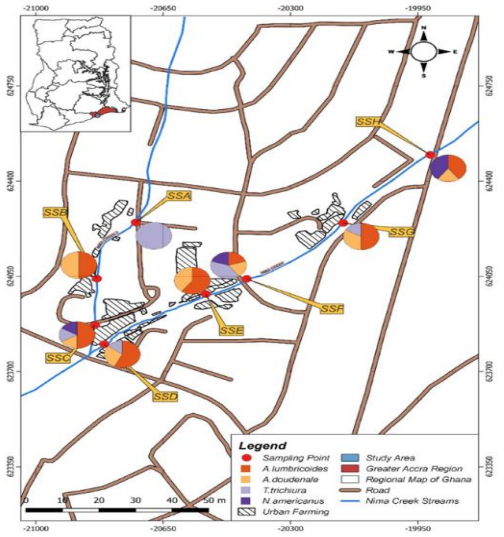


Figure 3.3.5: Distribution of STHs over the sampling sites.

Conclusion

Wastewater surveillance tool was used successfully to detect the presence of STH in an area populated with urban farmers. This method is less-intrusive, cost-effective and sensitive and provides community-level data on the prevalence and diversity of STH infections which can be used in informing and designing mass drug administration strategies.

Recommendation

Wastewater surveillance is a cost-effective and sensitive tool and it is recommended for routine monitoring of STH infections to support efforts of the 2021-2030 NTDs roadmap that targets the exploration of new tools for disease surveillance.

Impact of the study on the national economy

STH still presents significant health challenges for individuals living in endemic communities despite significant efforts of the national NTD program in reducing the burden of some STHs. Following the 2021-2030 NTDs roadmap, it has become important to design sensitive and cost-effective surveillance tools. Wastewater epidemiology can be employed as a technique in this regard and will aid in the timely and sensitive diagnosis of STH infection and further support the achievement of United Nations Sustainable Development Goal (SDG) 3 which focuses on good health and well-being.

3.3.1.2 Molecular Screening of Chewing Sticks and Sponges Found on the Ghanaian Local Market for Diarrhoea-Causing Microbes - A Pilot Study

(Research Team: Dr Samuel Armoo – Principal Investigator, Gideon Twieku, Emmanuel Armah, Prof. Mike Yaw Osei-Atweneboana)

Introduction

In Ghana, chewing sticks and sponges are used in conjunction with toothbrushes or used alone in situations where access to a toothbrush is limited. These traditional teeth cleaning agents are mostly made from plants such as *Garcinia mannii* (Sokodua) and *Azadirachta indica* (Neem tree) which have been reported to have antioxidant and antimicrobial properties. On the local Ghanaian market, chewing sticks and sponges are sold either tied with rubber bands, openly on

tables or head pans by hawkers or spread out on mats. These pose a likely health hazard since chewing sticks and sponges are purchased and used for oral hygiene with no prior cleaning and treatment, justifying the need to investigate if there are any microbial contaminants that can affect overall health. This information will support the need for proper methods of storage and handling of chewing sticks and sponges.

Objective

The objective was to assess the presence of selected diarrhoeal-causing pathogens (Rotavirus A*, Escherichia coli, Salmonella spp.* and *Vibrio cholerae*) on chewing sticks and sponges sold as ready-to-use teeth cleaning agents in a Ghanaian market.

Activities undertaken

A total of 10 samples (5 chewing sticks and 5 chewing sponges) were randomly purchased from the Agbogbloshie market in Accra (Figure 3.3.1). These samples were transferred into sterile ziplock bags, labelled appropriately and transported to the Biomedical and Public Health Research Unit laboratory of the Institute for sample processing, nucleic acid extraction and amplification. The list of primer sequences is shown in Table 3.3.1.

Figure 3.3.1: Chewing sponges sold at Agbogbloshie market in Accra.

Table 3.3.1: List of primer sequences and expected band sizes.

Pathogen	Forward Primer (5-3')	Reverse Primer (5-3')	Size (bp)
BRSV	GCAATGCTGCAGGACTAGGTATAAT	ACACTGTAATTGATGCCCCATTCT	124
Rotavirus	CAGTGGTTGATGCTCAAGATGGA	TCATTGTAATCATATTGAATACCCA	131
S. typhi	TGTGGTAAAGGAACTCGGTAAA	GACTTCCGATACCGGGATAATG	109
V. cholerae	CGCTTTATTGTTCGATGCGTTA	ACTCGGTTATCGTCAGTTTGG	121
E. coli	ATGAAAGCTGGCTACAGG	GGTTTATGCAGCAACGAGACG	256

Key results achieved so far

Data from the molecular analysis indicated that there were no positives identified for Rotavirus A, *Salmonella spp.* and *V. cholerae.* However, *E. coli* was detected (Figure 3.3.2) in 40% of chewing sponge and 60% of chewing stick samples (Figure 3.3.3). We could not detect any significant association between sample type and the presence of *E. coli* (Fisher's Exact test; p-value = 1.000). Expected band size was 256 bp. DL represents a 100 bp ladder; PC and NC are positive and negative controls, respectively. Samples TS003, TS004, CS002, CS004 and CS005 were positive.

Conclusion

Despite the advantages of chewing sticks and sponges, the detection of *E. coli* on samples is a cause for concern since they indicate faecal contamination and can cause diarrhoeal diseases.

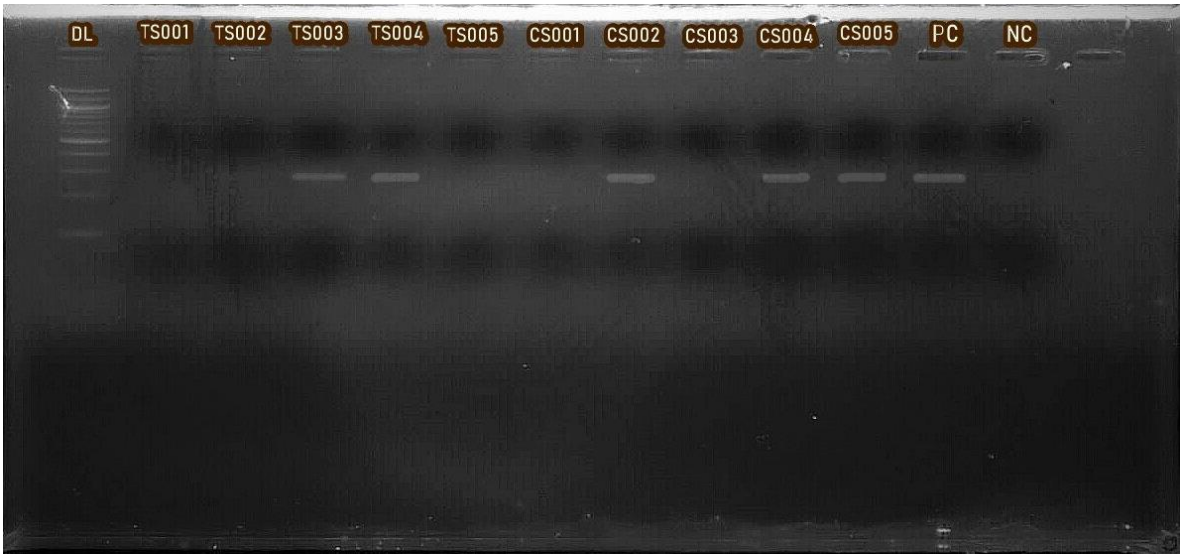


Figure 3.3.2: Agarose gel image showing amplification of *E. coli* target DNA.

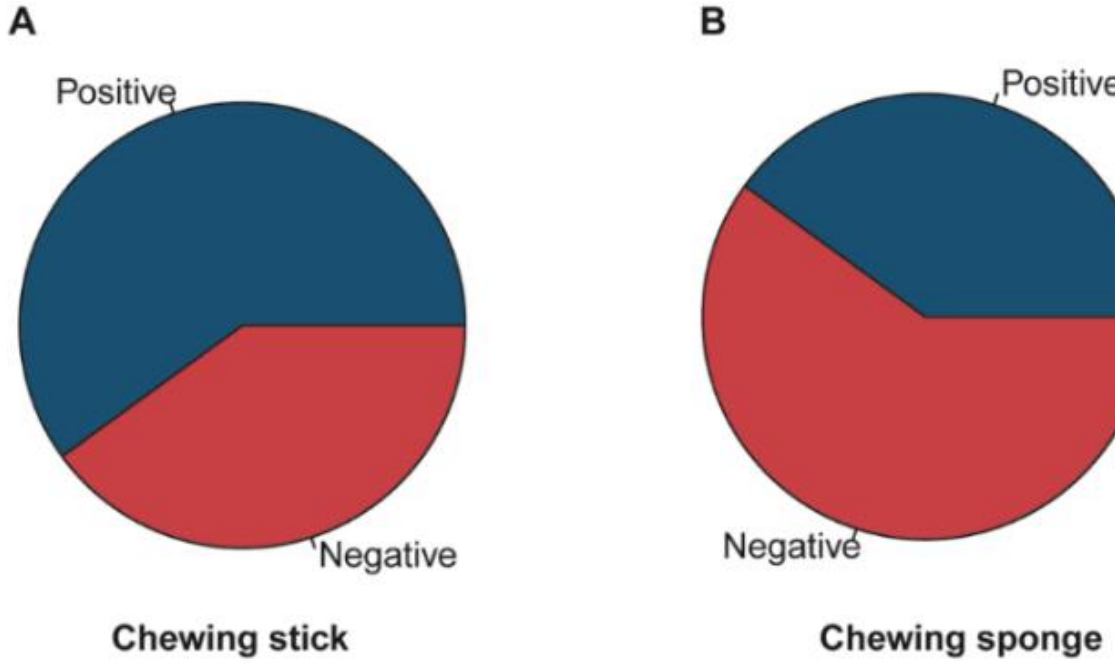


Figure 3.3.3: Positivity rates of *E. coli* among chewing stick and sponge samples screened.

Recommendation

It was recommended that chewing sticks and sponges should be washed clean before being used for oral health. In addition, there should be training of producers and retailers on improved hygienic packaging and handling of these essential cleaning agents.

Impact of the study on the national economy

Diarrhoeal diseases can have significant impact on the national economy due to low productivity rates of affected individuals. This study detects a potential cause of diarrhoeal diseases in Ghana, and recommends interventions. Implementing strategies to reduce the burden of diarrhoeal disease can help improve the overall output of the national economy.

3.3.1.3 Molecular Diagnosis of Pyrethroid Insecticide Knockdown Resistance Genotype in New Abirem-Ghana

(Research Team: Dr Samuel Armoo – Principal Investigator, Isaac Agyapong, Richard Malm, Abigail Buahin, Gideon Twieku, Nana Aso Amonoo, Prof. Mike Yaw Osei-Atweneboana)

Introduction

Malaria is a significant public health concern in Ghana and across Africa. One strategy used in controlling the malaria vector, the female Anopheles mosquito, is the use of insecticides. One of such potent insecticides are pyrethroids, which are capable of knocking down mosquitoes, thus reducing disease transmission significantly. In recent years, many studies have reported resistance in mosquitoes to this class of insecticides and thus pose significant hinderance to efforts geared towards eradication of malaria. This resistance is driven by mutations in the gene coding for sodium channels, and thus identification and understanding of such mutations are critical for assessing the presence and impact on pyrethroid resistance.

Objective

The objective was to screen for the presence of gene modifications in sodium channels that are responsible for pyrethroid insecticide resistance in mosquitoes.

Activities undertaken

Larvae of anopheles mosquitoes were sampled from mosquito breeding hotspots rain water puddles, water storage containers and shallow waters of the Pra and Mamang rivers (Figure 3.3.6). The larvae were cultured to adult mosquitoes according to WHO criteria (Figure 3.3.7). This was followed by sample processing of the adult mosquitoes, DNA extraction and genotyping of pyrethroid resistance.

Figure 3.3.6: Sampling for mosquito larvae at some lentic water points (A) Dip used for sample collection according to WHO criteria (B) Sampling at a rain water puddle (C) Sampling from a water storage container within the community.

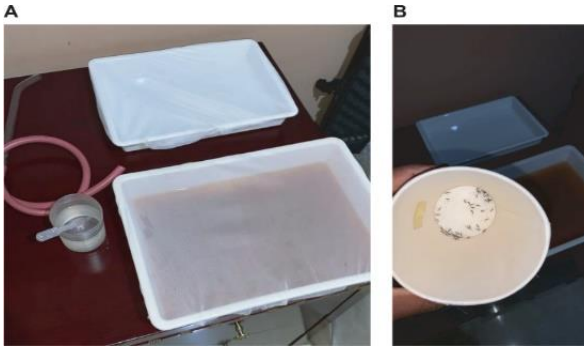


Figure 3.3.7: Laboratory culturing of mosquito larvae to adult stages (A) A tray containing water, with a net covering, used to keep larvae till they emerge as adults (B) A cup, with a net covering, used to contain emerged adult mosquitoes.

Key results achieved so far

A total of 271 samples were collected from the sampling sites and cultured into adult mosquitoes. All culex mosquitoes were excluded from the study leaving 86 anopheles mosquitoes for PCR genotyping. The PCR results were interpreted as follows: Pyrethroid insecticide resistant mosquito (195 base pairs), and pyrethroid insecticide susceptible mosquito (137 bp). Out of the anopheles mosquitoes used for genotyping, 94.2% were identified to have the pyrethroid insecticide resistance gene (Figure 3.3.8), indicating high resistance against the

knockdown effect of pyrethroids. This was higher than the expected 87% estimation by the WHO.

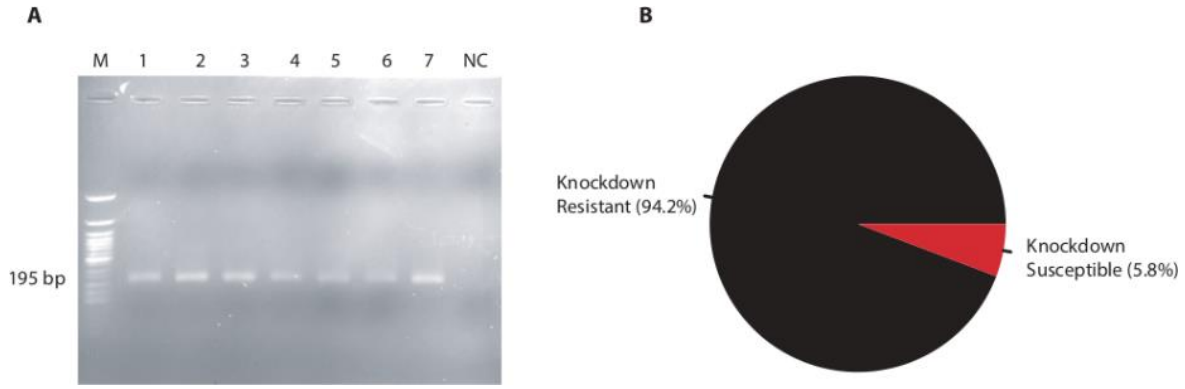


Figure 3.3.8: PCR genotyping of anopheles mosquitoes to determine their pyrethroid insecticide resistance profiles (A) An agarose gel image showing expected band size for genotyping. M is 50 base pair (bp) molecular weight marker, NC: negative control; and 1 to 7 are mosquito samples with band size of 195 (knockdown resistant) (B) A pie chart showing the distribution of knockdown resistant and susceptible Anopheles mosquitoes within the catchment area of the NGRL Akyem mine.

Conclusion

There was a high prevalence of pyrethroid insecticide resistance (94%) in the sample population which was higher than the 87% projection by the WHO. This high prevalence poses significant threat to efforts of malaria eradication in the country as insecticide usage is one of the key strategies for malaria vector control.

Recommendation

Given the high prevalence of pyrethroid insecticide resistance, it was recommended that an integrated approach to malaria vector control which includes regular surveillance of malaria vectors to identify their insecticide resistance profiles should be considered.

Impact of the study on the national economy

Significant efforts have been made towards eradication of malaria with strategies such as vaccination, use of insecticide treated nets and insecticide sprays. However, the high prevalence of pyrethroid resistance and the growing evidence of resistance from other studies pose significant challenges to these strategies which have been in place for malaria eradication. This further derails efforts in achieving the Sustainable Development Goal 3 (Good health and well-being) as malaria is a major public health concern which puts a lot of stress on the health of individuals in the country.

3.3.1.4 Assessment of the Application of Rodent Repellents by Fruit Sellers at the Agbogbloshie Market and Its Possible Health Implications

(Research Team: Dr Samuel Armoo – Principal Investigator, Stephanie Asante, Ian Peters, Gideon Twieku)

Introduction

Agbogbloshie market is a hub for the sale of fruits and vegetables both on wholesale and retail. Due to the nature of foodstuffs sold at the Agbogbloshie market and the poor drainage systems, the market is prone to rodent infestation. The management of rodent infestation and attacks involves a concerted approach which involves cleaning of the environment to prevent the growth and infestation of rodents, the use of biological and chemical control substances and

the use of physical control methods such as booby traps. In Ghana, these control strategies are used by individuals in varied combinations based on their needs and the type of rodent they seek to ward off. Despite the efficacy, chemical rodenticides and repellents have been reported to be poisonous when ingested, and thus must be used with caution.

Objective

The objective was to assess the usage of rodent repellents among fruit sellers at Agbogbloshie market.

Activities undertaken

Questionnaires consisting of a series of interactive open-ended and closed-ended questions were administered. The questionnaires focussed on collecting data on participant demographics, the type of fruit sold and their rodent repellent strategies. The data collected were collated using MS Excel and statistical analysis was performed using SPSS version 27 and R (version 4.0).

Key results achieved so far

A total of sixty adult women participated in the study with majority of them working in the market for over 10 years as shown in Table 3.3.2. Different fruits were sold by the participants (Figure 3.3.9) and the major causes of food losses were post-harvest loss and pest and rodent attacks (31%) (Figure 3.3.10 and Figure 3.3.11). This was consistent with participants reporting seeing rodents almost every day or at least once a week as shown in Table 3.3.3. Due to the high percentage of rodent attacks, fruits sellers employ several strategies to prevent rodent attacks. The use of rodenticides (52.1%) and fumigation of market stalls (35.4%) were the most common traditional methods used in warding off rodents and preventing attacks (Figure 3.3.12). The application of rodenticides was mainly using commercially available rodenticides sold under brand names such as Fast 10 and Super killer and by occasional government fumigation exercises (Figure 3.3.13). The study participants also reported the use of unconventional rodent repellents such as naphthalene balls and body powder (Figure 3.3.14). Interestingly, some of the study participants also reported the use of these rodenticides directly on the fruits (mostly body powder and “kokonte” powder) as shown in Table 3.3.3.

Conclusion

Rodent attacks pose significant economic losses to fruit sellers and as such, they resort to using different strategies to ward off rodents including the use of rodenticides and other unconventional substances such as body powder which is directly applied on fruits. Despite the use of various types of rodent repellent chemicals, no regulation is put in place to check whether they are used appropriately.

Recommendation

Frequent checks must be done by the Food and Drugs Authority (FDA) to evaluate the types and methods of application of the rodent and pest repellents used by fruit sellers in the market. Another recommendation will be frequent fumigation exercises conducted in the market by the government to ensure that only safe rodent repellents are used in the appropriate procedure to prevent the likelihood of exposure of fruits to harmful chemicals.

Impact of the study on the national economy

Fruits are consumed by a vast majority of the population with little treatment before consumption, as they are ready-to-eat foods. Chemicals like body powder which is applied directly on fruits such as watermelon can easily be washed off before consumption. However,

such substances are not supposed to be consumed and if proper washing is not performed, it could lead to possible ingestion which would result in illness. Moreover, rodents attack on fruits could lead to an outbreak of diseases including but not limited to zoonosis as rodents are potent reservoirs and vectors for the transmission of several infectious diseases.

Table 3.3.2: Participant demographics.

Variable	Frequency (n=60)	%
Level of Education		
Basic School	19	31.7
Junior High School	14	23.3
No formal education	26	43.3
Senior High School	1	1.7
Years Spent in the market		
Less than 1 year	1	1.7
1 - 5 years	6	10.0
5 – 10 years	14	23.3
More than 10 years	39	65.0

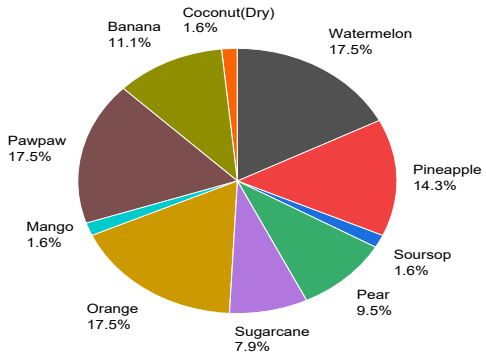


Figure 3.3.9: Graphical distribution of the different fruits sold by participants.

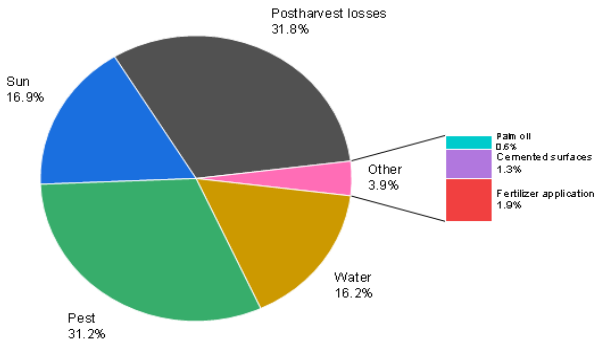


Figure 3.3.10: Reported causes of food loss by study participants.

Table 3.3.3: Rodent attacks and management.

Variable	Frequency (n=60)	%
Frequency of seeing rodents		
Every day	34	56.7
One to three times a week	26	43.3
Once a month	0	0
Never	0	0
Experiencing rodent attacks		
Yes	48	80
No	12	20
Use chemicals to deter rodents		
Yes	45	75
No	15	25
Application of rodenticides/repellents		
Floor/surrounding	35	58.3
Directly on the fruit	10	16.7
Do not apply rodenticides/repellents	15	25
Expectations from Government		
Frequent tidying of the market	2	
Provision of amenities (e.g., Bins)	2	
Frequent fumigation	10	

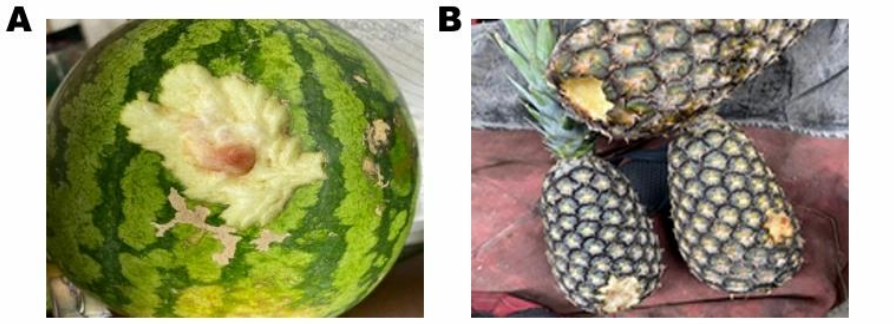


Figure 3.3.11: Fruits that have been attacked by rodents (A) Watermelon that has been attacked by a rodent (B) Pineapples that have been attacked by a rodent.

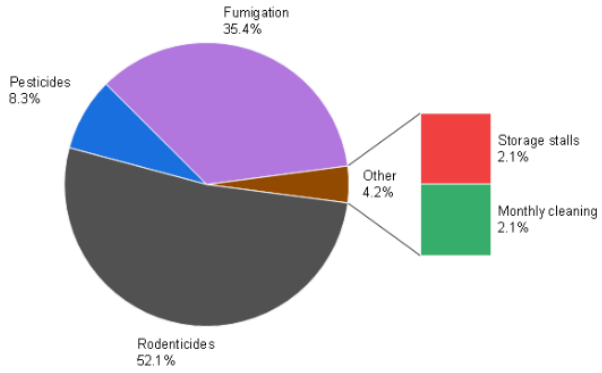


Figure 3.3.12: Distribution of participants responses on strategies used to prevent rodent attacks.

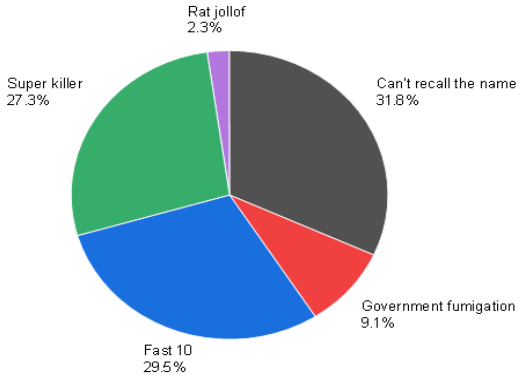


Figure 3.3.13: Distribution of types of rodenticides participants use.

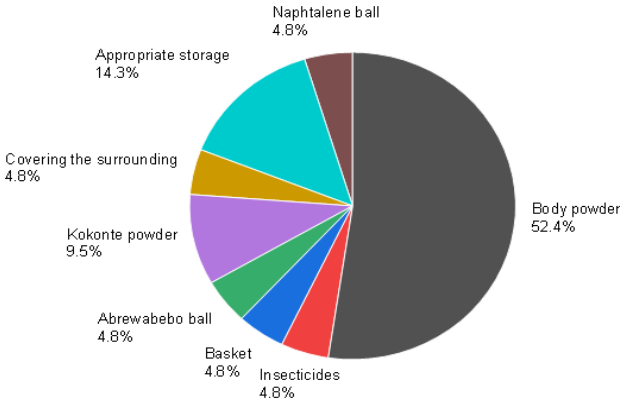


Figure 3.3.14: Other strategies used by vendors to repel rodents.

3.3.1.5 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: Emmanuel Odartei Armah – Principal Investigator, Dr. Lawrencia Osae-Nyarko, Mr. Isaac Ohene Agyapong, Mr. Kwame Mawutor Ahiabu, Mr. Bright Idun, Miss Freda Kwarteng, Miss Mohammed Naael)

Collaborating Agency: Foundation to Prevent Antimicrobial Resistance

Introduction

Antimicrobial resistance (AMR) continues to be a major setback to disease control worldwide. Elderly people are considered the main reservoirs of multidrug-resistant organisms (MDROs).

While AMR surveillance among the aged is extensively done in hospital settings, nursing homes have received little or no attention. The project team at the Biomedical and Public Health Research Unit (BPHRU) of the CSIR-Water Research Institute, undertook a surveillance of the prevalence of uropathogens and investigated the resistance pattern of genes amongst the aged living in Ghanaian care homes. The alarming rate of MDR recorded amongst the study populations highlighted the need for education. Therefore, the researchers embarked on an AMR awareness campaign at Tabitha Home Care, Pokuase. The project commenced in 2022 and is expected to end in 2025.

Objectives

The objectives were to:

i. determine the uropathogens prevalence and resistance pattern of genes among the elderly living in Ghanaian care homes; and
ii. educate and raise awareness on AMR among elderly living in Ghanaian care homes and their caregivers.

Activities undertaken

Sample collection*:* First morning urine samples were collected from 118 study participants, aged 55 to 99 years, in four different Care homes in Accra. The samples were transferred to the medical microbiology laboratory of the BPHRU of CSIR-WRI for analysis.

Laboratory analysis: Urine samples collected were subjected to Urinary Tract Infections (UTI) testing, Microbial culture and biochemical tests, antimicrobial susceptibility testing and extended-spectrum betalactamases genes (ESBLs) screening.

Awareness creation and education on AMR: The research team embarked on an AMR awareness campaign to educate the study participants as well as their health care professionals and home managers on ways to reduce the occurrence of AMR in these homes. The outreach was organized in Tabitha Home Care, Pokuase, and brought together 80 elderly persons from four different nursing homes. Facilitators spoke extensively on the indiscriminate use of antibiotics and over-the-counter medications, as well as maintenance of personal hygiene. Pictures of the research team with managers of Tabitha Home Care, some participants and the teaching session are shown in Figure 3.3.15.

Key results achieved so far

Extended-Spectrum Betalactamases (ESBLs) genes present in the samples were detected through the antimicrobial sensitivity testing and the molecular analysis. Feedback from the elderly people as well as discussions following the AMR education revealed that they had gained understanding on antimicrobial resistance and willingly agreed to adhere to sanitation practices so as to reduce the occurrence of UTI and its associated antimicrobial resistance. All health officers present indicated that they have gained an enhanced knowledge on AMR and would adhere to health delivery practices that would ensure the reduction of AMR occurrence.

Conclusion

UTIs are common among elderly people in nursing homes in Ghana. Majority of UTI isolates harbored resistance genes. AMR education and awareness campaign conducted helped to improve understanding on the impacts of the misuse of antibiotics among elderly people and staff of the Tabitha Home Care, Pokuase, leading to their decision to strictly adhere to practices that would ensure drastic reduction of the occurrence of AMR**.**

Recommendation

The research team recommends continual surveillance of AMR in nursing homes to enhance acquisition of more data to inform policy. Also, continual education and AMR awareness campaign should be carried out to reduce AMR occurrence.

a.

b.

c.

Figure 3.3.15: Some pictures from the study (a) Some of the study participants, (b) The PAR team with managers of Tabitha Home Care and (c) Teaching session.

Impact of the study on the national economy

AMR awareness campaigns as well as laboratory findings are necessary for educating the general populace and building capacities of healthcare professionals, policymakers, researchers etc. for research and policy decisions towards reduction in the burden of drug-resistant infections. Consequentially, reduction in these drug-resistant infections would result in a healthier population and reduction in healthcare cost, thereby improving the economy of the nation.

3.3.1.6 Strengthening the Ethics and Regulatory Capacity in Ghana (STREC – Ghana)

(Research Team: Prof. Mike Yaw Osei-Atweneboana – Principal Investigator, Miss Emefa Pamela Selormey, Mr. Zaid Haruna)

Collaborating Agencies: Council on Health Research for Development (COHRED) -Switzerland, Pharma-Ethics Health Research Ethics Committee - South Africa, Pharmalys-Senegal, Food and Drugs Authority-Ghana, EthiXPERT-Kenya

Introduction

Empirical studies to understand the regulatory and ethics situation in Ghana is limited. However, to conduct high-quality research, there is the need to strengthen the regulatory and ethics capacity and optimize research participants' projection. The project commenced in 2019 and is expected to end in 2024.

Objectives

The overall objective was to strengthen the regulatory and ethics capacities of Ghana. The specific objectives were to:

i. review the existing regulatory and ethics capacity situation in Ghana in order to identify key gaps that need to be addressed;
ii. establish a responsive research and ethics coordination system in the country with a view to strengthen the regulatory capacity and general ethics review system in the country;
iii. provide specialized and targeted-high level clinical trial review training to those involved in coordination, regulation and monitoring of clinical trials; and
iv. develop an efficient clinical trials portfolio by implementing a tested and proven online ethics review system in the ccountry.

Activities undertaken

Activities carried out during the year included the following:

i. RHInnO ethics software installation and training.
ii. IT capacity and infrastructural assessment of selected IRBs/IRECs.
iii. Installation of institutional and national RHInnO Ethics packages for selected IRBs/IRECs.
iv. Training IREC personnel on the use of the RHInnO ethics platform for selected IRBs/IRECs.
v. Training workshop on clinical trials and good clinical practices (GCP) for all IRBs/IRECs in the country.
vi. Standard Operating Procedures (SOP) development for ethics review committees.
vii. Advanced ethics, GCP and review of clinical trials training plan, including how the training is evaluated for all IRBs/IRECs in the country.

Key results achieved so far

Three (3) IRBs/IRECs which include the Council for Scientific and Industrial Research-Institutional Review Board (CSIR-IRB), University of Development Studies Institutional Review Board (UDS-IRB) and the University of Cape Coast Institutional Review Board (UCC-IRB) were selected to participate in the project. The signing of the user agreement was followed by the installation of the RHInnO Ethics platform for each of the IRECs with the CSIR-IRB designated with the national RHInnO ethics platform. To facilitate this process, an administrator's details form was sent to the three IRECs to allow them to identify the designated individuals from their institutions to coordinate the platform. A total of 52 IRB member's capacity was strengthened on how to review/evaluate complex clinical trials.

Conclusion

The internet interface reduced the manual effort of IRB administrators, reviewers, and applicants. The training courses gave participants excellent insights into the ethical concerns and obstacles related with research, including clinical trial research. The talks and case studies emphasized the need of respecting participants' rights, obtaining informed consent, supporting justice and fairness, and carrying out scientifically legitimate research. It also provided insight on the implications of past and contemporary ethical transgressions, as well as the necessity for stringent ethical norms to protect study subjects.

Recommendation

The following recommendations were given at the end of the reporting year:

i. Harmonize existing Standard Operating Procedures (SOPs) of the various Institutional Review Boards (IRBs)/Institutional Ethics Committees (IECs) in the country.
ii. Train other IRB/IEC members on how to review complex clinical trials.
iii. Establish the National Ethics Committee to regulate the activities of IRB/IEC in the country.

Impact of the study on the national economy

The RHInnO ethics platform has reduced the time required to process research protocols. This has allowed the board to approve more research protocols in a shorter amount of time, resulting in more income for the institution.

Furthermore, the initiative has effectively taught over 150 professionals on how to review complicated clinical trials and research projects. This has enhanced the human resource in research and clinical trial ethics review.

3.3.1.7 Reducing Microbial Load on Raw Vegetables Using Various Types of Vinegar and Different Concentrations of Potassium Permanganate ($MnKO_4$)

(Research Team: Mensah, George Tetteh – Principal Investigator: Brown, Charles; Adokwei, Lomo-Mainoo; Dorothy Naa Lomoley and Elorm, Richard Koku*)*

Collaborating Agencies: **School of Biomedical and Allied Health Sciences, Univ of Ghana, Korle Bu**

Introduction

Most vegetables are consumed raw, hence the need to ensure pathogen-free vegetable to the market to make their consumption a non-public health problem. To achieve this, a study which involves using vinegar (various types) and potassium permanganate to ensure parasite-free vegetables was undertaken.

Objective

The objective was to reduce microbial load on vegetables eaten raw, by using various concentrations of white vinegar, apple cidar vinegar and potassium permanganate.

Activities undertaken

Vegetables were bought from selected markets in Accra and processed for microbial load. The vegetables were then washed with varied concentration of white vinegar, apple cider vinegar and potassium permanganate. Thereafter, the vegetables were checked for the effect of these food additives on the microbial load.

Key results achieved so far

There was total elimination of the parasites when 10% or above of the reagents were used. For all the reagents used (Potassium permanganate, and various types of vinegar) the parasites were eliminated after the third washing with 10% concentration of each one of them. However, at 5% concentration about 60 % of the parasites were eliminated. From the results obtained, food vendors are advised to wash three times with at least 10% of the reagents followed by a fourth wash with potable water.

Conclusion

The study proved the effectiveness of vegetable disinfectants. A 10% concentration of white vinegar, apple cider vinegar and potassium permanganate were effective in eliminating microbes on raw vegetables.

Impact of the study on the national economy

The findings from the study could help reduce infections due to microbial contamination on these vegetables and associated infections due to their consumption. This could lead to increased man hours on the production line and enhanced financial status.

APPENDICES

APPENDIX I: Membership of the Management Board

1.	Mr. Anthony Boateng	Chairman
2.	Prof. Mike Y. Osei-Atweneboana	Member
3.	Ing. Dr. Worlanyo K. Siabi	Member
4.	Mr. Samuel K. Appenteng	Member
5.	Mr. Magnus Nunoo	Member
6.	Mrs. Genevieve Yankey	Member
7.	Ing. Dr. Daniel Asenso-Gyambibi	Member

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

1.	Prof. Mike Y. Osei-Atweneboana	Director (Chairman)
2.	Dr. Anthony Yaw Karikari	Deputy Director
3.	Dr. Emmanuel Obuobie	Head, Surface Water & Climate Change Division (SWCCD)
4.	Dr. George Tetteh Mensah	Head, Environmental Biology, Biotechnology & Health Division (EBB&HD)
5.	Dr. Elias Asuming-Brempong	Head, Biomedical and Public Health Research Unit (BPHRU)
6.	Dr. Collins Tay	Head, Environmental Chemistry and Sanitation Engineering Division (ECSED)
7.	Dr. Ruby Asmah	Head, Fishery and Aquaculture Division (FAD)
8.	Mr. Collins Okrah	Head, Groundwater & Geoscience Division (GWGD)
9.	Mr. Emmanuel Asiedu-Darko	Head, Administration Division (ADMIN.)
10.	Mrs. Doris Damoah	Acting Head, Finance Division (FD)
11.	Mr. Ebenezer Ofosu-Nkrumah	Acting Head, Commercialization Division (CD)
12.	Dr. Etornyo Agbeko	Officer-In-Charge, ARDEC – Akosombo
13.	Dr. Emmanuel Tetteh-Doku Mensah	Officer-In-Charge, ARDEC – Tamale
14.	Dr. William Wilson Anku	President, Research Staff Association (RSA) – Local
15.	Mr. Samuel Kanati	Rep. CSIR Administrators Association Ghana (CAAG)
16.	Mr. Evans Osei	Rep. Senior Staff Association (SSA)
17.	Mr. Francis A. Boakye	Chairman, Trade Union Congress (TUC) – Local
18.	Mrs. Rebecca Tekpertey	Administrative Officer (Secretary)

APPENDIX III: List of Senior Members and Senior Staff

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. (Mrs.) Ruby Asmah	Principal Research Scientist
4.	Dr. Collins Tay	Chief Research Scientist
5.	Dr. Kwadwo A. Asante	Principal Research Scientist
6.	Mr. Emmanuel Asiedu-Darko	Principal Administrative Officer
7.	Ing. (Dr.) Emmanuel Obuobie	Senior Research Scientist
8.	Ing. (Dr.) Frederick Y. Logah	Senior Research Scientist
9.	Mr. Collins Okrah	Senior Research Scientist
10.	Mr. Humphrey F. Darko	Senior Research Scientist
11.	Mr. Theodore Quarcoopome	Senior Research Scientist
12.	Mrs. Regina Banu	Senior Research Scientist
13.	Dr. Mark O. Akrong	Senior Research Scientist
14.	Dr. Michael Kumi	Senior Research Scientist
15.	Mrs. Sarah Penstil	Senior Research Scientist
16.	Dr. (Mrs.) Marian Amu-Mensah	Senior Research Scientist
17.	Dr. Samuel Armoo	Senior Research Scientist
18.	Dr. George T. Mensah	Senior Research Scientist
19.	Dr. Francis A. Assogba	Senior Research Scientist
20.	Ing. Dr. Deborah Darko	Senior Research Scientist
21.	Dr. Emmanuel Tetteh-Doku Mensah	Senior Research Scientist
22.	Dr. Agbeko Etornyo	Senior Research Scientist
23.	Dr. Seth K. Agyakwah	Research Scientist
24.	Dr. Elias Asuming-Brempong	Research Scientist
25.	Dr. Franklin Obiri-Nyarko	Research Scientist
26.	Mr. Patrick A. Mainoo	Research Scientist
27.	Mr. Gerard Quarcoo	Research Scientist
28.	Mr. Solomon A. Owiredu	Research Scientist
29.	Ms. Saada Mohammed	Research Scientist
30.	Mr. Evans Manu	Research Scientist
31.	Dr. (Mrs.) Rhoda Lims Diyie	Research Scientist
32.	Mr. Michael Dorleku	Research Scientist
33.	Mr. William E. Arko	Research Scientist

No.	Name	Designation
34.	Mrs. Zita Naangmenyele Abuntori	Research Scientist
35.	Mr. Edward J. Tettevi	Research Scientist
36.	Dr. (Mrs.) Ruth Ayanful-Torgby	Research Scientist
37.	Dr. Pennante N. A. Bruce-Vanderpuije	Research Scientist
38.	Dr. William W. Anku	Research Scientist
39.	Dr. Mariam Y. Ameveworwor	Research Scientist
40.	Dr. Frank Adu-Nti	Research Scientist
41.	Dr. Raymond Kojo Agbadzi	Research Scientist
42.	Dr. Yaw Adjei Anane	Research Scientist
43.	Dr. Prosper Bazaanah	Research Scientist
44.	Dr. Patrick S. K. Fatsi	Research Scientist
45.	Dr. Obed Fiifi Fynn	Research Scientist
46.	Dr. Emmanuel Koboja Magna	Research Scientist
47.	Dr. Lawrencia Kwarteng	Research Scientist
48.	Dr. Betty Oppong Bandoh	Research Scientist
49.	Dr. Akua Kyerewa Botwe	Research Scientist
50.	Dr. Appiah Ebenezer Koranteng	Research Scientist
51.	Dr. Sylvester A. Boadi	Research Scientist
52.	Dr. Jacob Agyekum	Research Scientist
53.	Dr. Sumabe Kasim Balagra	Research Scientist
54.	Mr. Kwabena O. Benson	Scientific Secretary
55.	Mr. Emmanuel O. Armah	Principal Technologist
56.	Ms. Ayesha A. Amadu	Principal Technologist
57.	Ing. Ralph Tagoe	Principal Technologist
58.	Mrs. Martha D. Agyemang	Principal Technologist
59.	Mrs. Sandra V. Asare	Principal Technologist
60.	Mrs. Lilly O. Konadu	Principal Technologist
61.	Mrs. Mercy Johnson-Ashun	Principal Technologist
62.	Ms. Hawa Ahmed	Principal Technologist
63.	Mr. Bismark A. Akurugu	Principal Technologist
64.	Ing. Gabriel Appiah	Principal Technologist
65.	Mr. Franz A. Gaisie-Essilfie	Principal Technologist
66.	Mr. Faisal A. Nuru-Ahmed	Principal Technologist
67.	Mr. Mark Osei-Owusu	Principal Technologist
68.	Mr. Jude O. Quansah	Principal Technologist
69.	Mr. Martin A. Adakpeya	Principal Technologist

No.	Name	Designation
70.	Mrs. Lady B. A. Adomako	Principal Technologist
71.	Mrs. Theodora L. E. Agbotui	Principal Technologist
72.	Mr. Haruna Zaid	Principal Technologist
73.	Mr. Divine W. Hotor	Principal Technologist
74.	Mr. Emmanuel Adu-Ofori	Principal Technologist
75.	Mr. Deryl N. O. Kuevi	Principal Technologist
76.	Dr. Nyamadi Akpene Aku	Principal Technologist
77.	Mr. Imoro Nfayem	Principal Technologist
78.	Mrs. Abigail N. Akuetteh	Principal Technologist
79.	Mr. Emmanuel K. Opoku	Principal Technologist
80.	Mr. Eugene Sintim Gyabaah	Principal Technologist
81.	Ms. Adelina Akuamoah Boateng	Principal Technologist
82.	Ing. Patricia Granaham	Principal Technologist
83.	Ing. Frank T. Oblim	Principal Technologist
84.	Mrs. Karyn Ewurama Quansah	Principal Technologist
85.	Nana Aso Amonoo	Principal Technologist
86.	Ms. Queenstar Dedei Quarshie	Principal Technologist
87.	Mr. Acheampong Addo	Principal Technologist
88.	Mrs. Dora D. Ocran	Principal Technologist
89.	Mr. Daniel K. Amoah	Principal Technologist
90.	Mr. Ebenezer Ofosu-Nkrumah	Marketing Officer
91.	Mr. Samuel Kanati	Administrative Officer
92.	Mrs. Rebecca Tekpertey	Administrative Officer
93.	Mrs. Lydia Kusi	Administrative Officer
94.	Mr. Victor Agyemang	Administrative Officer
95.	Ms. Sylvia Amponsah	Public Relations Officer
96.	Mrs. Doris Damoah	Accountant
97.	Mrs. Regina A. Atsu	Accountant
98.	Ms. Sem Shelipstics	Accountant
99.	Mr. Simon K. Anane	Estate Officer
100.	Mrs. Esther Mate-Ahmed	Accountant
101.	Ms. Salima Abdulai	Administrative Officer
102.	Ms. Clarissa Y. Nutsugah	Marketing 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.	Mr. Christopher Y. Nfojoh	Chief Technical Officer
4.	Mrs. Benedicta Osei-Tutu	Chief Administrative Assistant
5.	Ms. Millicent Adu-Boakye	Chief Technical Officer
6.	Mr. Samuel A. Antwi	Chief Auditing Assistant
7.	Mr. Francis A. Boakye	Chief Technical Officer (Systems Administrator)
8.	Mr. Ebenezer N. D. Koranteng	Chief Marketing Assistant
9.	Mrs. Priscilla Ampofo-Yeboah	Chief Administrative Assistant (Secretary)
10.	Mr. Serapis A. Asiedu	Chief Technical Officer
11.	Mr. Victor Nii Mante	Chief Technical Officer
12.	Mr. Michael D. Afram	Chief Technical Officer
13.	Ms. Yaa Asabea Agadzi	Chief Technical Officer
14.	Mr. Alex Yeboah	Chief Accounting Assistant
15.	Mr. Alfred A. Adjei	Chief Accounting Assistant
16.	Ms. Genevieve G. Kwogana	Chief Administrative Assistant (Secretary)
17.	Mr. Emmanuel M. Obeng Bekoe	Chief Technical Officer
18.	Mr. Serlom Borbor	Chief Technical Officer
19.	Ms. Murjanatu Abdul-Hamid	Chief Technical Officer
20.	Mr. Eric Y. Darko	Chief Technical Officer
21.	Ms. Esther A. Sowah	Chief Technical Officer
22.	Mrs. Dorothy Krodua	Chief Administrative Assistant (Secretary)
23.	Mr. Evans V. Osei	Chief Technical Officer
24.	Mrs. Cecilia Dwamena-Yeboah	Chief Administrative Assistant (Secretary)
25.	Ms. Joyceline Asare-Bediako	Chief Administrative Assistant
26.	Mr. Enoch Karbo	Chief Accounting Assistant
27.	Ms. Linda A. Nuamah	Principal Technical Officer
28.	Mr. Richard K. Kwapong	Principal Assistant Printer
29.	Mrs. Matilda A. Asinor	Principal Accounting Assistant
30.	Mr. Ebenezer D. Mensah	Principal Works Superintendent
31.	Ms. Joyce O. Appiah	Principal Administrative Assistant
32.	Ms. Doris Derpog Nyime-Baare	Principal Administrative Assistant
33.	Mr. Bright K. Idun	Principal Technical Officer
34.	Mr. Richard Kuddy	Principal Technical Officer
35.	Mr. Lawson Maxi-Millian Abaah	Principal Technical Officer
36.	Mr. Fredrick Sakyi	Principal Stores Superintendent
37.	Mr. Isaac Kwarteng	Senior Works Superintendent
38.	Mr. John K. Mensah	Senior Stores Superintendent
39.	Mr. Lawrence Yawson	Senior Technical Officer
40.	Ms. Naa Adjeley Kuma	Senior Technical Officer
41.	Mr. Isaac Agyepong	Technical Officer
42.	Mr. Kwame Mawutor Ahiabu	Technical Officer
43.	Mr. Bright Selorm Amedorme	Technical Officer
44.	Mr. Manfred Dakorah Asiedu	Technical Officer
45.	Mr. Michael Mawuenyiga Agbeti	Technical Officer
46.	Mr. Kwame Anim Afriyie	Technical Officer
47.	Ms. Freda Kwarteng	Technical Officer
48.	Mr. Felix J. Ofosu	Technical Officer

No.	Name	Designation
49.	Mr. Abdul-Rahaman Mohammed-Sadat	Technical Officer
50.	Ms. Dorothy Lomo-Mainoo	Technical Officer
51.	Ms. Getrude Nortey	Technical Officer
52.	Ms. Deborah Adjei	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.	Mr. Benjamin Boakye Tenkorang	Purchasing Assistant
60.	Mr. Joshua Ferguson	Administrative Assistant
61.	Nana Afua O. Boateng	Administrative Assistant
62.	Ms. Nawal Moro Buri	Technical Officer
63.	Mr. Mario Chrisk	Technical Officer
64.	Mr. Samuel Birikorang	Technical Officer
65.	Mr. Evans Tarko Dankwa	Technical Officer
66.	Mr. Innocent Kwakugah	Accounting Assistant
67.	Mr. Paa Kobina Sagoe Gyapong	Accounting Assistant
68.	Mr. Thompson G. Nyamesah	Technical Officer
69.	Mr. Issahaku Tofic	Technical Officer
70.	Ms. Eunice Nyarko Darko	Accounting Assistant
71.	Ms. Rejoice Darkey	Marketing Assistant
72.	Mr. Samuel Kwadwo Debrah	Technical Officer
73.	Mr. Kelvin Kweku Donkor	Technical Officer
74.	Ms. Amanda Maasoyuor Karbo	Administrative Assistant
75.	Ms. Grace Kwaku-Anim	Technical Officer
76.	Ms. Joyce Kplorla Kusorgbor	Technical Officer
77.	Mr. Joel John Otchere-Baffour	Technical Officer
78.	Ms. Abena Konadu Owusu-Senya	Technical Officer
79.	Ms. Abigail Sefah	Marketing Assistant
80.	Mr. Gideon Twieku	Technical Officer
81.	Mr. Frank Twumasi Oppong	Technical Officer
82.	Mrs. Doretta Enyonam Aboagye-Debrah	Purchasing Assistant
83.	Ms. Victoria Lilian Sackey	Administrative Assistant
84.	Ms. Abigail Dede Ometse Quaynor	Administrative Assistant
85.	Ms. Cindy Xolali Anane	Technical Officer
86.	Mr. Frank Goka	Security Officer
87.	Mr. Issah Hamidu	Security Officer
88.	Mr. Charles S. Bonful	Security Officer
89.	Mr. Kassim B. Seidu	Security Officer
90.	Mr. Jones Ofori	Security Officer
91.	Mr. Anthony K. Morkeh	Security Officer
92.	Mr. Mike Ben Niekye	Security Officer
93.	Mrs. Doris Obeng Bekoe	Front Desk Officer
94.	Mr. Alexander Siaw	Works Superintendent
95.	Mr. Mario Danban Kugre	Technical Officer
96.	Ms. Linda Brako	Administrative Assistant
97.	Ms. Amegazo Millicent Mansa	Technical Assistant (Catering)

Staff Distribution among the Divisions and Sections

Division/ Section	Senior Members	Senior Staff	Junior Staff	Total
Directorate	2	-	-	2
Commercialization	4	8	1	13
Surface and Climate Change	12	1	-	13
Ground Water and Geoscience	9	5	-	14
Environmental Chemistry and Sanitation Engineering	16	13	-	29
Environmental Biology, Biotechnology & Health	8	9	-	17
Biomedical and Public Health Research Unit	20	10	2	32
Fishery and Aquaculture	19	7	9	35
Finance	4	13	-	17
Audit Unit	-	2	-	2
Administration				
• Personnel Section	6	17	1	24
• Transport/Mechanic Workshop Section	-	4	5	9
• Estate Section	1	1	13	15
• Security Section	-	7	12	19
Total	101	97	43	241
Contract Appointment				
• Directorate	1	1	-	2
• CSIR College of Science and Technology (CCST)	1	-	-	1
• Fishery and Aquaculture Division	-	-	5	5
• Administration Division (Estate)	-	-	3	3
• CSIR-WRI	1	-	-	1
Total	3	1	8	12
Overall Total	104	98	51	253

APPENDIX IV: Human Resource Activities

Post Retirement Contract Appointment /Contract Appointment

No.	Name	Designation	Staff Category	Division	Effective Date
1.	Prof. Joseph A. Ampofo	Chief Research Scientist	Senior Member	CSIR-WRI	31-Dec.- 2023 to 30 Dec.-2025
2.	Ms. Grace Narh	Labourer	Junior Staff	FAD	01-Feb.-2024 to 31 Jan.-2025
3.	Mr. Enoch Ahadzi	Labourer	Junior Staff	FAD	01-Feb.-2024 to 31 Jan.-2025
4.	Mr. Mohammed Sani	Labourer	Junior Staff	FAD	01-Feb.-2024 to 31 Jan.-2025
5.	Mr. Owiredu Darkwah	Labourer	Junior Staff	FAD	01-Feb.-2024 to 31 Jan.-2025
6.	Mr. Stephen Amanor Tetteh	Farm Hand	Junior Staff	FAD	01-Feb.-2024 to 31 Jan.-2025
7.	Mr. Samuel Annang	Driver	Senior Staff	Admin	02 Apr.-2024 to 31 Mar.-2025
8.	Ms. Sogloba Disayikom	Cleaner	Junior Staff	Estate	10 Jan.-2024 to 9 Jan.-2025
9.	Mr. Eric Kresti	Technical Officer	Senior Staff	FAD	02 Apr.-2024 to 30 Sept. 2024
10.	Mr. Joseph Daani	Gardener	Junior Staff	Estate	01 Nov.-2023 to 31 Oct.-2024
11.	Ms. Abigail Adobea	Cleaner	Junior Staff	Estate	01 Nov.-2023 to 31 Oct.-2024

Promotion/Upgrading

Senior Members

No.	Name	Division/ Section	From	To	Effective Date of Promotion/ Upgrading
1.	Dr. Ing. Frederick Logah	SWCCD	Senior Research Scientist (Non-PhD)	Senior Research Scientist (PhD)	01-Nov.-2022
2.	Dr. Mark Osa Akrong	EBBHD	Senior Research Scientist (Non-PhD)	Senior Research Scientist (PhD)	01- Mar.- 2023
3.	Dr. Balagra Kasim Sumabe	BPHRU	Principal Technologist	Research Scientist	15 - June - 2023
4.	Dr. Jacob Agyekum	SWCCD	Principal Technologist	Research Scientist	01- Mar.- 2023
5.	Mr. Daniel K Amoah	ECSED	Principal Technical Officer	Principal Technologist	01- Mar.- 2023
6.	Ms. Clarissa Y. Nutsugah	CD	Senior Marketing Assistant	Marketing Officer	23-Oct. - 2022
7.	Mrs. Dora D. Ocran	CD	Principal Library Assistant	Principal Technologist	14- Dec. - 2022
8.	Ms. Salima Abdulai	Admin.	Principal Administrative Assistant	Administrative Officer	31- Mar. - 2022
9.	Mrs. Esther Mate-Ahmed	FD	Chief Accounting Assistant	Accountant	31- Mar. - 2022

Senior Staff

No.	Name	Division	Previous Designation	Current Designation	Effective Date
1.	Ms. Joyceline Asare-Bediako	Admin.	Principal Administrative Assistant	Chief Administrative Assistant	01-Jan.-2023
2.	Mrs. Cecilia Dwamena-Yeboah	Admin.	Principal Administrative Assistant	Chief Administrative Assistant	01-Jan.-2023
3.	Ms. Rachel Agyemang	BPHRU	Technical Officer	Senior Technical Officer	01-Jan.-2023
4	Naa Adjeley Kuma	BPHRU	Technical Officer	Senior Technical Officer	01-Jan.-2023
5	Mr. Evans Osei	CD	Principal Technical Officer	Chief Technical Officer	01-Jan.-2023
6	Ms. Esther Anyeley Sowah	ECSED	Principal Technical Officer	Chief Technical Officer	01-Jan.-2023
7	Ms. Freda Kwarteng-Boampong	BPHRU	Senior Technical Assistant	Technical Officer	21-June-2022
8	Ms. Linda Brako	Admin.	Senior Clerk	Administrative Assistant	01-Sept.-2022
9	Ms. Doris D. Nyimebaare	Admin.	Administrative Assistant	Principal Administrative Assistant	09-Nov.-2022
10	Ms. Millient Amegazo	Admin.	Catering Assistant	Technical Officer (Catering)	01-Jan.-2016

Transfer

No	Name	Designation	Category of Staff	Division/ Section	From	To	Date
1.	Mr. Enoch Karbo	Chief Accounting Assistant	Senior Staff	Finance	CSIR-ARI	CSIR-WRI (Tamale)	01-May-2023
2.	Ms. Lilian Victoria Sackey	Admin. Assistant	Senior Staff	Admin.	CSIR-WRI (Accra)	CSIR-WRI (Akosombo)	01-Jan -2023
3.	Mr. Benjamin Ashaley Quaye	Chief Auditing Assistant	Senior Staff	Finance	CSIR-FRI	CSIR-WRI	06-Feb.-2023
4.	Mr. Emmanuel Asiedu-Darko	Senior Admin. Officer	Senior Member	Admin.	CSIR-PGRRI	CSIR-WRI	01-Jan.-2023
5.	Mr. Patrick Kofi Fatsi	Research Scientist	Senior Member	F&A	CSIR-WRI (Accra)	CSIR-WRI (Akosombo)	03-Jul. -2023
6.	Mr. Emmanuel K. Magna	Research Scientist	Senior Member	F&A	CSIR-WRI (Akosombo)	CSIR-WRI (Tamale)	01-Nov. -2023

Compulsory Retirement

No.	Name	Designation	Category of Staff	Division/Section	Effective Date of Retirement
1.	Dr. Gloria N. D. Addico	Principal Research Scientist	Senior Member	EBB&HD	03-Apr.-2023
2.	Mrs. Patience D. K. Atsakpo	Chief Technologist	Senior Member	ECSED	27-Apr.-2023
3.	Mrs. Claudia Bentum	Administrative Officer	Senior Member	Admin.	19-Jan.-2023
4.	Dr. Anthony Y. Karikari	Deputy Director - Chief Research Scientist	Senior Member	Directorate	15-Sept.-2023
5.	Mr. Oswald K. Nyimebaare	Principal Accountant	Senior Member	Finance	24-Jan.-2023
6.	Mr. Godwin Amegbe	Principal Technical Officer	Senior Staff	EBB&HD	19-Oct.-2023
7.	Mr. Anthony Arko	Senior Security Officer	Senior Staff	Admin. (Security)	03-Jul.-2023
8.	Mr. Edem. K. Ayegbe	Principal Works Superintendent	Senior Staff	Admin. (Transport)	23-Nov.-2023
9.	Mr. Emmanuel Owusu Ayim	Security Officer	Senior Staff	Admin. (Security)	17-Jul.-2023
10.	Mr. Cephas Dzah	Security Officer	Senior Staff	Admin. (Security)	05-Dec.-2023
11.	Ms. Joycelin J. Osibo	Chief Library Assistant	Senior Staff	CD	07-Dec.-2023
12.	Mr. Samuel A. Antwi	Chief Auditing Assistant	Senior Staff	Finance	04-Feb.-2023
13.	Mr. Lawrence A. K. Seshie	Senior Security Assistant	Junior Staff	Admin. (Security)	16-Mar.-2023

Resignation

No.	Name	Designation	Category of Staff	Division/Section	Effective Date
1.	Mr. Mark Ofori Boateng	Accountant	Senior Member	Finance	01-July-2023
2.	Mr. Isaac Owusu-Frimpong	Principal Technologist	Senior Member	BPHRU	21-Aug.-2023

APPENDIX V: Human Resource Development - Staff Pursuing Various Courses – 2023

No.	Name of Officer	Designation	Training Required	Division/ Section	Date Started	Programme Duration	Expected Date for Completion	Full Time/ Weekend	Status
1.	Michael Dorleku	Research Scientist	PhD. Analytical Chemistry (UCC)	ECSED	Aug, 2019	3 years	Aug, 2023	Local (Full-Time)	Ongoing
2.	Gerard Quarcoo	Research Scientist	PhD. Microbiology (KNUST)	EBB&HD	Aug, 2018	4 years	Aug, 2022	Local (Full-Time)	Extended
3.	Saada Mohammed	Research Scientist	PhD. Environment and Health (Vrije Universiteit, Amsterdam)	ECSED	Sept, 2017	4 years	Aug, 2021	Foreign (Full time)	Yet to submit completion report and Certificate
4.	Regina Banu	Research Scientist	PhD. Environmental Sanitation and Waste Management (KNUST)	EBB&HD	Sept, 2017	4 years	Sept, 2021	Local (Full-Time)	Ongoing
5.	Ayesha Algade Amadu	Principal Technologist	PhD. Environmental Science and Engineering (Nanjing Univ. of Science and Technology, China)	EBB&HD	Aug, 2018	4 years	Aug, 2022	Foreign (Full time)	Extended
6.	Lady Asantewah Boamah Adomako	Principal Technologist	PhD. Medical Microbiology (Univ. of Ghana Legon)	EBB&HD	Jan, 2023	4 years	Jan, 2025	Local (Full-Time)	Ongoing
7.	Ayishetu Wortey	Senior Clerk	BBA Human Resource Management (Methodist Univ. College Ghana)	ADMIN.	Aug, 2019	4years	Aug, 2023	(Local) Weekend	Yet to submit completion report and Certificate
8.	Bismark Awinbire Akurugu	Principal Technologist	PhD. Earth Science (Univ. of Ghana)	GWGD	Aug, 2019	4years	Aug, 2023	Local (Full-Time)	Ongoing
9.	Mark Osei Owusu	Principal Technologist	PhD. Water Resources Engineering Management (KNUST)	SWCCD	Sept, 2019	4years	Aug, 2023	Local (Full-Time)	Ongoing
10.	Mohammed Bello Mustapha	Chief Technical Officer	MPhil. Sanitation Studies (Univ. of Ghana)	EBB&HD	Jan, 2021	2years	Aug, 2023	Local (Full-Time)	Ongoing

11.	Serapis Asiedu Appiah	Chief Technical Officer	MPhil Environmental Science (Sanitation and Engineering)	ECSED	Nov, 2021	2years	Nov, 2023	Local (Full-Time)	Ongoing
12.	Yaa Asabea Agadzi	Principal Technical Officer	MPhil. Aquaculture (CCST)	FAD	Oct, 2020	2years	Oct, 2022	Local (Full-Time)	Ongoing
13.	Franz Alex Gaise Essilfie	Principal Technologist	PhD. Climate Change and Land Use (KNUST)	SWCCD	Sept, 2019	4years	Sept, 2023	Local (Full-Time)	Ongoing
14.	William Ekow Arko	Research Scientist	PhD. Environmental Engineering (China Univ. of Geosciences, Wuhan)	ECSED	Sept, 2019	4years	Sept, 2023	Foreign (Full-Time)	Ongoing
15.	Patrick A. Mainoo	Research Scientist	PhD. Geophysics (KNUST)	GWGD	Sept, 2019	4years	Sept, 2023	Local (Full-Time)	Extended
16.	Victor Mante	Chief Technical Officer	MSc. Water Supply and Environment Sanitation (KNUST)	ECSED	Jan, 2023	2years	Jan, 2025	Local (Full-Time)	Ongoing
17.	Selorm Borbor	Principal Technical Officer	MPhil. Microbiology (Univ. of Ghana)	EBB&HD	Jan, 2023	2years	Jan, 2025	Local (Full-Time)	Ongoing
18.	Gertrude Nortey	Technical Officer	MPhil. Environmental Science (Univ. of Ghana)	EBB&HD	Jan, 2023	2years	Jan, 2025	Local (Full-Time)	Ongoing
19.	Sadat Abdul Rahman	Technical Officer	MPhil. Statistics: Biostatistics and Data Analysis (Univ. of Ghana)	BPHRU	Jan, 2023	2years	Jan, 2025	Local (Full-Time)	Ongoing
20.	Samuel Kanati	Administrative Officer	Charted Institute of Human Resource Management (IHRMP)	Admin	Jan, 2023	2years	Jan, 2025	Weekend	Ongoing
21.	Simon Kwesi Anane	Estate Officer	Professional Training and Quantity Surveying (GHIS)	Admin (Estate)	May, 2022	1 year	May, 2023	Part Time	Ongoing
22.	Dorothy Lomo-Mainoo	Technical Officer	MPhil. Applied Parasitology (Univ. of Ghana)	EBB&HD	Jan, 2022	2years	Jan, 2024	Local (Full-Time)	Ongoing
23.	Faisal A. Nuru	Principal Technologist	PhD. Applied Health Sciences (Univ. of Aberdeen, UK)	BPHRU	March, 2022	3years	March, 2024	Foreign (Full-Time)	Ongoing

24.	Michael Kumi	Senior Research Scientist	PhD. Chemistry (Univ. of Johannesburg, South Africa)	ECSED	Jan, 2020	4years	Jan, 2024	Foreign (Full-Time)	Ongoing
25.	Emmanuel Odartei Armah	Principal Technologist	PhD. Microbiology (Univ. of Ghana)	BPHRU	Jan, 2023	4years	Jan, 2027	Local (Full-Time)	Ongoing
26.	Solomon Amoah Owiredu	Research Scientist	PhD. Fisheries Oceanography	FAD	Sep, 2019	4years	Sept, 2023	Foreign (Full-Time)	Ongoing
27.	Hawa Ahmed	Principal Technologist	PhD. Biomedical Science	EBB&HD	Oct, 2023	4years	Oct, 2027	Foreign (Full-Time)	Ongoing
28.	Mr. Evans Manu	Research Scientist	PhD Earth Science	GWGD	Aug, 2016	4years		Foreign (Full-Time)	Ongoing
29.	Benedicta Osei-Tutu	Chief Administrative Assistant	MBA. Human Resource Management (Methodist Univ. Ghana)	Admin	August, 2023	2 years	Aug, 2025	Local (Weekend)	Ongoing
30.	Mrs. Priscilla Ampofo-Yeboah	Chief Administrative Assistant	MBA. Human Resource Management (Central University)	Admin	Oct, 2023	2 years	Oct, 2025	Local (Weekend)	Ongoing
31.	Joyce K. Kusorgbor	Technical Officer	MPhil. Aquaculture (CCST)	FAD	Oct, 2022	2 years	Oct, 2024	Full time (yet to submit Study Leave and Bond form)	Ongoing
32.	Mr. Ayarika Awalikake Felix	Technical Assistant	BSc. Agriculture (KNUST)	FAD (ARDEC)	January, 2023	2 years	Jan, 2025	Local (Weekend)	Ongoing
33.	Mr. Benjamin Tenkorang Boakye	Purchasing Assistant	MBA Accounting and Finance (UPSA)	Finance	September, 2023	2 years	Sept, 2025	Local (Weekend)	Ongoing
34.	Gideon Tweiku	Technical Officer	MPhil Molecular Medicine (KNUST)	BPHRU	January, 2023	2 years	Jan, 2025	Local (Full time)	Ongoing
35.	Zita Naangmenyele Abuntori	Research Scientist	PhD. Irrigation and Drainage Engineering (UDS)	ECSED (Tamale)	Nov, 2020	3 years	Nov, 2023	Local (Full time)	Extended

APPENDIX VI: National Service and Industrial Attachment

National Service Personnel Posted to the Institute in 2023

No.	Name	Institution	Programme	Division
1	Quartey Deborah	Accra Technical University	HND Secretaryship and Management Studies	Admin.
2	Gagadosu Grace	Knutsford University College	BSc. Business Administration (Human Resource Management)	Admin.
3	Osei Valerie Obuobi	University of Professional Studies	BSc. Public Relations Management	Admin.
4	Ruth Zoumanigui	University of Professional Studies	BSc. Business Administration	Admin.
5	Frederick Agyemang	UG	BSc. Administration	FD
6	Siaw Krodua Freda	Pentecost University College	BSc. Logistics and Supply Chain Management	FD
7	Zakari Mansur	KNUST	BSc. Telecommunication Engineering	CD
8.	Addo Dufie	UG	BSc. Biological Sciences (Marine Science)	FAD
9.	Zamba-Zamba Hamidat	UG	BSc. Biological Sciences (Marine Science)	FAD
10.	Winston Kevin Oskan	UG	BSc. Biological Sciences (Marine Science)	FAD
11.	Dunyoh Phebe Selassie	KNUST	BSc. Aquaculture and Water Resources Management	FAD
12.	Twum Hillary Afia Benewaa	UG	BSc. Biological Sciences (Marine Science)	FAD
13.	Tetteh Zakiya Abdalla	UG	BSc. Biological Sciences (Marine Science)	FAD

14.	Ayertey Nora Naa Dede	UDS	BSc. Renewable Natural Resources	FAD
15.	Munta Mahdi	UG	BSc. Biological Sciences (Marine Science)	FAD
16.	Siaw Irene Narkwor	UG	BSc. Biological Sciences (Marine Science)	FAD
17.	Appiah Michael Osei	UG	BSc. Biological Sciences (Marine Science)	FAD
18.	Owusu Bempah Kevin	KNUST	BSc. Natural Resources Management	FAD
19.	Iddrisu Suhaila	UG	BSc. Family & Consumer Sciences (Family & Child Studies)	BPHRU
20.	Gyan Anthony Akuffo	UG	BSc. Biological Sciences (Animal Biology with Biochemistry)	BPHRU
21.	Serwaa Charity	UHAS	BSc. Medical Biochemistry and Molecular Biology	BPHRU
22.	Agbesi Woetsa Francisca	UDS	BSc. Biochemistry	BPHRU
23.	Teye Obed Nartey	KNUST	BSc. Biochemistry	BPHRU
24.	Sidney Alando	UG	Biomedical Engineering	BPHRU
25.	Aminu Huzaima	UDS	BSc. Biotech and Molecular Biology	BPHRU
26.	Iddrisu Humulhaira	KNUST	BA. Geography and Rural Development	SWCCD
27.	Mattey Kingsley Sedomfia	UEW	BA Geography Education	SWCCD
28.	Teyekpiti Solomon	Accra Technical University	HND Civil Engineering	SWCCD
29.	Commey Jeffery Nii Armah	Koforidua Technical University	HND Civil Engineering	SWCCD
30.	Amartey Michael Tetteh	Accra Technical University	BTech. Civil Engineering	SWCCD

31.	Boafo Shadrack Kwaku	Accra Technical University	HND. Science Laboratory Technology	EBB&HD
32.	Owusu Tertia	Accra Technical University	HND. Science Laboratory Technology	EBB&HD
33.	Tekpor Jude Kofi	KNUST	BSc. Environment Science	EBB&HD
34.	Mawusi Edmund	UG	BSc. Biological Sciences	EBB&HD
35.	Bribi Banister Yaw Dela	UG	BSc. Biological Sciences	EBB&HD
36.	Baddoo Peter Nii Apai	UG	BSc. Biological Sciences (Animal Biology & Conservation Science with Biochemistry)	EBB&HD
37.	Toxla Irene Esinam	UG	BSc. Biological Sciences (Biology)	EBB&HD
38.	Inusah Abdul Hamid	UDS	BSc. Environmental Science	EBB&HD
39.	Christian Ansah Anaafi-Kwapong	UG	Biochemistry and Plant Biology	EBB&HD
40.	Sumala-Ang Belinda	Accra Technical University	HND. Science Laboratory Technology	EBB&HD
41.	Edith Atakora	KNUST	BSc. Chemical Engineering	ECSED
42.	Ebate Alexander	Accra Technical University	HND. Science Laboratory Technology	ECSED
43.	Odonkor-Teye Lilian	KNUST	BSc. Chemical Engineering	ECSED
44.	Elizabeth Afoley Mensah	Accra Technical University	HND. Science Laboratory Technology	ECSED
45.	Forson George Acquah	Accra Technical University	HND. Science Laboratory Technology	ECSED
46.	Bamfo Kwabena Ntiri	KNUST	BSc. Chemical Engineering	ECSED

47.	Doe Godwin Kofi	UCC	BSc. Chemistry	ECSED
48.	Alberta Safoa Gyamfi	KNUST	BSc. Chemistry	ECSED
49.	Tetteh Agnes	Takoradi Technical University	HND. Science Laboratory Technology	ECSED
50.	Tetteh Rachael	Koforidua Technical University	HND. Environmental Chemistry	ECSED
51.	Tetteh Docea Nueki	Accra Technical University	HND. Science Laboratory Technology	ECSED
52.	Glenys Cofie	UCC	BSc. Laboratory Technology	ECSED
53.	Erasmus Gyau Asare	UCC	BSc. Laboratory Technology	ECSED
54.	Amuzu Peter	KNUST	BSc. Geological Engineering	GWGD
55.	Borti Pearl	KNUST	BSc. Physics	GWGD
56.	Adjabeng Philip Asane	UG	BSc. Earth Science	GWGD
57.	Osei Kwakye Beulah	UG	BSc. Earth Sciences	GWGD
58.	Sowah Samuel Laryea	UG	BSc. Earth Sciences	GWGD
59.	Padi Andrew	UG	BSc. Earth Sciences	GWGD
60	Bodu Karim	UDS	BSc. Applied Physics	GWGD

Attachment Personnel Posted to the Institute in 2023

No.	Name	Institution	Programme	Division
1.	Biney Esuon Esi	KNUST	PhD Water Resource Management	SWCCD
2.	Nkansah John Boateng	KNUST	PhD Environmental Sanitation and Waste Management	ECSED
3.	Nana Ama Ohene Kumi	Univ. of Ghana	BSc. Plant and Environment	EBB&HD
4.	Emmanuel Kofi Nyame	Univ. of Ghana	BSc. Biological Science	EBB&HD
5.	Samuel Kwadwo Acheampong	Univ. of Ghana	BSc. Biological Science	EBB&HD
6.	Adu-Akyea Kofi	Univ. of Ghana	BSc. Biological Science (Biological Science)	EBB&HD
7.	Zegbla, Prisca Akpene Afi	Univ. of Ghana	BSc. Biological Science	EBB&HD
8	Eva Adjoa Agyepomaa Addo	Univ. College of Agriculture and Environmental Studies	BSc. Environmental Science and Management	EBB&HD
9.	Pappoe Gregory Nii Adotey	Accra Technical Univ.	B. Tech. Science Laboratory	ECSED
10.	Grace Debrah	UCC	BSc. Molecular Biology and Biotechnology	BPHRU
11.	Prince John Darkey	Univ. of Ghana	BSc. Marine and Fisheries Sciences	FAD
12.	Anna Amoakoa Appiah	Univ. College of Agriculture and Environmental Studies	BSc. Environmental Science and Management	EBB&HD
13.	Charity Agyeiwaa Asomani	UPSA	BSc. Business Administration	Admin.
14.	Ivy Kabuki Ocansay	UPSA	BSc. Business Administration	Admin.
15.	Nana Ama Ohene Kumi	Univ. of Ghana	BSc. Plant and Environmental Biology	EBB&HD
16.	Antwi Erica Maame Serwaa	Univ. of Ghana	BSc. Plant and Environmental Biology	EBB&HD

17.	Gideon Ato Yamoah	KNUST	BSc. Aquaculture and water resources Mgt.	FAD
18.	Rushud Ewudzie-Baah	KNUST	BSc. Aquaculture and water resources Mgt.	FAD
19	Afoakwa Betty	Univ. of Ghana	BSc. Chemistry (Physical Science)	GWGD
20.	Amuzu Peter	KNUST	BSc. Geological Engineering	GWGD
21.	Djonor Audrey Anthonia	Univ. of Ghana	BSc. Biological Science	FAD
22.	Amo Agyei Ransford	Univ. of Ghana	BSc. Marine Science	FAD
23.	Manne Ishmael Dambeebu	Univ. of Ghana	BSc. Marine and Fisheries Science	FAD
24.	Kevin Oskan Winston	Univ. of Ghana	BSc. Marine Science	FAD
25.	Ahinakwah Laryea Joel	Univ. of Ghana	BSc. Marine Science	FAD
26.	Twum Hillary	Univ. of Ghana	BSc. Marine Science	FAD
27.	Rhoda Naa Atswei	Univ. of Ghana	BSc. Marine Science	FAD
28.	Siaw Narkwor	Univ. of Ghana	BSc. Marine Science	FAD
29.	Atuobi-Yiadom Nana Yaw	Univ. of Ghana	BSc. Marine Science	FAD
30.	Abdul Mumin Seyeed Mohmmed	KNUST	BSc. Chemistry	ECSED
31.	Amakah Phiona Nana Akua	KNUST	BSc. Chemistry Engineering	ECSED
32.	Sackey Ivan	KNUST	BSc. Chemistry	ECSED

33.	Ansah Godson Woenam	KNUST	BSC. Biological Science	EBB&HD
34.	Abdul Rahman Kassim	Accra Technical University	HND Science Laboratory Technology	ECSED
35.	Ackon Francis Obed Kwesi	KNUST	BSc Agribusiness Management	FAD
36.	Jessica Edinam Ackuaku	KNUST	BSc. Biological Science	EBB&HD
37.	Mensah-Osei Kelvin Bonsu	KNUST	BSc. Aquaculture And Water Resource Management	FAD
38.	Homenya Kwaku Julius	University Of Ghana	BSc. Plant and Environmental Biology	EBB&HD
39.	Joy Ama Nyarko	KNUST	BA Political Studies	Admin.
40.	Hammond Ringland Dei	University Of Ghana	BA Information Studies	CD
41.	Addo Apowah	University Of Ghana	BSc. Plant and Environmental Biology	EBB&HD
42.	Boniface Jerry Brobbey	University Of Ghana	BSc. Plant and Environmental Biology	EBB&HD
43.	Brian Nana Ekow Ewudzie Ashley	University Of Ghana	BSc. arth Science	GWGD
44.	Ayim Elisha Adomako	Koforidua Technical University	BSc. Computer Network Management	CD
45.	Laryea Gabriel Nii Lantei	University Of Ghana	BSc. Biology	EBB&HD
46.	Anderson Blay George	University Of Ghana	BSc. Administration	Admin.
47.	Mary Amoako	KNUST	BSc. Aquaculture and Water Resource Management	FAD
48.	Adevu Philemon	University of Ghana	BSc. Plant and Environmental Biology	EBB&HD

49.	Adu Owusu Abena	KNUST	BSc. Biological Science	EBB&HD
50.	Esther Yahaya	KNUST	BSc. Aquaculture and Water Resource Management	FAD
51.	Boampong Nyameahyira Kusi Jehoshaphat	KNUST	BSc. Biochemistry	BPHRU
52.	Sidney Kroyurto Alando Samuel	University of Ghana	BSc. Biomedical Engineering	BPHRU
53.	Lamptey Valerie Naa-Koshie	University of Ghana	BA Political Science and Geography	Admin.
54.	Anita Akorfa Adjei	University of Ghana	BSc. Plant and Animal Biology	EBB&HD
55.	Anang Godwin Akpor	Accra Technical University	HND Secretaryship and Management	Admin
56.	Yeboah Joana Frempomaa	KNUST	BSc. Aquaculture and Water Resource Management	FAD
57.	Elizabeth Adomah Mensah	University of Ghana	BSc. Earth Science	GWGD
58.	Prince Nana Yirenkyi Apenteng	KNUST	BSc. Geological Engineering	GWGD
59.	Berning Sandra Serwaa	KNUST	BSc. Biological Science	EBB&HD
60.	Prince Delaetor Crambson	KNUST	BSc. Aquaculture and Water Resources Management	FAD
61.	Bernita Kekeli Yeboah	University of Ghana	BSc Biological Science	EBB&HD
62.	Teiko-Kanyivie Millicent	Accra Technical University	HND Science Laboratory Technology	ECSED
63.	Nii-Akai Tychicus addotey	University of Mines and Technology	BSc. Minerals Engineering	GWGD
64.	Kumi-Yeboah Kwesi	University of Energy and Natural Resources	BSc. Biological Sciences	EBB&HD

65.	Amon Comfort Naa Dei	University of Ghana	BSc. Biological Sciences	EBB&HD
66.	Godbless Owusu Adjei	University of Energy and Natural Resources	BSc. Biological Sciences	BPHRU

Summary of National Service /Industrial Attachment in 2023

Institution of National Service Personnel	**Number of Students**	**Institution of Industrial Attachment Personnel**	**Number of Students**
Kwame Nkrumah University of Science and Technology	10	Kwame Nkrumah University of Science and Technology	21
University of Ghana	20	University of Ghana	31
University of Cape Coast	3	University of Cape Coast	1
University of Development Studies	5	Koforidua Technical University	1
Accra Technical University	10	Accra Technical University	3
Koforidua Technical University	2	University College of Agric and Environmental Studies	2
University for Professional Studies	2	University for Professional Studies	2
Knutsford University College	1	University of Energy and Natural Resources	2
Pentecost University College	1	University of Mines and Technology	1
University of Health and Allied Sciences	1		
Total	55		63
		Overall Total	118

APPENDIX VI: LIST OF STAFF PUBLICATIONS

Journal Papers

1. Addi, M.; Amekudzi, L. K.; Obuobie, E. and Gyasi-Agyei, Y. (2023) Evaluation of fourteen precipitation products over the Pra and Densu river basins in Ghana, *submitted to International Journal of Climatology.*
2. Addai O., M., Fynn, O. F., Loh, Y. S. A., Chegbeleh, L. P., Alo, C., and Yidana, S. M. (2023). Climate and irrigation scenario analyses using three-dimensional numerical modelling: a case study of the Nasia sub-basin in the White Volta Basin, Ghana. *Hydrogeology Journal*, 1-19.
3. Agyekum, J., Amekudzi, L. K., Stein, T., Aryee, J. N., Atiah, W. A., Adefisan, E. A., and Danuor, S. K. (2023). Verification of satellite and model products against a dense rain gauge network for a severe flooding event in Kumasi, Ghana. *Meteorological Applications*, 30(5), e2150. https://doi.org/10.1002/met.2150
4. Agyekum, J., Annor, T., Quansah, E., Lamptey, B., Amekudzi, L. K., and Nyarko, B. K. (2023). Extreme temperature indices over the Volta Basin: CMIP6 model evaluation. *Climate Dynamics*, 61(1-2), 203-228. https://doi.org/10.1007/s00382-022-06503-x
5. Akpoti, K., Dembélé, M., Forkuor, G., Obuobie, E., Mabhaudhi, T. and Cofie, O (2023). Integrating GIS and remote sensing for land use/land cover mapping and groundwater potential assessment for climate-smart cocoa irrigation in Ghana. *Scientific Reports,* 13:16025, Nature portfolio, https://doi.org/10.1038/s41598-023-43286-5.
6. Akrong, M. O., Anning, A. K., Addico, G. N. D, Hogarh, J. N., Adu-Gyamfi, A., deGraft-Johnson, K. A. A., Ale, M., Ampofo, J. A., Meyer, A. S. (2023). Variations in seaweed-associated and planktonic bacterial communities along the coast of Ghana, *Marine Biology Research*, 19:4-5, 219-233, DOI: 10.1080/17451000.2023.2213894
7. Amadu, A.A., Abbew, A.W., Qiu, S., Addico, G.N.D., Hodgson, I., Duodu, S., Appiah, S.A. and Ge, S. (2023). Advanced treatment of food processing effluent by indigenous microalgae-bacteria consortia: Population dynamics and enhanced nitrogen uptake. *Algal Research*, *69*, p.102913.
8. Ameworwor, M. Y., Aggrey-Fyn, J. and Clottey, M. N.K. (2023). Implications of Socio-cultural Practices on Fisheries Management: A Case of the Bottom-set Gillnet Fishery in the Central Region of Ghana. *Ghana Journal of Science,* 64(1), 41-48p.
9. Ampofo, S., Annor, T., Aryee, J. N., Agyekum, J., and Amekudzi, L. K. (2023). Gridded daily rainfall data for Ghana for the period 1960-

2015: Approach and validation process. *Data in Brief*, 48, 109115. https://doi.org/10.1016/j.dib.2023.109115

10. Anani, F. A., Atsakpo, P. D. K., Donkor, K. K., Ayarika, F. A., Johnson-Ashun, M. and Danquah, E. T. (2023). Profitability of using five different commercial tilapia starter feeds on the Ghanaian market in Nile tilapia, *Oreochromis niloticus,* fingerlings production. *Aquaculture Studies*, 24(2), AQUAST1343. http://doi.org/10.4194/AQUAST1343
11. Anani, F. A., Donkor, K. K. and Ayarika, F. A. (2023). Profitability of small-scale grow-out production of caged Nile tilapia, *Oreochromis niloticus,* in the Volta Lake of Ghana. *Fisheries and Aquatic Life* (Under Review).
12. Armah, E. and Tuntufye, H. N. (2023). Polymorphism of 16SrRNA Gene and Its Association with Patho-genecity and Antimicrobial Resistance of Free Ranged Chicken. *Practice*, *1*, 16-25.
13. Bazaanah, P., and Mothapo, R.A. (2023). Sustainability of drinking water and sanitation delivery systems in rural communities of the Lepelle Nkumpi Local Municipality, South Africa. *Environment, Development and Sustainability (2023)*. DOI: https://doi.org/10.1007/s10668-023-03190-4
14. Bazaanah, P. and Litabe, M. N. (2023). Community participation in water and sanitation service delivery: An empirical case of Mantsopa Municipality, South Africa. *Data in Water Resources Engineering*, 2(4): 16 – 20: https://bdwre.com.my/archives/2bdwre2023/2bdwre2023-22-26.pdf
15. Boadi, S. A., Bosselmann, A. S., Owusu, K., Asare, R., & Olwig, M. F. (2023). Household Economics of Cocoa Agroforestry: Costs and Benefits. In: M. F. Olwig et al. (eds.), Agroforestry as Climate Change Adaptation: The Case of Cocoa Farming in Ghana, pp. 121-145. Cham: Springer International Publishing (Palgrave MacMillan). https://doi.org/10.1007/978-3-031-45635-0_5
16. Bosselmann, A. S., Boadi, S. A., Olwig, M. F., and Asare, R. (2023). Social Challenges and Opportunities in Agroforestry: Cocoa Farmers' Perspectives. In: M. F. Olwig et al. (eds.), Agroforestry as Climate Change Adaptation: The Case of Cocoa Farming in Ghana, pp. 93-119. Cham: Springer International Publishing (Palgrave MacMillan).
17. Chikezie, F. M., Opara, K. N., Ubulom, P. M. E., Yaro, C. A., Al-Akeel, R. K., Osei-Atweneboana, M. Y. and Batiha, G. E. S. (2023). Onchocerciasis transmission status in some endemic communities of Cross River State, Nigeria after two decades of mass drug administration with ivermectin. *Scientific Reports*, *13*(1), 5413.

18. Crawford, K.E., Hedtke, S.M., Doyle, S.R., Kuesel, A.C., Armoo, S., Osei-Atweneboana, M.Y. and Grant, W.N. (2023). Genome-based tools for onchocerciasis elimination: Utility of the mitochondrial genome for delineating *Onchocerca volvulus* transmission zones. *International Journal for Parasitology*.
19. Darko, D., Zhu, D., Quayson, M., Hossin, M.A., Omoruyi, O. and Bediako, A.K. (2023). A multicriteria decision framework for governance of PPP projects towards sustainable development. *Socio-Economic Planning Sciences*, p.101580.
20. Darko, H.F., Akrong M. O., Amu-Mensah M. A., Amu-Mensah F. K. and and Addico G. N. (2023). The Physico-Chemical Water Quality Assessment of Lake Bosomtwi: A Crater Lake in Ghana for Sustainable Management. *33rd Biennial Conference of the Ghana Science Association Book of Abstracts*, p82. (An abstract submitted at the 33rd Biennial Conference of the Ghana Science Association)
21. Diyie, R. L., Addo, A. E., Boateng, C. M., Oppong and Osei-Atweneboana. M. Y. (2023). Genetic evidence of the unique identity of the West African Mangrove Oyster (*Crassostrea tulipa*) from the Gulf of Guinea. *Regional Studies in Marine Science*, Volume 67, https://doi.org/10.1016/j.rsma.2023.103205
22. Diyie, R. L., Addo, S., Armah, E., Boateng, C., Wayo, J. and Osei-Atweneboana, M. Y. (2023) Low Genetic Diversity and Moderate Genetic Differentiation Among Wild Populations of Crassostrea Tulipa Revealed by Simple Sequence Repeat Analysis: Implications for Conservation and Breeding. *Available at SSRN 4444908*.
23. Dorleku, M., Gibrilla, A., Ganyaglo, S., Duah, A., Osae, S. and Essumang, D. K. (2023). Spatio-temporal variation of groundwater chemistry in the Upper Oti Basin of Ghana. *Environmental Monitoring and Assessment*, *195*(1), 246.
24. Echeta, O.C., Adjei, K.A., Andam-Akorful, S.A., Gyamfi, C., Darko, D., Ayock, I.J., Odai, S.N. (2023) Machine learning-based technique for predicting improved short-latency rainfall estimates in data-scare regions. Submitted to *Journal of Hydrology: Regional Studies* (*under review*)
25. Fynn, O. F., Dzikunoo, E. A., Chegbeleh, L. P., and Yidana, S. M. (2023). Enhancing adaptation to climate change through groundwater-based irrigation. *Sustainable Water Resources Management*, *9*(1), 36.
26. Gonzalez, J.M., Tomlinson, J.E., Martínez Ceseña, E.A., Basheer, M., Obuobie, E., Padi, P. T., Addo, S. Baisie, R., Etichia, M., Hurford, A., Bottacin-Busolin, A., Matthews, J., Dalton, J., Smith, D.M., Sheffield, J., Panteli, M. and Harou, J.J. (2023). Designing diversified renewable

energy systems to balance multisector performance. *Nature Sustainability*, pp.1-13. https://doi.org/10.1038/s41893-022-01033-0.

27. Gyasi-Agyei, Y., Obuobie, E., Yu, B., Addi, M. and Yahaya, B. (2023). Optimal selection of daily satellite precipitation product based on structural similarity index at 1 km resolution for the Pra catchment, Ghana. *Sci Rep* 13, 16702. https://doi.org/10.1038/s41598-023-43075-0.
28. Kumi, Michael, Anku, Wilson W, Antwi, Yeboah B, Penny, Govender P. (2023) Evaluation of the suitability of integrated bone char-and biochar-treated groundwater for drinking using single-factor, Nemerow, and heavy metal pollution indexes. *Environmental Monitoring and Assessment*. 195(6):647.
29. Kumi, M., Anku, W. W., Penny, P. G., and Obiri-Nyarko, F. (2023). Bench-scale integrated bone and biochar bed treatment of geogenic fluoride contaminated groundwater from Bongo in Ghana. *Groundwater for Sustainable Development*, 21,100929. https://doi.org/10.1016/j.gsd.2023.10092
30. Logah, F.Y., Obuobie, E., Adjei, K.A., Gyamfi, C., and Odai, S.N (2023). Capability of satellite rainfall products in simulating streamflows in the Black Volta Basin. *Sustainable Water Resources Management*, *9*(3), pp.1-14. https://doi.org/10.1007/s40899-023-00871-w.
31. Magna, E.K., Tornyie, F., Ofosu-Koranteng, F., Mensah, E.T-D., Larbi, L and Mbage, B. (2023). Occurrence and Environmental Risk Assessment of Antibiotics in Water and Sediment from Fish Farms in the Lower Volta Lake of Ghana. *Chemistry Africa*. https://doi.org/10.1007/s42250-023-00727-y
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