EVALUATION OF CDC NCIRD'S GLOBAL HEALTH SECURITY LABORATORY CAPACITY BUILDING PROJECTS 2016 - 2019

December 2020

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We would like to thank the key informants that dedicated their time to speaking with us and acknowledge the following people and organizations for their contributions to this project.

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This project was supported by Cooperative Agreement Number NU2GGH001993 between the U.S. Centers for Disease Control and Prevention (CDC) and the Association of Public Health Laboratories, Inc. The contents of this report are solely the responsibility of the authors and neither represent the official views of CDC nor reflect CDC's endorsement of a product or procedure.

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INTRODUCTION

The Global Health Security Agenda (GHSA) is a multi-sectoral and multilateral effort launched in 2014 to accelerate global progress toward alignment with the International Health Regulations (IHR) (2005), the World Organization for Animal Health's Performance of Veterinary Services, the Biological Weapons Convention, and other international frameworks and agreements. It comprises 67 countries and aims to improve countries' abilities to prevent, detect, and respond to infectious disease threats (CDC, 2020). GHSA was conceptualized in response to the ever-increasing risk of widespread infectious disease outbreaks, coming to fruition directly after the outbreak of Ebola in West Africa.

Through GHSA, more than 100 countries will complete an evaluation of their health security capacity and undergo planning and resource mobilization to address gaps in their global health security (GHS) and begin implementing activities by 2024 (Global Health Security Agenda). Participating countries work with governments and partners to reach targets across 11 domains, known as Action Packages (AP). Each AP includes a 5-year target, indicators to measure progress, and monitoring and evaluation activities to support successful implementation. The APs focus on core strengths needed to effectively combat outbreaks and epidemics such as disease surveillance, laboratory systems, workforce development, and emergency management (CDC, 2016b).

UNITED STATES APPROACH TO GHSA

The United States Centers for Disease Control and Prevention (CDC) plays a leading role in the global implementation of GHSA (CDC, 2016a). CDC's GHSA efforts aim to prevent and reduce the likelihood of natural, accidental, or intentional outbreaks; detect threats early to save lives; and respond rapidly and effectively using multi-sectoral, international coordination and communication. The CDC works directly on nine objectives, listed below.

1. Prevent the emergence and spread of antimicrobial drug-resistant organisms and emerging zoonotic diseases, and strengthen international regulatory frameworks governing food safety.
2. Promote national biosafety and biosecurity systems.
3. Reduce the number and magnitude of infectious disease outbreaks.
4. Launch, strengthen, and link global networks for real-time biosurveillance.
5. Strengthen the global norm of rapid, transparent reporting and sample sharing.
6. Develop and deploy novel diagnostics and strengthen laboratory systems.

7. Train and deploy an effective biosurveillance workforce.
8. Develop an interconnected global network of Emergency Operations Centers and multi-sectoral response to biological incidents.
9. Improve global access to medical and non-medical countermeasures during health emergencies

GHS LABORATORY CAPACITY BUILDING PROJECTS

The CDC is a lead country for GHSA National Laboratory System Action Package (GHSA Action Package Detect-1), which aims to meet the following objective: "A nationwide laboratory system able to reliably conduct at least five of the 10 core tests on appropriately identified and collected outbreak specimens transported safely and securely to accredited laboratories from at least 80 percent of districts in the country (CDC, 2014).

CDC's National Center for Immunization and Respiratory Disease (NCIRD) collaborated with the Association of Public Health Laboratories (APHL) and Institut Pasteur (IP) to design and implement the GHS Laboratory Capacity Building Projects (hereinafter "Capacity Building Projects"). The Capacity Building Projects address two core aims: (1) build and sustain laboratory capacity for pathogen detection and outbreak response, which contributes to achieving CDC objectives six and seven, and (2) improve specimen transport quality and efficiency, which contributes to objective five. These projects included concurrent and sequential activities.

APHL's Capacity Building Projects were initially funded under the APHL-CDC Strengthening Public Health Laboratories (SPHL) five-year cooperative agreement and subsequently funded under the APHL-CDC Strengthening Public Health Laboratories Internationally (SPHLI) five-year cooperative agreement. APHL received $4,232,919 for the Capacity Building Projects between 2015 and 2019. IP also received $400,000 from CDC to implement Capacity Building Projects, receiving $250,000 for the first two years and $150,000 for the last two years.

Over four years, dozens of countries across Africa and Asia received infectious disease diagnostic test kits through the International Reagent Resource (IRR), external quality assessment (EQA) panel reviews, support for packaging and shipping specimens, training and workshop sessions to develop laboratory skills, and other capacity building assistance. Table 1 below outlines the roles of various partners engaged throughout this multiyear program.

Table 1: List of organizations involved in the GHS Laboratory Capacity Building Projects

Entity	*Abbreviation*	*Role*
Centers for Disease Control and Prevention National Center for Immunization and Respiratory Diseases	CDC NCIRD	Funder
Association of Public Health Laboratories	APHL	Implementing partner
Institut Pasteur	IP	Implementing partner
International Reagent Resources	IRR	Supply provider
Quality Control for Molecular Diagnostics	QCMD	EQA provider
CDC Country Offices	none	Liaison
In-Country Laboratories	none	Beneficiary

The logic model (Figure 1) provides a summary of the inputs, outputs, and outcomes of the GHS laboratory capacity building projects.

Figure 1: Logic Model

Inputs	Outputs (Activities, Products)	Outcomes / Impacts		
		Short Term	Medium Term	Long Term
• IRR • CDC (funding, subject matter expertise, strategy) • Select laboratories in Asia and Africa • APHL (management, subject matter expertise) • Institute Pasteur (management, subject matter expertise) • Supplies, equipment, EQA panel • Previously developed tools / materials	• External quality assessment (panel and results) • Workforce development (in person trainings) • Provision of equipment and supplies (specimen transport, reagents) • Capacity Building Assistance (outbreak response consultations, Measles/ rubella self-assessment tool, E-learning modules for scientific writing, sample transport) • Peer Support ("Mentorship program", Discussion forum for scientific writing, sample transport)	• Laboratories equipped to transport, receive, maintain, and store specimens • Laboratorians have KSA to ship specimens domestically and internationally • Laboratories equipped with supplies and equipment for specific respiratory pathogen testing • Laboratorians have KSA to use test kits to perform testing according to quality standards • Laboratorians have KSA to detect pathogens of interest • Laboratorians have KSA to implement quality improvement activities based on EQA results	• Laboratories are providing reliable data to external partners • Laboratories are contributing to evidence base/scientific community • Laboratories have implemented policy and practice changes based on GHS Project activities • Laboratories have implemented packaging and shipping supplies into specimen transport systems • Increase in JEE scores (unlikely to get for this project period as each country only has one score)	• Laboratories in beneficiary countries are self sufficient • Decrease in disease burden in beneficiary countries • Improved quality of disease surveillance in beneficiary countries • Increase in timeliness of outbreak response in beneficiary countries • Increase in global health security

NOTE: APHL = Association for Public Health Laboratories, CDC = Centers for Disease Control and Prevention, EQA = External Quality Assessment, GHS = Global Health Security, IRR = International Reagent Resource, JEE = Joint External Evaluation, KSA = Knowledge, Skills, and Abilities

Implementation Timeline and Participation

The GHS Laboratory Capacity Building Projects were implemented from 2016 to 2019, shown in more detail in Figure 2. Overall, 27 countries participated in the Capacity Building Projects. Details about which countries participated in which projects, and the corresponding implementing partner, are provided in Figure 3.

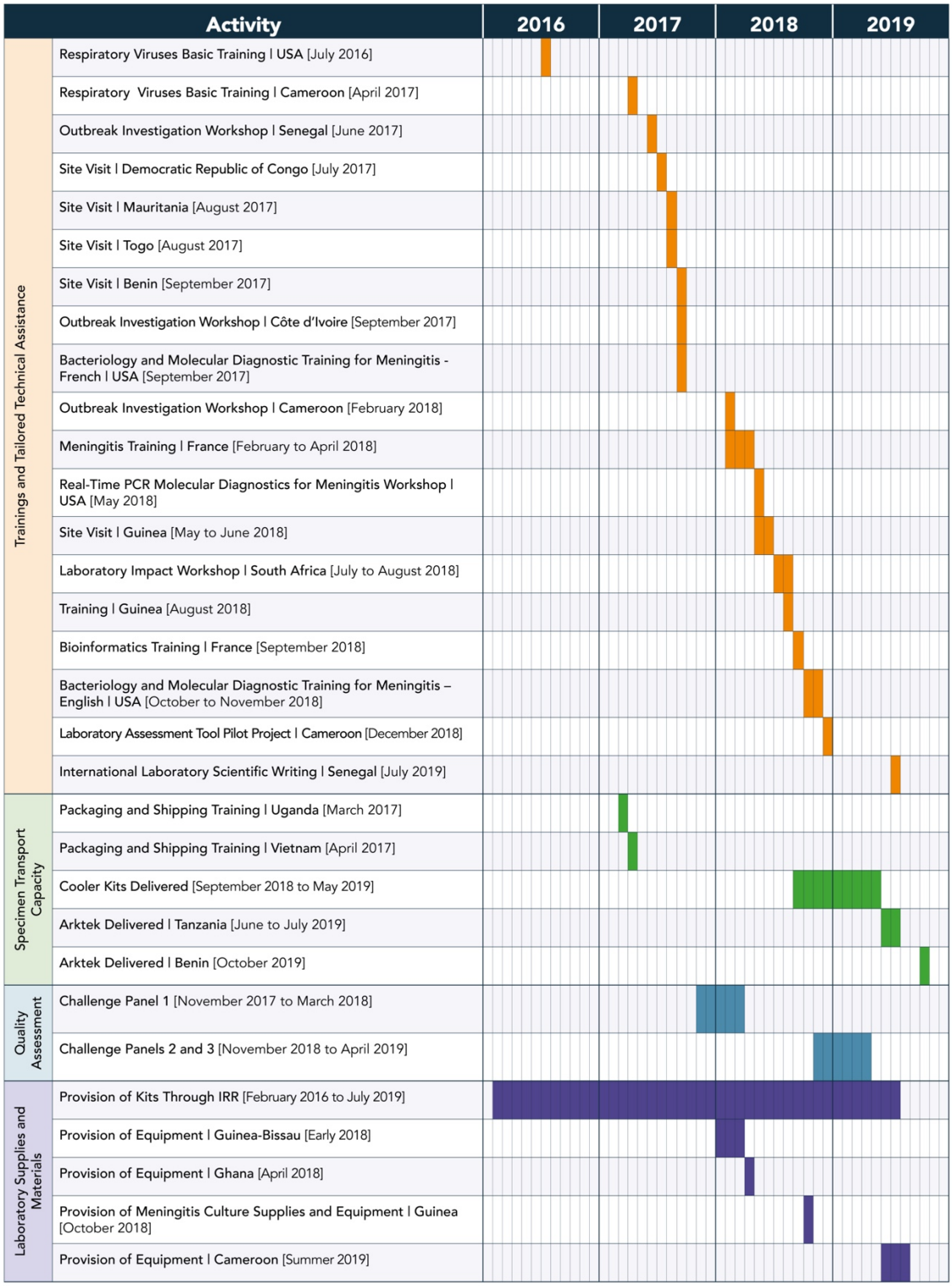

Figure 2: Timeline of GHS Capacity Building Projects activities by project year.

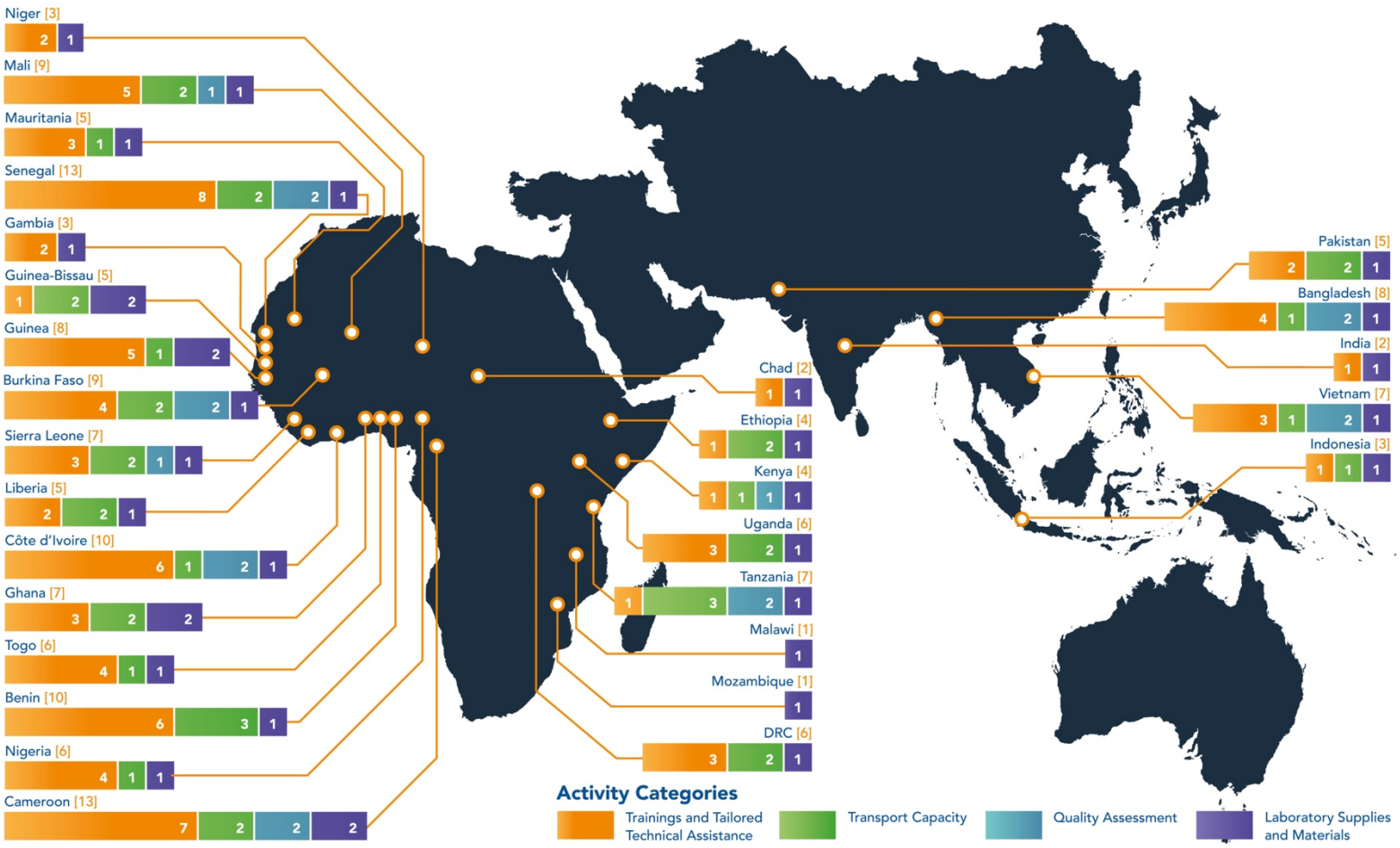

Figure 3: Distribution of Participation in GHS Capacity Building Project Activities by Country

PROJECT OVERVIEW

APHL contracted with SGNL Solutions (SGNL) to conduct a retrospective evaluation of the Capacity Building Projects implemented by APHL and IP from 2016 through 2019 calendar years. While Federal funding for these projects was allocated in 2015, implementation through APHL and IP began in 2016. Though some activities continued during 2020, only those completed by calendar year 2019 were included in the analysis.

SGNL designed a mixed-methods retrospective evaluation plan to address the five research questions (Box 1), which were developed at the outset of the project in collaboration with CDC and APHL. SGNL aimed to maximize data collection while minimizing burden on stakeholders, particularly considering that many of the potential survey respondents and key informants involved with this evaluation were actively responding to the COVID-19 global pandemic. This was achieved through various primary data collection and secondary data analysis methods. The evaluation plan is available in Appendix A.

SGNL's evaluation plan assessed the outputs, outcomes, and impacts of the Capacity Building Projects. To provide examples of gains realized and challenges encountered, SGNL developed three case examples featuring Benin, Cameroon, and Pakistan, found in Appendix H. However, for reasons noted in the limitations section later in the report (e.g., limited response rates, lack of data) the case examples are not generalizable to the remainder of the participating laboratories.

Box 1

Research Questions

- Describe the context for the GHS Laboratory Capacity Building Projects and the overarching strategy.
- How much money did the CDC invest in NCIRD GHS Laboratory Capacity Building Projects?
- Describe how NCIRD GHS Laboratory Capacity Building Projects amplified and dampened CDC NCIRD goals and priorities.
- Describe how NCIRD GHS Laboratory Capacity Building Projects amplified and dampened country program goals and priorities.
- What can we learn about how to improve project implementation at CDC and partner organizations beyond the process evaluation already completed?

Because the existing data collected were not uniform across activities in timing or measures, it was difficult to conduct a retrospective pre-post outcome evaluation. Instead, the evaluation intends to describe the Capacity Building Projects and the benefits for stakeholders. In addition, SGNL sought to illuminate implementation successes and challenges to improve future initiatives. SGNL engaged representatives from the following stakeholders in the evaluation process: CDC NCIRD, APHL, IP, CDC Country Offices, and In-Country Labs.

METHODS

DATA INVENTORY AND GAP ANALYSIS

SGNL first conducted a data inventory and gap analysis that catalogued and assessed the qualitative and quantitative information sources made available by APHL and CDC NCIRD. The purpose of the gap analysis was to determine what additional information was needed to answer the research questions.

APHL provided SGNL with access to a collection of documents that provided formative, process, and impact information about the activities implemented as part of the Capacity Building Projects. The collection consisted of over 90 documents across 15 succinct activities. The documents covered a range of types, including:

- Concept notes and proposals,
- Pre-, post-, and follow-up survey data for training activities,
- EQA panel results,
- Financial information,
- Training materials,
- Supply allocations, and
- Activity and annual reports.

SGNL created an inventory tool using Microsoft Excel to systematically assess the content, completeness, and fit of each data source. Each document was abstracted for the variables listed in Table 2.

Table 2: Variables included in the data inventory tool

Variable	*Definition*
Source ID	Input the source ID assigned by SGNL
Document name	Input the file name
Document type	Describe the information collection methodology/information type (e.g., pre/post, interview, count, description)
Time period	Describe when the information was collected
Respondents	Name the entity that completed the tool or provided the information (e.g., individual, lab, organization)
Administrator	Name the entity that administered the tool/collected the data or created the document.
Measurement/assessment	List what was measured/assessed/described in the document
Source type	Indicate if this is a primary or secondary information source
Data storage location	Indicate where the information is stored

Standard for comparison	Indicate if there is a standard for comparison (i.e., a widely accepted/expected/desired outcome)
Data availability	Indicate if SGNL has access to the information
Issues	List any issues or concerns with the information source (e.g., quality, completeness)

The SGNL team received training on how to use the inventory tool. Then, each reviewer completed the inventory process for all documents associated with one activity. The team collectively reviewed and reconciled the results to improve interrater reliability. All of the documents were assigned a unique ID by SGNL and randomly assigned to reviewers to input into the inventory tool. The complete data inventory spreadsheet is available for review.

After completing the inventory, SGNL conducted a gap analysis to ascertain the extent to which the research questions could be answered with the information available and what additional information was needed. The inventory led to the provision of additional documents by APHL and CDC. The gap analysis report is available in Appendix B.

All documents in the inventory were coded, synthesized, and summarized as part of the qualitative analysis process. The codebook for qualitative analysis is in Appendix F.

Cost Analysis

SGNL conducted a analysis to understand the cost of implementing or maintaining the Capacity Building Projects, inclusive of NCIRD, APHL and IP's initial and actual costs. SGNL reviewed cost information from NCIRD, APHL, and IP program proposals, budgets and allocations notices, invoices, expense reports, and records of payments from the 2016 through 2019 calendar years. The analysis including only known financial costs (i.e., those involving an allocation or exchange of funding), not indirect economic costs (i.e., the estimated value of resources such as volunteer time, donated/unfunded space, materials, equipment, hidden contributions of time that are often not a direct exchange of funding) and only known costs incurred from NCIRD, APHL and IP directly providing goods and services to laboratory beneficiaries. SGNL sought to identify cost categories and determine which to include in the cost analysis based on the

purpose of the analysis and availability of information/documents. Typically, cost categories include labor (salaried and contract labor), facilities, supplies, equipment, shipping, and travel/accommodations. In this case, we considered whether the cost analysis was limited to inputs directly provided to beneficiaries or inclusive of NCIRD, APHL, IP personnel labor and operational (facilities, utilities, supplies/equipment) costs needed to design and execute the Capacity Building Projects.

PRIMARY DATA COLLECTION AND ANALYSIS

SGNL designed various primary data collection methods to gather insight and evaluate aspects of the Capacity Building Projects, including project design, project implementation, project impact, and budget and resource allocation. These methods included key informant interviews, a training participant survey, and a literature review.

Key Informant Interviews

To augment the information available through the document inventory, SGNL invited 53 individuals from CDC, CDC country offices, in-country labs, IP, and APHL to participate in 60-minute qualitative key informant interviews (KII). Individuals who accepted the invitation were asked to indicate their availability via a scheduling poll, and KIIs were scheduled with members of the SGNL team. A breakdown of the interviewees by affiliation can be seen in Table 3.

Table 3: Distribution of key informant interview invitations and participation by stakeholder type

Affiliation	*# invited*	*# interviews completed*
CDC	28	8
Implementing Partners	11	6
Laboratorians	14	3

Interviewers used an interview guide with questions specific to the stakeholders' roles in the Capacity Building Projects. The interviews with CDC headquarters staff

covered project initiation and design, alignment with country priorities, funding and resource allocation, and barriers and facilitators. Staff from the CDC country offices received questions about project implementation, alignment with country priorities, impact and outcomes of activities, and barriers and facilitators. SGNL interviewed the in-country laboratory staff on project participation, alignment with country priorities, impacts and outcomes, and barriers and facilitators. APHL and IP staff were also asked to participate in interviews to provide insight to project design and implementation, resource allocation, and barriers and facilitators. The full interview questions can be found in Appendix C.

All interviews were conducted using Zoom and were recorded for transcription and record-keeping purposes, with the permission of each interviewee. Audio files were submitted to Rev Transcription services immediately following each interview. Each transcript was then reviewed and coded with Dedoose, a cloud-based analysis software, using a closed coding method. Each coder independently coded at least three interviews, compared results, and discussed discrepancies to improve inter-rater reliability. All interview transcripts were coded, synthesized, and summarized as part of the qualitative analysis process. The codebook for qualitative analysis is in Appendix F.

Training Participant Survey

Individuals who participated in one or more of the laboratory training activities offered by APHL and IP between 2016 and 2019 and for whom an email address was available (n=161) received a link to complete a survey. The survey was programmed in Qualtrics in both English and French and contained 18 questions to assess the impact of the trainings and to gather feedback to improve future activities. Respondents were asked to select the activities in which they participated (i.e., self-identify training participation) and then were prompted to answer questions about only the trainings for which they indicated attendance. SGNL did not validate the self-reported training attendance. Responses options were either a five-point Likert scale or an open-ended text block. On average, it took respondents 15 minutes to complete the survey.

The survey was open for 43 days, and respondents received at least two reminder emails. The survey achieved an overall response rate of 49%. Table 4 provides the

response rate by country. Table 5 compares the documented number of participants for each training to respondents' self-reported participation from the survey.

Table 4: Response rates for survey of training participants, by country

	# invitations distributed	*# respondents*	*Response rate*
Bangladesh	8	6	75%
Benin	9	5	56%
Burkina Faso	10	4	40%
Cameroon	17	4	24%
Cote d'Ivoire	21	4	19%
Gambia	3	3	100%
Ghana	4	1	25%
Guinea	4	3	75%
Guinea-Bissau	3	2	67%
India	2	1	50%
Indonesia	3	2	67%
Kenya	2	1	50%
Mali	9	6	67%
Mauritania	2	1	50%
Niger	2	1	50%
Nigeria	7	5	71%
Pakistan	5	3	60%
Senegal	10	4	40%
Sierra Leone	7	3	43%
Tanzania	3	3	100%
Togo	7	3	43%
Uganda	7	4	57%
Vietnam	16	9	56%

Table 5: Comparison of number of documented participants and self-reported participants, by training

	# documented participants	*# survey respondents who self-reported participating*
CDC molecular training (RT PCR Assays) | July 2016 | Georgia, USA	15	8
Packaging and shipping training | March 2017 | Uganda	27	14
Molecular training on respiratory viruses | April 2017 | Cameroon	10	2
Packaging and shipping training | June 2017 | Vietnam	12	11
Outbreak response workshop: (1) July 2017 | Senegal; (2) Sept. 2017 | Cote d'Ivoire; (3) Feb. 2018 | Cameroon	UKN	5
Bacteriology and molecular diagnostic training for meningitis | Sept. 2017 | Georgia, USA	17	7
Meningitis training | Spring 2018 | France	12	9
Real-Time PCR Molecular Diagnostics for Meningitis Workshop | May 2018 | Minnesota, USA	12	9
Bioinformatics training | Sept. 2018 | France	6	0
Bacteriology and molecular diagnostic training for meningitis | Oct. 2018 | Georgia, USA	16	13
Scientific writing workshop | July 2019 | Senegal	17	15

Results from the English and French versions were combined and translated to English, and then analyzed using IBM SPSS. The open-ended questions were included in the qualitative analysis. The English and French versions of the email invitation and survey can be found in Appendix C.

Literature Search

SGNL conducted a search of peer-reviewed literature to identify manuscripts published by individuals who participated in one or more of the activities offered by APHL and IP between 2016 and 2019 (n=186). SGNL used Google Scholar to search for peer reviewed articles published between 2016 and 2020 using the identified names, laboratories, and countries. See Appendix D for the detailed bibliography.

FINDINGS

This section presents the limitations of and findings from SGNL's data collection and analysis. The findings are organized by research question. First SGNL provides a description of the activities implemented as part of the Capacity Building Projects. Then, SGNL details the outputs and impacts of each activity. Finally, the SGNL describes the facilitators of and barriers to implementation.

The findings presented in this report are subject to the following limitations.

LIMITATIONS

There were several limitations that prevent these findings from being comprehensive and generalizable across projects and countries, including the pandemic response, lack of baseline data, low response rates, inconsistencies in evaluation and monitoring, and incomplete data. The limitations are described more fully below.

Pandemic Response

The evaluation project was conceived and initiated prior to the COVID-19 pandemic. All parties involved in implementing the evaluation plan felt the global shutdown's impact, and many were engaged directly in response activities. As a result, SGNL scaled back the data collection strategies to account for the many demands placed on public health laboratories, CDC NCIRD, and APHL. For example, SGNL administered one simple survey for all training participants rather than multiple, highly targeted surveys.

Lack of Baseline Data

Neither CDC NCIRD nor the implementing partners collected baseline data about the participating countries' priorities, needs, assets, or performance. While potential sources of data existed, SGNL could either not obtain them (e.g., WHO outbreak

reporting history) or a second point-in-time measurement did not exist for comparison (e.g., JEE reports).

Low Response Rates

SGNL originally planned to conduct interviews with representatives from all participating laboratories. SGNL did not achieve high participation rates for the key informant interviews. Specifically, we conducted interviews with laboratorians from only three participating countries. While SGNL combined the interviews with other data to draw conclusions about the Capacity Building Projects overall impact, it was challenging to draw firm conclusions about the specific effects on individual countries. While the low response rates for SGNL's surveys and interviews could be attributed to the COVID-19 pandemic, it is also worth noting that the implementing partners experienced difficulty generating responses for activity-specific evaluation efforts prior to the pandemic.

Inconsistencies in Evaluation and Monitoring

APHL and IP took very different approaches to monitoring the implementation and evaluating the impact of their implemented activities. When there was overlap in approach (e.g., pre/post KSA surveys for trainings, training satisfaction questionnaires), the survey items and answer scales were not always consistent. Also, no effort was taken to measure the "dose" of activities received by each participating country, laboratory, or individual. While the implementing partners did collect data to measure processes, outputs, and outcomes, it was difficult to link datasets to track improvements over time or across countries in any meaningful way.

Incomplete Data

Much of SGNL's analysis depended on access to project documentation. As is often the case with complex, multi-year projects, staff turnover and gaps in information management practices meant that valuable information was missing. It was not always possible to identify the names and contact information for all laboratory participants for each activity.

QUESTION 1

Describe the context for the GHS Capacity Building Projects and the overarching strategy.

To help countries move towards successful, independent disease response by increasing laboratory capacity, CDC partnered with APHL and IP to develop the GHS Laboratory Capacity Building Projects. Initially, they aimed to implement short-term "quick win" activities that would yield an immediate increase in laboratory capacity upon activity completion. Over time, the Capacity Building Projects evolved to have long-term objectives that supported existing NCIRD projects and priorities.

APHL and IP implemented several types of projects to address different types of gaps and weaknesses in the capacity of country laboratories. Some were focused more on infrastructure, including equipment procurement, international reagent resources (IRR), packaging and shipping support, and external quality assessment (EQA) panels. Others focused on workforce capacity, and included various workshops and trainings designed to improve the skills of laboratorians.

International Reagent Resources Expansion

The CDC established the IRR as a central repository of laboratory testing supplies for registered public health laboratories across the globe. IRR acquires, authenticates, and produces reagents that scientists need to carry out basic research and develop improved diagnostic tests, vaccines, and detection methods. Registered laboratories have access to reagents, test kits, and information to study and detect influenza viruses at no expense (International Reagent Resource).

In 2016, the CDC expanded the IRR to include 14 new custom products and ancillary commercial products required to run the CDC respiratory virus real-time reverse transcription PCR (rRT-PCR) assays. This included a kit for severe acute respiratory infection (SARI) surveillance and an outbreak investigation kit that can detect up to 33 common respiratory viruses and bacteria. Through the IRR expansion, APHL and IP could extend laboratory capacity trainings to non-influenza respiratory laboratories. High-risk country laboratories were trained on CDC diagnostic protocols and laboratory

outbreak response procedures. In addition to the initial IRR expansion, multiplex test kits, which enable laboratories to identify rapidly the potential pathogen causing illness, were later introduced to the IRR.

Laboratories in GHSA target countries were registered with IRR and trained on how to purchase singleplex and multiplex reagents and kits directly from the IRR to expedite communication and access.

Workforce Capacity Building Activities

APHL and IP offered a number of workforce development opportunities for laboratory staff, detailed in Table 6.

Table 6: Trainings offered through the GHS Capacity Building Projects, by implementing partner

Training	*Purpose*	*Reach*	*Date*	*Location*	*Implementing Partner*
Real-Time RT-PCR Assays for Non-Influenza Respiratory Viruses	Basic training on respiratory viruses	15 individuals from 8 countries	July 2016	Georgia Public Health Laboratory (Atlanta, GA, USA)	APHL
Meningitis Trainings	Training on identification of agents involved in acute bacterial meningitis (ABM) and the role of hospital laboratories and reference centers	12 individuals from 5 countries	Feb 2018 Mar 2018 Apr 2018	Paris, France	IP
Molecular Diagnosis of Non-influenza Respiratory Viruses Training	Basic training to build or strengthen the diagnostic capabilities for non-influenza respiratory viruses	10 individuals from 6 countries and peer trainers from 4 countries	April 2017	Centre Pasteur in Cameroon	IP
Bacteriology and Molecular Diagnostic Training for Meningitis - French	Training to enhance laboratory performance for the detection of bacterial meningitis pathogens using bacterial culture methods	17 individuals from 9 countries	Sept 2017	Atlanta, GA	APHL
Real-Time PCR Molecular Diagnostics Workshop for Meningitis	Training for PCR testing for bacterial pathogens	12 individuals from 6 countries	May 2018	Minnesota Public Health Laboratory (Minneapolis, MN)	APHL
Laboratory Impact Workshop	Forum for GHSA laboratories to present country implementation successes and challenges and acquire skills and knowledge to enhance sustainability of their laboratory programs	64 individuals from 22 countries	Jul-Aug 2018	Johannesburg, South Africa	APHL
Bioinformatics Training	Training on next generation sequencing (NGS) techniques to monitor emerging threats and characterize pathogens of interest	6 individuals from 3 countries	Sept 2018	Paris, France	IP

Bacteriology and Molecular Diagnostic Training for Meningitis - English	Training to enhance laboratory performance for the detection of bacterial meningitis pathogens using bacterial culture methods	16 individuals from 8 countries	Oct/Nov 2018	Atlanta, GA	APHL
International Laboratory Scientific Writing Workshop	Foundational training on writing and submitting scientific manuscripts	17 individuals from 10 countries	July 2019	Dakar, Senegal	APHL

Tailored Workforce and Capacity Development

Based on identified needs, APHL and IP facilitated the delivery of tailored capacity building assistance to many laboratories.

Non-influenza Respiratory Virus Technical Assistance Site Visits

Following the 2017 training on molecular diagnosis of non-influenza respiratory viruses, IP arranged follow-up visits to the Democratic Republic of Congo (July 2017), Mauritania (August 2017), Togo (August 2017), and Benin (September 2017). During the site visits, subject matter experts from Senegal, Cote d'Ivoire, and/or Cameroon spent several days with trainees at their home labs to assess needs, support onsite implementation of the methods and procedures learned during the basic training, and troubleshoot challenges. IP provided summaries of each visit to document the challenges identified and solutions offered.

Meningitis Testing Capacity Development

The implementing partners procured equipment for several laboratories to enhance meningitis testing capacity. APHL procured a CO2 incubator, BSC, freezer, refrigerator, autoclave and 175 packs of 5% sheep blood agar plates for the Ministry of Health in Ghana to achieve more rapid detection of bacterial meningitis. All items were delivered and installed by April 2018. IP procured laboratory equipment for a laboratory in Guinea-Bissau. All items were delivered and installed in early 2018. IP procured a PCR machine for a laboratory in Cameroon. All items were delivered and installed in Summer 2019.

APHL procured bacterial meningitis culture supplies and equipment for a laboratory in Kankan, Guinea. A biosafety cabinet was installed and certified in January 2018. Additional supplies were purchased and delivered by October 2018, with the exception of one generator, which was misplaced during shipment and replaced in 2019. In April 2018, two laboratorians from Kankan, Guinea, participated in a week-long training on bacterial meningitis. In May-June 2018, IP staff traveled to Kankan to help implement and reinforce some of the lessons from the bacteriology training. Finally, in

August 2018, CDC and APHL held a training in Kankan on the identification of bacterial meningitis pathogens and appropriate laboratory and biosafety practices for handling these specimens. In addition to the Kankan staff, heads of five neighboring prefecture laboratories attended the final training to learn how to submit specimens to the Kankan laboratory. The average knowledge gain from pre-test to post-test for the final training was 36%. At the conclusion of this activity, the Kankan regional laboratory established the capability of identifying bacterial meningitis pathogens and improved capacity for the identification of meningitis pathogens in this region.

Laboratory Assessment Tool

APHL and CDC developed a tool to assess a wide range of laboratory capabilities and capacities for measles and rubella diagnostics and surveillance. APHL conducted a pilot test of a laboratory assessment tool in Cameroon in December 2018. The tool was intended to inform resource allocation and workforce development by identifying laboratory strengths, opportunities for improvement, training needs, and supply, critical equipment, and reagent needs. An APHL assessor and CDC staff met with ministry of health and laboratory representatives over five days for interviews, observations, and testing. A debrief was conducted with key stakeholders to present preliminary findings and recommendations. Following the assessment, a detailed report was provided to the participating laboratory, the CDC, and APHL.

The pilot process identified a number of strengths and weaknesses for the laboratory in Cameroon. The laboratory had adequate physical infrastructure to support its mission, including reliable power, cross-trained staff, advanced testing, specimen archiving for at least one year, biosafety and biosecurity capabilities, and collaborative work with key partners at the national (e.g., ministry of health, district health offices) and international (e.g., WHO, CDC) levels. Challenges included delays of up to two to three months to receive reagents and supplies and no dedicated budget for measles and rubella surveillance testing.

Outbreak Investigation Capacity

IP designed and implemented three workshops designed to strengthen laboratory epidemic management plans. The outbreak response workshops took place in Senegal (June 2017), Cote d'Ivoire (September 2017), and Cameroon (February 2018). The workshops consisted of a series of presentations on the management of epidemics, a capabilities assessment, and a tabletop exercise. The activity focused on preparedness capabilities at the national level (e.g., protocols for collection, management, and transport of samples, communication, coordination) and laboratory level (e.g., biosecurity and diagnostic protocols, workforce competencies, equipment, continuity plans). The Senegal workshop was successful in producing a detailed report on strengths and weaknesses in laboratories as well as recommendations from subject matter experts (SMEs). The recommendations were relayed to the invasive pneumococcal disease (IPD) team to facilitate collaboration between the IPD team and IP SMEs for implementation. The Cote d'Ivoire workshop resulted in a detailed list of strengths and weaknesses within the labs as well as recommendations for improvement. The Cameroon workshop produced a list of strengths, weaknesses, identified needs and recommendations specific to three modules: 1) Identification of an epidemic and activation of the laboratory reinforcement, 2) Monitoring activities during an increase laboratory activity, 3) Demobilization of laboratory reinforcement.

Sustainable National Specimen Transport Activities

Many laboratories were using coolers that were not well insulated, were difficult to decontaminate, and were not meant for multi-use to transport specimens across the country for testing. To ensure timely, safe, and proper submission of respiratory and other infectious disease specimens, APHL and CDC designed a capacity building activity related to packaging and shipping.

APHL organized trainings to present best practices and information on appropriate specimen collection, handling, packaging, and shipping, focusing on maintaining cold chain, and adhering to International Air Transport Association (IATA) requirements for respiratory and cerebral spinal fluid specimens. Over three days,

participants were instructed on the collection, storage, and handling techniques to assure high-quality specimens appropriate for molecular and culture-based testing methods. Twenty-seven participants from 13 countries attended the training in Entebbe, Uganda, in March 2017, and 16 participants from four counties attended the training in Hanoi, Vietnam, in April 2017.

From September 2018 to April 2019, APHL and CDC implemented a packaging and shipping supply activity to complement the skills built during the trainings. Twenty-five countries were invited to complete a needs assessment questionnaire to assess laboratory needs and determine the quantity and types of supplies needed. Twenty responded and were deemed eligible to receive free cooler kits containing reusable Vibe coolers, secondary containers, locks, and guidance documents.

As a pilot project, Aucma, a company that manufactures a long-term cold-storage device known as the Arktec, provided additional devices to Benin and Tanzania for biological specimen transport. These recipients were chosen based on their responses to the initial needs assessment questionnaire and CDC recommendations. The laboratories that received an Arktek were provided with a user manual and charts that compared the Vibe cooler with the Arktek to describe the best use case of each type of storage device.

Quality Assessment Activities

APHL oversaw the administration of external quality assessment (EQA) panels to assess laboratories' capabilities to accurately detect specific viral and bacterial respiratory pathogens based on their participation in capacity building support offered through this initiative. There were four EQA panels distributed in two cycles. Each cycle included one viral and one bacterial panel. Laboratories were invited to receive EQA panels based on their participation in GHS Capacity Building Projects. The panels, produced by the non-profit Quality Control for Molecular Diagnostics (http://www.qcmd.org), resulted in confidential individual reports that were returned to the respective laboratories. CDC NCIRD also received the results.

The initial cycle was administered between November 2017 and March 2018. Sixteen of 21 eligible laboratories agreed to participate. Fourteen of those laboratories returned results for the viral panel and eight returned results for the bacterial panel. The

second deployment was administered between November 2018 and April 2019. Twenty one of 23 eligible laboratories agreed to participate. Thirteen returned results for the viral panel and six returned results for the bacterial panel.

QUESTION 2

How much money did CDC invest in NCIRD GHS Laboratory Capacity Building Projects (initial funded amount and actual expenses)?

SGNL was not able to obtain detailed accounting information about the budgets and actual expenses for the Capacity Building Projects due to CDC's and APHL's limited bandwidth for data requests during in the COVID-19 pandemic response. SGNL could not accurately categorize and calculate the funding and expenses or provide a thorough and meaningful response to this research question. Therefore, the limited findings of the cost analysis were excluded from this report at SGNL's recommendation and with the approval of APHL and CDC.

QUESTION 3

Describe how NCIRD GHS activities amplified and dampened CDC NCIRD goals and priorities?

This section describes the extent to which the GHS Laboratory Capacity Building Projects amplified and dampened CDC NCIRD goals and priorities and helped achieve specific short-, mid-, and long-term outcomes (as described in the logic model on page 6). SGNL relied on the data provided by APHL and CDC and data collected by SGNL through a survey, interviews, and desk research, to document the outcomes.

Short-Term Outcomes

The GHS Laboratory Capacity Building Projects sought to achieve the following short-term outcomes:

- Participating laboratory staff have the KSA needed to ship specimens domestically and internationally.
- Participating laboratory staff have the KSA needed to use test kits to perform testing according to quality standards.
- Participating laboratory staff have the KSA needed to detect pathogens of interest.
- Participating laboratory staff have the KSA needed to implement quality improvement activities based on EQA results.
- Participating laboratories are equipped to receive, maintain, and store specimens.
- Participating laboratories are equipped with supplies and equipment for specific respiratory pathogen testing.

Gains in Knowledge, Skills, and Abilities

For most training events, KSA gains were measured through pre- and post-tests, follow-up surveys administered around six to nine months post training, and/or observations noted in implementation partner reports. The documents provided by APHL and IP indicated modest average gains in pre/post knowledge across all trainings. The results are summarized in Table 7 below.

Table 7: Summary of Pre/Post and Follow Up Surveys by Training Activity

Event	*Date*	*Per/Post Test Results*	*Follow-up Results*
Real-Time RT-PCR Assays for Non-Influenza Respiratory Viruses | APHL	July 2016	--Average pre-test score was 27.25/41 (66.46%) and the average post-test score was 29.83/41 (72.75%), giving a modest average gain of 2.58 points (6.29%) --Majority of respondents either strongly agreeing or agreeing with statements about the quality of the training. --Open ended comments suggest that participants felt the course was beneficial and addressed gaps in knowledge/skills.	Not Available
Molecular Diagnosis of Non-influenza Respiratory Viruses (Basic Training) | IP	April 2017	--The post-test evaluation of participants revealed a clear improvement.	Not Available
Bacteriology and Molecular Diagnostic Training for Meningitis- French | IP	September 2017	--Results showed that there was a 14% knowledge gain (mean pretest score of 73% vs. mean posttest score of 87%)	Not Available
Meningitis Training | IP	Spring 2018	Not Available	Not Available
Real-Time PCR Molecular Diagnostics for Meningitis Workshop | APHL	May 2018	--There was an average knowledge gain of 22% from pre-test to post-test.	Not Available
Laboratory Impact Meeting | APHL	July-August 2018	--Course evaluations indicated that the majority of attendees felt individual session learning objectives had been met. --Participants reported how helpful it was to hear presentations from their peers for solutions that are more applicable to their lower resource settings than are sometimes presented at didactic workshops.	Nine-month follow-up evaluation: --96% response rate --100% of respondents indicated that the workshop impacted their overall knowledge of best practices for laboratory program implementation and collaboration either significantly or somewhat. --94% of respondents stated they shared the information from the workshop with their colleagues including other technical staff, biosafety officers, laboratory directors and supervisors.

			--72% reported that they wrote new or updated standard operating procedures.
Bioinformatics Training | IP	September 2018	Not Available	Not Available
Bacteriology and Molecular Diagnostic Training for Meningitis – English | APHL	October/ November 2018	--Average knowledge gain of 11% (mean pretest score of 71% vs. mean posttest score of 82%)	Six-month follow-up evaluation: --85% of respondents reported that their knowledge of meningitis pathogen identification significantly improved from prior to the workshop until the present, while 15% stated it improved somewhat. --92% of respondents stated they shared the information from the workshop with their colleagues, primarily other technical staff in their laboratories.
International Laboratory Scientific Writing | APHL	July 2019	--8% knowledge gain --On average, attendees reported high satisfaction rates and experienced knowledge gain	Not Available

SGNL's follow-up survey to training participants found that most respondents strongly agreed that the trainings they attended resulted in sustained gains towards the short-term outcomes (see Table 8). Results from the three outbreak response workshops, which were tailored exercise-based learning experiences, were combined and resulted in the lowest average rating with only 25% of respondents strongly agreeing that they were better able to create epidemic response plans. The scientific writing workshop had the next lowest average rating, with 73% of respondents strongly agreeing that the training increased their capacity to prepare data for publication.

Table 8. Percentage of respondents who agreed with statements about trainings

Training	Statement	Number of self-reported participants	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
CDC molecular training (RT PCR Assays) | July 2016 | Georgia, USA	I am better able to use molecular testing methods to detect non-influenza respiratory viruses.	8	0.00%	0.00%	0.00%	0.00%	100%
Packaging and shipping training | March 2017 | Uganda	I am better able to transport and handle specimens.	14	0.00%	0.00%	0.00%	14.30%	85.70%
Molecular training on respiratory viruses | April 2017 | Cameroon	I am better able to use molecular testing methods to detect non-influenza respiratory viruses.	2	0.00%	0.00%	0.00%	0.00%	100%
Packaging and shipping training | June 2017 | Vietnam	I am better able to transport and handle specimens.	11	0.00%	0.00%	0.00%	18.20%	81.80%
Outbreak Response Workshop | July 2017 |Senegal	I am better able to create an operational plan that includes measures that must be taken in the context of an epidemic.	1	0.00%	0.00%	0.00%	0.00%	100%
Bacteriology and molecular diagnostic training for meningitis | September 2017 | Georgia, USA	I am better able to detect and serotype meningitis pathogens.	9	0.00%	0.00%	0.00%	14.30%	85.70%
Outbreak Response Workshop | September 2017 | Cote d'Ivoire	I am better able to create an operational plan that includes measures that must be taken in the context of an epidemic.	4	0.00%	0.00%	50%	25%	25%
Meningitis trainings | Spring 2018 | France	I am better able to use laboratory methods to identify agents involved in acute bacterial meningitis.	9	0.00%	0.00%	0.00%	0.00%	100%
Outbreak Response Workshop | February 2018 | Cameroon	I am better able to create an operational plan that includes measures that must be taken in the context of an epidemic.	0	0.00%	0.00%	0.00%	0.00%	0.00%

Bacteriology and molecular diagnostic training for meningitis | May 2018 | Minnesota, USA	I am better able to detect and serotype meningitis pathogens.	9	0.00%	0.00%	0.00%	11.10%	88.90%
Bioinformatics training | Sept. 2018 | France	I am better able to prepare samples for next generation sequencing and analyze and exploit next generation sequencing results.	0	0.00%	0.00%	0.00%	0.00%	0.00%
Real-Time PCR Molecular Diagnostics for Meningitis Workshop | Oct./Nov. 2018 | Georgia, USA,	I am better able to detect bacterial meningitis pathogens, including Streptococcus pneumoniae, and Haemophilus influenza.	13	0.00%	0.00%	0.00%	23.0%	76.9%
Scientific writing workshop | July 2019 | Senegal	I am better able to prepare existing data for manuscript publication.	15	6.70%	0.00%	0.00%	20.00%	73.30%

External quality assessments (EQAs) were used to determine if KSA gains improved laboratorians' abilities to use test kits to perform testing according to quality standards. There were EQA cycles in 2017 and in 2018, and each cycle included viral and bacterial panels. The detailed results can be seen in Table 9. In general, laboratories performed better over time in their ability to detect viral pathogens than bacterial pathogens using molecular methods. APHL reported that participation in the EQAs dropped from year to year.

In the 2017 cycle, one laboratory did not perform satisfactorily requested onsite technical assistance prior to the 2018 deployment. In just over a week from the request, an APHL member consultant traveled to provide the requested technical assistance. Over five days, they facilitated multiple exercises, gave technical presentations, and provided real-time assistance while the laboratorians ran extractions.

Table 9: Percent of pathogens correctly identified from EQA challenge results from viral and bacterial panels in 2017 and 2019

Laboratory	Viral Panel		Bacterial Panel	
	2017-18	2018-19	2017-18	2018-19
Bangladesh (Dhaka)	75%	80%?	100%?	100%?
Bangladesh (Dhaka)	83%	90%?	-	-
Burkina Faso	83%	90%	70%	100%
Cameroon	100%	100%	100%	90%
Côte d'Ivoire	58%	70%	70%	90%
India (New Delhi)	92%	-?	-	-
India (Pune)	83%	100%	60%	-
Kenya	42%	-	-	-
Mali	83%	-	30%	-
Senegal	100%	100%	90%	80%
Sierra Leone	-	30%	-	-
Tanzania	92%	100%	100%	100%
Viet Nam (NIHE)	100%	100%	-	-
Viet Nam (PI-HCM)	83%	80%	-	-
Viet Nam (PI-NT)	75%	100%	-	-
Viet Nam (TIHE)	75%	70%	-	-

The GHS Laboratory Capacity Building Projects did not include specific trainings on quality improvement. Instead, CDC, IP, and/or APHL worked directly with laboratories to address quality issues. SGNL was not able to determine if the goal of

increasing KSA to implement quality improvement activities was met; however, some interviewees described quality improvement support provided for the labs they serve.

> *"When [the country laboratory] has had issues with testing, we would always go back and do a root cause analysis report and figure out where things went wrong and then help correct them. But at this time, they've been fairly independent for now maybe about a year and a half and they have not failed an EQA panel to date." – CDC Interviewee*

With regard to specimen handling, the outcomes of interest included KSA to ship specimens domestically and internationally. Following each packaging and shipping training, participants took an exam for International Air Transport Association (IATA) certification. Of the 33 attendees representing 17 countries, 32 received IATA certification.

Finally, 97% of respondents (n=76) to SGNL's survey reported that they transferred knowledge gained from the training (CDC) they attended to colleagues from their home laboratories by hosting internal trainings, sharing resources, and providing mentorship.

Laboratory Capacity

Capacity outcomes of interest included possession of supplies and equipment needed to test for specific respiratory pathogens and of equipment needed to receive, maintain, and store specimens. With regard to access to equipment and supplies for testing, outcomes were measured through IRR drawdown tracking and material shipment and installation tracking.

From February 2016 to July 2019, the IRR shipped 1,328 individual products, supporting respiratory virus RT-PCR testing for 57 different laboratories in 29 countries (see Table 10). In general, the reaction to the expansion of the IRR to include non-influenza reagents, and specifically the multiplex assay, was extremely positive.

> *"We could only provide so much through IRR and a number of these countries wanted more and more and more because they loved the program and wanted to expand it. And as much as we wanted to provide them with everything, we couldn't. It showed them the utility of expanding*

the scope of their testing, and they jumped on board with their own funding and pursued that." – CDC Interviewee

Table 10: Countries with expanded non-influenza virus reagent access to IRR that engaged in laboratory capacity strengthening activities (February 2016-July 2019)

Country	*# laboratories ordering from IRR*	*Total products ordered*			
		2016	*2017*	*2018*	*2019*
Bangladesh	3	9	28	0	13
Benin	1	7	0	0	20
Burkina Faso	3	0	32	53	6
Cameroon	1	1	35	4	13
Chad	1	0	0	0	12
Côte D'Ivoire	1	3	31	9	8
Democratic Republic of Congo	1	0	21	8	6
Ethiopia	1	1	14	6	30
Gambia	1	0	12	35	13
Ghana	3	0	26	41	23
Guinea	1	0	11	18	3
Guinea-Bissau	1	0	0	0	6
India	14	10	69	41	70
Indonesia	2	6	0	0	0
Kenya	2	5	7	30	1
Liberia	1	0	0	37	0
Malawi	1	0	0	0	1
Mali	2	2	0	53	0
Mauritania	1	0	2	53	0
Mozambique	1	0	0	17	2
Niger	1	0	0	0	19
Nigeria	2	0	28	9	20
Pakistan	1	6	18	2	7
Senegal	2	1	42	47	10
Sierra Leone	2	0	0	23	20
Tanzania	1	7	3	9	5
Togo	1	0	13	22	13
Uganda	1	1	0	10	22
Vietnam	4	8	22	13	0

In terms of packaging and shipping supplies, records indicate that central laboratories in 20 participating countries were shipped a total of 328 cooler kits (see Figure 4).

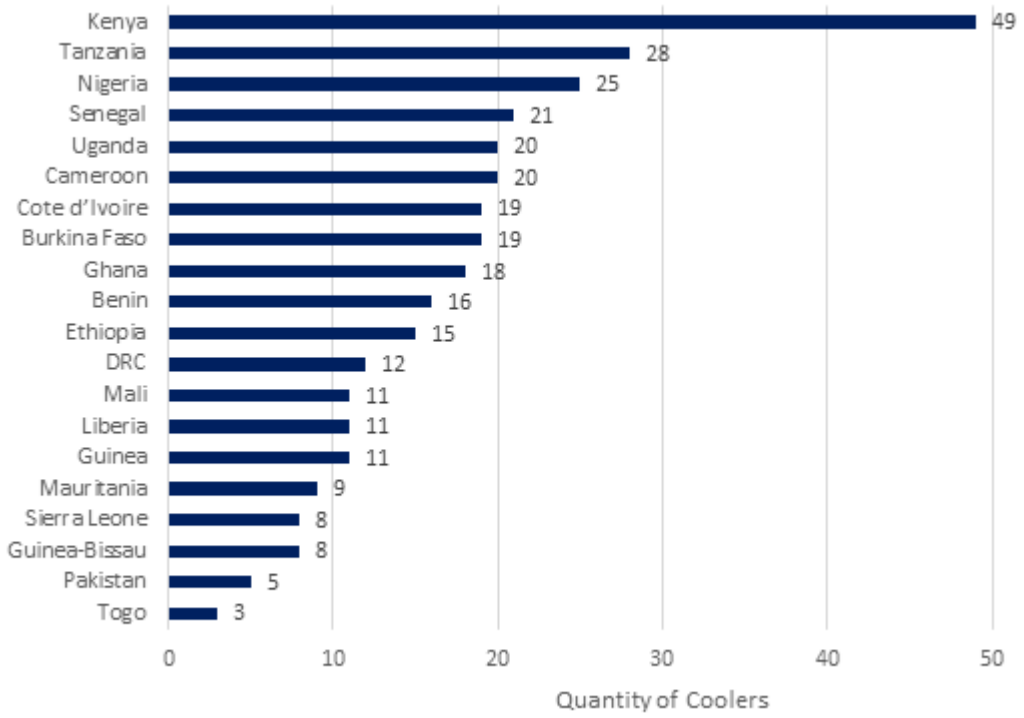

Figure 4: Quantity of cooler kits distributed by country

A follow-up evaluation was distributed to each country six months after they received their cooler kits. At six months, only three of 13 respondents reported that they had deployed the kits for use in their specimen transport systems. The majority of laboratories had not deployed the kits and provided the following reasons for not doing so: did not decide on sites to receive supplies, coolers are being saved for outbreaks/other uses, did not understand they were supposed to distribute to other regions, and did not understand the locking mechanism.

The evaluation results, though limited, did indicate the kits had been used for a variety of purposes, including Lassa fever, a Monkey Pox outbreak, and Yellow Fever. Participants reported the cooler kits were beneficial to biocontainment and safe transport of samples. Participants requested additional kits and training for their sample transport

systems. APHL attempted to create a discussion community called ColLABorate to allow peer-to-peer sharing and CDC technical support to countries that received kits, but participation uptake was low.

For the Arktek device distribution, follow-up inquiry found that both recipient laboratories encountered complications with the customs office and confusion around picking up the device at the port of entry, although the devices were eventually retrieved.

Laboratory equipment procured for four countries was delivered and installed successfully.

Mid-Term Outcomes

The GHS Laboratory Capacity Building Projects sought to achieve the following mid-term outcomes:

- Participating laboratories have implemented policy and practice changes based on activities.
- Participating laboratories have implemented packaging and shipping supplies into specimen transport systems.
- Participating laboratories are contributing to evidence base/scientific community.
- Participating laboratories are providing reliable data to external partners.
- Participating laboratories see an increase in JEE scores.

Implementation of Policy and Practice Changes

According to SGNL's survey, 72% (n=54) of respondents reported that their home laboratories had implemented changes to policies or practices based on the trainings they attended. When asked to describe the changes to policies or practices, respondents' responses fell into six themes: 1) Adopted, developed, revised, and updated procedures and protocols, 2) established effective communications between laboratories, 3) established quality assurance mechanisms, 4) procured and installed new equipment (PCR machines and bio-safety cabinets), 5) initiated proper data and result recording, and 6) wrote publications and reports. Table 11 provides a detailed list of policy and practice changes described by respondents.

Table 11: Self- Reported Policy and Procedure Changes by Country

Country	*Number of respondents*	*Self-reported Changes to Policies and Protocols*
Bangladesh	2	Changed protocol for sample collection and testing Established stricter aseptic measures
Benin	5	Established analyses and corrective procedures in the event of bad analysis Established new protocols for testing cerebrospinal fluid Establishing molecular platform for influenza virus diagnostic Improved diagnostic methods Reduced lead time for results Improved transport of cerebrospinal fluid samples to the national laboratory
Burkina Faso	3	Committed to the quality approach in the laboratory Reviewed and drafted diagnostic protocols
Cameroon	2	Systematized implementation of meningitis results confirmations Updated required documents and defined roles and responsibilities of actors for international transports
Cote d'Ivoire	3	Established response plan, emergency supply procedures, and laboratory level procedures for epidemic Implemented change in procedure so molecular diagnosis of meninges is systematically carried out for epidemiological surveillance of acute bacterial meningitis Designed training courses to meet laboratorian needs
Ghana	1	Changed policy to require triple packaging is followed and all samples are accompanied by a completed investigation form
Guinea	2	Improved accreditation process to align with other countries Participated in external quality evaluations, such as South Africa, WHO, and BIO-MERIEUX Appointed quality assurance resources within the laboratory Drafted standard operating procedures Developed continuous staff training plan and periodic staff evaluation systems
Guinea-Bissau	2	Created new sheets for sending and receiving the samples in laboratory network Established effective communication between laboratories Implemented periodic recycling of laboratory technicians. Adapted and improved molecular biology laboratory procedures
India	1	Adopted laboratory protocols from training workshops
Indonesia	1	Made improvements to make specimen handling compliance with IATA standards
Kenya	1	Implemented weekly written reports
Mali	4	Revised guidelines for transportation of infectious substances algorithm for the identification of meningeal pathogens Changed to a direct method with RT-PCR when serotyping pneumococci instead of extraction Improved project rationale for developing goals Improved master mis preparation and plate layout for influenza testing Producing a laboratory Biosafety manual for laboratories
Mauritania	1	Developed standard operating procedures and biosecurity manual through mentorship

Nigeria	4	Discarded Pastorex kit supplies and further usage Acquired PCR machine and Biosafety cabinet Incorporated DNA extraction protocol for culture isolates and e-tests as part of routine antibiotic assay for indeterminate antibiogram results
Pakistan	2	Processed influenza samples for other respiratory pathogens Developed system to ensure each sample shipment is inspected and approved by IATA certified shipment experts
Senegal	4	Updated procedures for direct diagnosis of causative agents of meningitis Developed standard operating procedures for samples transport and set up technical working group on sample referral system Incorporated use of IATA standard operating procedures for packaging and shipping dangerous good and molecular testing for all cerebrospinal fluid specimen we receive
Sierra Leone	1	Improved proper data recording and result recording
Tanzania	3	Developed protocol on appropriate specimen collection, handling, packaging and shipping with more focus on maintaining cold chain and adherence to IATA Increase in applying non-influenza protocol to samples that test negative for Influenza Increased adhering of WHO guideline on the packaging and shipping of infectious samples
Togo	1	Wrote standard operating procedure for detection for non-influenza virus Reviewed the algorithm of detection influenza virus including the detection of other respiratory viruses
Vietnam	4	Updated and issued some new protocols (e.g., Realtime PCR for Meningitis assay, sample packaging)

Implementation of Packaging and Shipping Supplies into Transport System

At six months after the provision of packaging and shipping supplies, only three of 13 responding countries reported that they had deployed the cooler kits for use in their specimen transport systems. Two countries received Arktek devices, APHL was not able to further evaluate the use of the for either recipient.

Contributions to Scientific Community

Of the 186 individuals who participated in any activity, SGNL determined that 83 contributed to a total of 145 peer-reviewed publications during the project period of 2016-2019 but given the lag time that is experienced when getting a manuscript published, we have also included 2020. Training participants from Bangladesh, Cameroon, Cote d'Ivoire, and Senegal generated the most publications (Figure 5).

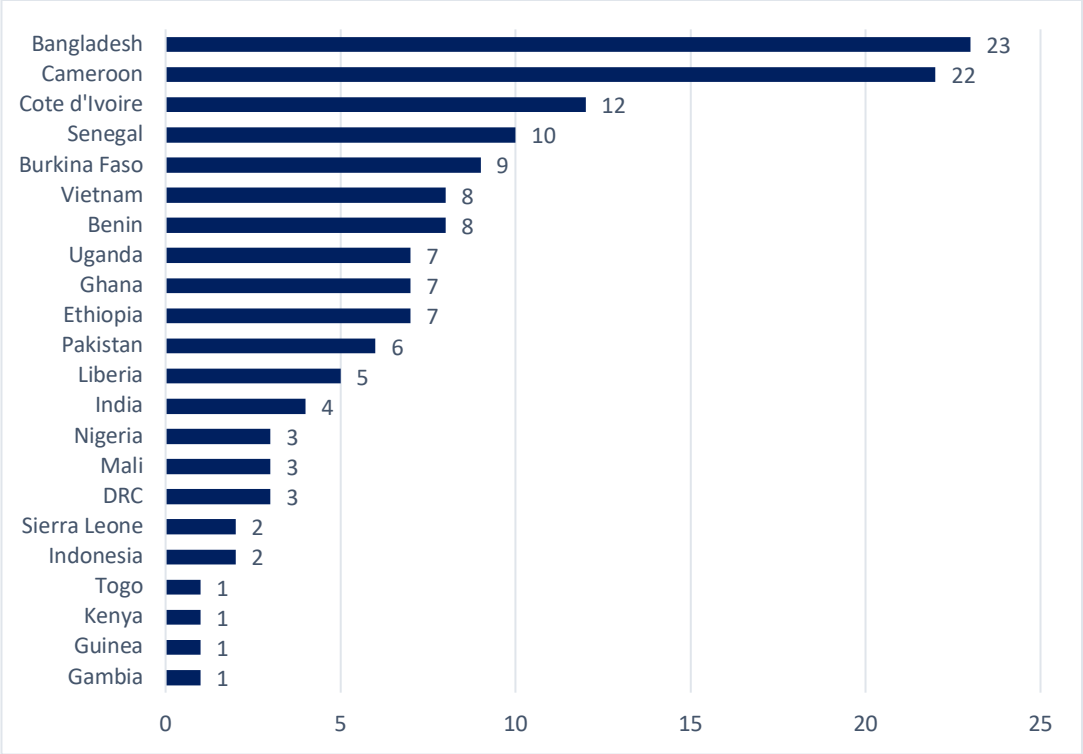

Figure 5. Number of peer-reviewed manuscripts published from 2016 to September 2020, by country

In general, the number of manuscripts accepted for publication by training participants increased from 2016 to 2019, with 12 published in 2016, 26 in 2017, 43 in 2018, and 38 in 2019. As of September 2020, 26 manuscripts were published. A complete list of publications can be found in Appendix D.

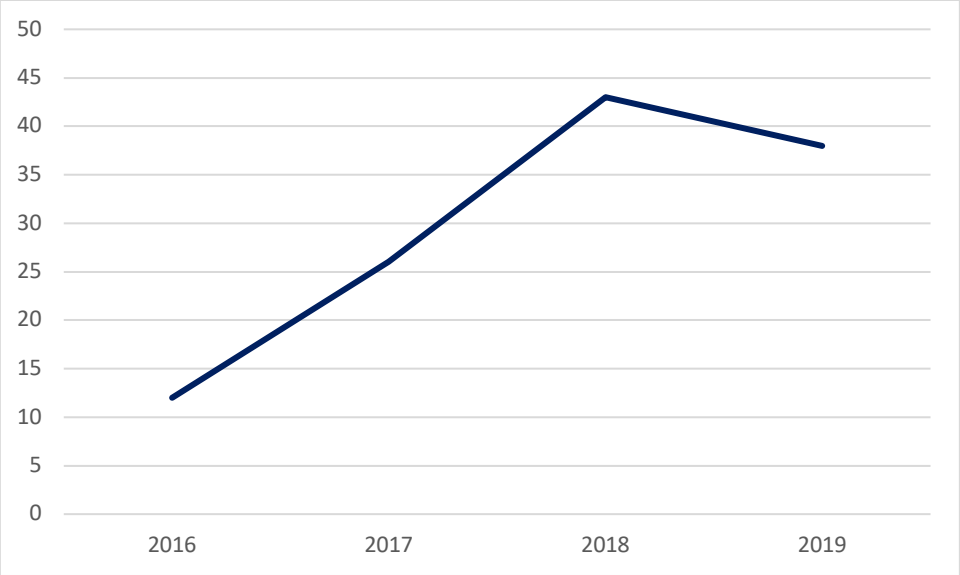

Figure 6. Number of peer-reviewed manuscripts published from 2016 to 2019, by year

Provision of reliable data to external partners and JEE score increases

SGNL was not able to identify data to describe outcomes related to the provision of reliable data to external partners. In addition, participating laboratories did not have multiple JEE assessments during the project period, making it impossible to measure any improvements in scores.

Long-Term Outcomes

The GHS Laboratory Capacity Building Projects sought to achieve the following long-term outcomes.

- Participating laboratories are self-sufficient.
- Participating laboratories have contributed to improved quality of surveillance.
- Participating laboratories have contributed to increases in timeliness of outbreak response.
- Participating laboratories have contributed to decreases in disease burden.
- Participating laboratories have contributed to increases in global health security.

While SGNL's evaluation did not intend to assess the long-term outcomes, interviewees did speak positively about the overall approach to and impact of the

Capacity Building Projects, noting improvements in laboratorian skills, policies and practices, and contributions to the protection of public health.

> *"You could see that [laboratory staff] actively took [what they learned in the trainings] back and are using that to help improve items inside of their country and set up standard operating procedures … [S]ome of those things we're seeing come to fruition now a few years later… and that's exciting to me." – CDC Interviewee*

> *"We obviously observed some progress. They now use the PCR in their diagnostics. I think a lot of them, or if not all of them, have been registered in the [IRR] to receive the kit." – Implementing Partner Interviewee*

> *"In this laboratory, when I visited it for the first time, there was almost nothing… After the training, they went back and organized the laboratory as it has to be." – Implementing Partner Interviewee*

> *"There's one ultimate goal is to make sure the countries become independent. We haven't gotten there yet, but… if you talk about expectations for little baby steps at the implementation level, I actually am happy with the countries and the collaborators because we are able to achieve all those goals and objectives along the way." – CDC Interviewee*

QUESTION 4

Describe how NCIRD GHS amplified and dampened country program goals and priorities?

SGNL was not able to collect information about the self-determined priorities of each country or laboratory prior to the start of the Capacity Building Projects. Given the COVID-19 pandemic, SGNL scaled back its data collection "asks" of the beneficiary laboratories, many of whom were responding to the pandemic, and document collection activities were excluded. In addition, SGNL was unable to interview a significant number of country laboratory staff. The lack of baseline and comparison data as well as the low participation rate means no meaningful descriptions or conclusions about the ability of the Capacity Building projects to specifically amplify or dampen county program goals and priorities can be provided at the time of this analysis.

QUESTION 5

What can we learn about how to improve project implementation at CDC and partner organizations beyond the process evaluation already completed?

Implementation Barriers and Facilitators

SGNL identified numerous factors that may have helped or hindered the implementation of the GHS Laboratory Capacity Building Projects and the attainment of desired short-, mid-, and long-term outcomes. This section describes the barriers and facilitators experienced by the CDC, implementing partners, and beneficiary laboratories. For the implementing partners, examples focus on the work of designing and carrying out project work plans. For the beneficiary laboratories, examples focus on the work of integrating the knowledge, skills, and materials gained through participation in the Capacity Building Projects.

Implementation Barriers and Facilitators Experienced by CDC, APHL, and IP

Partnerships

CDC NCIRD recognized limitations in its own workforce capacity and relied on partners with complementary skills and capabilities for the GHS Laboratory Capacity Building projects. Several interviewees noted that APHL was selected as a sub-awardee for this initiative because of technical and programmatic abilities, international reach, and proven track record. APHL was viewed as a strong partner for general capacity building.

> *"CDC has a long history of working with APHL successfully. They're a trusted partner…and they also have a global arm and experience in capacity building and on an international level." – CDC Interviewee*

> *"[APHL has] a really great relationship with the national public health labs…which has made them very successful in doing a lot of the projects for the laboratory. And they do a great job with training, people really like going to the trainings, and I feel like they have good impact." – CDC Interviewee*

Similarly, interviewees praised IP for its existing footprint in targeted countries and the ability to conduct trainings and workshops in French, which made them a valuable partner for increasing laboratory capacity in several West African countries.

> *"Working with Institut Pasteur, especially in Francophone Africa, [was a] natural intersection, because they're already the testing centers for a lot of the respiratory diseases." – CDC Interviewee*

The strong existing relationships, especially between NCIRD and APHL, contributed to the capacity of the implementing partners to make adjustments when needed.

> *CDC and APHL are pretty strong partners in this way, and that we do accept that when things aren't working, we just do something different and don't get stuck in trying to ram our way forward doing things just because we said we were going to. – Implementing Partner Interviewee*

However, while APHL and IP were tried and trusted partners, some of the activities for which they received funding may not have been the best match for their capabilities. For example, APHL received funding to procure and distribute packaging and shipping materials, a function the organization does not perform on a routine basis.

Project Design

While GHSA dictated the general strategies and the countries of interest, the implementing partners could use JEE reports, screening questionnaires, needs assessments, and CDC in-country staff perceptions to target invitations to laboratories and tailor capacity building activities appropriately.

> *"A major goal is to support the country. And as far as the country needs and priority, it's definitely based on the need assessment, whether … you do a full scope assessment or you work with the multiple partners … saying, well we all agree, this is the priority for the country right now." – CDC Interviewee*

> *"Every country has different needs. Every country has different infrastructure. Every country has got different outbreaks and these*

differences need to be considered prior to project implementation." – Implementing Partner Interviewee

These assessment and screening methods were not always effective. For example, one activity was based on a single successful activity previously conducted by a CDC staff person. What was overlooked was that the original activity was likely successful because of the on-the-ground, one-on-one support provided by CDC staff.

Many countries expressed a high need for packaging and shipping supplies across their systems but, once they received the requested cooler kits, did not distribute the materials to regional laboratories or integrate the materials into their workflow.

"Just because a country expresses interest doesn't actually mean that they have a plan for how to use it or that it even fits within their processes and organization." – Implementing Partner Interviewee

APHL and IP also noted that the activities did not always align with the countries' national priorities, making it sometimes difficult to secure buy-in or support from the ministries of health. For example, non-influenza respiratory diseases were not a priority for most of the participating countries. It was sometimes difficult to encourage laboratory staff expand capacity in this area when they had so many competing demands.

As NCIRD, APHL, and IP engaged with the laboratories, they identified additional capacity building opportunities. Interviewees described a tension between focusing on objectives developed at the initiation of the project until they achieved the desired outcomes versus remaining flexible to address emerging needs. Several interviewees described the escalating commitment experienced by capacity building assistance providers. The more they engage with countries, the more gaps they identify, and the more support they offer to address the gaps. All of these gains must be maintained to meet the outlined goals.

"You identify new gaps, you implement activities to reinforce that…the older activities that you implemented, you don't want that to go away." – CDC Interviewee

Implementing partners noted that some of the most beneficial activities seemed to come about when they were able to respond to the stated needs of the countries, rather than the needs perceived by CDC staff.

> *"The more thoughtful projects came because we were able to stop and breathe and say, 'What is truly needed now', not just 'what do we have to come up with in a few weeks' time because the money had to be earmarked." – Implementing Partner Interviewee*

> *"Over time, we got a sense of what seemed to work really well, where we seem to actually make some significant impact and do good things." – Implementing Partner Interviewee*

Project Management

Implementing partners expressed a concern that a lack of coordination and communication among global health security stakeholders lessened the activities' overall impact by overburdening country laboratory staff, duplication of efforts, and underutilizing available subject matter expertise.

> *"If [CDC Staff] are driving some of our work, then we really need their help in the field implementing it rather than just blindly sending this stuff out there and hoping that people use it the way we intended without somebody helping them do that." – Implementing Partner Interviewee*

> *"The global health security project overall was being led out of CGH at CDC, the center for global health. And then in-country, there's project officers for different kinds of projects that CDC has, that are on the ground, and that work either in the country or with the country. And if at a center level they had one idea of how to proceed, there were subject matter experts and or project officers lower in the center that had different ideas on what the priorities should be." – Implementing Partner Interviewee*

Similarly, some interviewees shared that coordination between CDC and APHL/IP was challenged by lack of clarity around overarching goals, implementation strategies, and CDC contacts/leads, especially at the initiation of the project.

"The funding was still coming from the global health security arm of CDC, which is in a totally different center. At times there were varying priorities and a little bit of a disconnect there… We were definitely working with the same people [in country], and working towards some of the same goals, and at times were doing duplicative efforts." – Implementing Partner Interviewee

"I think that in the beginning it was difficult because nobody inside of CDC really knew each other and what the centers were doing across the board. Communication about getting all the right players together was a little bit difficult." – CDC Interviewee

"It's our role to make sure that the right partners are engaged at every step of the way. It's our role to make sure that we and the partners have the same expectations of what's going to come out of a training or a workshop or a project. And that part can be really, really, really difficult because [each country has] lots of external organizations that want to work with them. It's not like CDC and APHL are the only ones" – CDC Interviewee

At the start of the initiative, the large budget and short timeframe generated a sense of urgency to obligate the funds before the end of the fiscal year to ensure the money was available for subsequent budget years. Various partners expressed frustration at requirements to conform to artificial deadlines (e.g., fiscal years) rather than being responsive to what was happening in real time. Several interviewees from implementing partners shared that the initial rush limited the ability to conceptualize the details of activities thoughtfully upfront.

"All the funding had to be spent in the first few months of when we received the funding… they wanted this done and implemented really quickly" – CDC Interviewee

"[Having clearly defined goals is] not realistic given the way we work, given the way federal appropriations happen when you might get this bucket of money that has to be spent really quickly." – Implementing Partner Interviewee

<u>Logistics</u>

At their conception, the Capacity Building Projects focused on easy-to-implement tactics that would result in observable increases in laboratory capacity within a short

timeframe. While the strategies seemed simple on paper, both APHL and IP experienced logistical challenges to implementation.

Several of the activities required more time and steps to implement than expected, particularly those related to procuring and transporting equipment and supplies. As a result, the implementing partners needed to shift human and financial resources, which resulted in unexpected costs, delays in timelines, or scrambling to pull activities off. For example, one activity required an implementing partner to unpack and re-kit supplies, which the partner had not planned for and was not equipped to handle within existing facilities or staff resources. The partner was able to identify a fulfillment center to resolve the issue. In another example, implementing partners struggled to secure sufficient laboratory supplies for a training and had to reschedule the event. Unresponsive or unreliable vendors and prolonged fulfillment timelines also resulted in delays.

Transporting the items and installing them at the recipient laboratories did not always go smoothly. For example, challenges with customs policies and procedures and disruptions to in-country transportation systems due to strikes led to delays in delivering the goods to several laboratories. One laboratory was unable to accept reagents less than one year from the date of expiration based on national regulations, which made it difficult sometimes to get reagents into the country. In some cases, the materials and supplies were less expensive than the fees paid for customs and storage.

> *"To me, it seemed like a great majority of the issues with procurement had to do with importing laws and regulations. There's so much tax on things coming in and the people who may or may not be supplying reagents for a country can't or won't pay for certain taxes. And then the labs who are trying to receive things can't pay them or won't pay them." – CDC Interviewee*

Several interviewees noted that countries in high-risk or low-resource areas are frequently offered free supplies and are reluctant to turn them down. However, these countries often cannot deploy the resources efficiently or effectively. For example, one country received a large portion of the packaging and shipping supplies but did not plan how to distribute them to regional laboratories. The cooler kits sat in storage rather than being put to use. In another country, the point of contact had difficulty getting someone to

pick up shipments from the customs office. Other reasons laboratories offered for not integrating cooler kits into practice included saving the supplies for outbreaks, not understanding they were supposed to distribute supplies to other laboratories, and not understanding how to use the supplies.

The implementing partners often did not have staff on the ground to investigate disruptions to the supply chain or mismanagement of resources to determine how best to get the items to the intended laboratories.

> *"Without having on-the-ground support, it was difficult for APHL and CDC to quickly and effectively resolve [logistical] issues with many of the countries." – Implementing Partner Document*

The implementing partners faced similar challenges when organizing trainings and workshops. The participating laboratories, implementing partners, vendors, and fiscal sponsors were from a large number of African, Asian, European, and North American countries. In some cases, restrictive visa requirements prevented participants from easily traveling to training sites. For example, laboratorians from one Central African country could not attend a training in France because their visa applications were denied by the European Union. Also, visa fees were not originally included in some project budgets, which resulted in unexpected costs, some of them paid out of pocket by implementing partner staff.

Monitoring and Evaluation

There did not appear to be an overarching evaluation strategy for the CDC's engagement in GHSA initiatives or the NCIRD's GHS Laboratory Capacity Building Projects. APHL and IP did attempt to gather information to measure the implementation and impact of each activity. For training and workshops, APHL measured knowledge gain through pre- and post-tests, assessed participant experience and satisfaction through an event evaluation, and sent a six-month assessment to evaluate impact. IP's monitoring and evaluation methods were less formalized and appeared to include surveys and site visit reports. APHL and IP did not have a standard approach to reporting on implementation and outcomes.

For APHL, electronic surveys were the primary means of assessing the impact of trainings and workshops, measuring the impact of activities on laboratory policies and practices, and determining if supplies and equipment were put into use. In-person training participants complained that the pre/post tests used to measure knowledge gain were too long. Paper-based surveys were burdensome for staff to compile and analyze, but electronic surveys were easier for participants to overlook or ignore. Language was also a barrier for monitoring and evaluation. Some participants were not comfortable completing surveys in English or found the French translations confusing. Surveys are challenging when respondents don't have access to someone to explain how to answer a question given their specific context.

> *"And so a written survey without anybody kind of there to give immediate feedback to clarify questions, to maybe prompt them by example is challenging. And also just getting people to fill out surveys is challenging." – Implementing Partner Interviewee*

Interviews and project reports indicate implementing partners were unable to achieve high response rates, especially for follow-up surveys. Therefore, they were not able to determine longer term impacts (e.g., use of supplies and materials, updates to policies and protocols) for specific activities. For example, APHL was not able to get any responses to a survey fielded to determine if laboratories were using the Arktek devices. Other CDC offices are also conducting assessments and surveys, but the efforts are not coordinated to minimize burden on the laboratory staff and training participants.

EQA panels were intended to measure whether the laboratories were able to process specimens correctly after receiving training and kits and if they needed additional support to maintain that capacity. However, participation in the annual challenges diminished from year to year, making it difficult to measure shifts in capacity.

> *"[EQA panels were] more of a formal check point to see if the laboratories are able to process specimens correctly using the CDC assays for those targeted markers. That was one of the ways we were able to measure whether or not they've maintained that capacity or needed some additional support to be able to maintain that capacity." – CDC Interviewee*

Overall, beneficiary laboratories did not seem incentivized to participate in monitoring and evaluation activities. Unless longer-term objectives are agreed-upon and communicated at the outset, it can be difficult to maintain engagement with the recipient lab.

> *"[For] true implementation projects to be successful, you need to have a method of accountability … where the lab that's accepting this service or resource receives coaching along the way and goals that they need to meet." – Implementing Partner Interviewee*

Finally, the GHS Laboratory Capacity Building Projects are just one of many GHSA and non-GHSA projects in which countries participate, making it hard to directly attribute impact of individual activities.

> *"Every year we have our progress supports and CGH also has their milestones. I will say that it's been difficult to see the NCIRD impacts sometimes not always, but sometimes it's been difficult to see that in the progress support that CGH maintains and synthesizes the information for the National Security Council." – CDC Interviewee*

> *"I just think there's a lot of work going on everywhere within CDC … I think sometimes it's hard to have good visibility on how the [impact of NCIRD's work] is being captured. So, I think that it's difficult to see just because the centers within the agency aren't completely lined up on their reporting processes for all of the work in the field." – CDC Interviewee*

> *"To tease out these couple of projects and say, what impacted these two projects have is really, really difficult". – CDC Interviewee*

Implementation Barriers and Facilitators Experienced by Beneficiary Laboratories

Training Design

The trainings conducted throughout the project period provided a hands-on experience for those who attended, which participants described as beneficial to learning. Events also offered opportunities to network, receive mentorship, and exchange ideas

with peers, which was unique for many who did not have established communication channels with other labs in their region. Many of the participants also participated in multiple activities, giving them the chance to form familiar relationships with laboratorians from other countries and staff from CDC, APHL, and IP. The trainings and workshops created a sense of a "collaborative network" for troubleshooting and skill-sharing.

However, several components of the trainings hindered the uptake of knowledge and new skills by attendees. For example, some training participants were not comfortable attending English language trainings, and the laboratories in which the trainings took place were often more advanced or modern than the trainees' home laboratories. Additionally, trainings were only able to accommodate one or two people, not all staff, from each participating laboratory. Invitations to travel to trainings were sometimes provided to higher ranking staff, not technicians, which meant the learning opportunities were not always received by the right person or people in the laboratory.

> *"Because [the training was] free, there was this definitely a side to this where there were high level officials who were sent to that training because it was free and then they would also get a per diem. And there was a problem in that it didn't hit the person on the ground who would be actually packaging and shipping materials." – CDC Interviewee*

> *For courses, it's definitely an issue of staff turnover or sometimes getting through the politics of each country, getting the right person there, not the person that wants the trip to whichever location we're doing it in. – Implementing Partner Interviewee*

While some of the offerings were sequential, or built upon one another, others were designed to be one-off sessions. For more advanced countries, the trainings were seen as an opportunity to refresh or refine skills. For less advanced countries, follow-up trainings and the dissemination of standard operating procedures and other resources designed for laboratory staff members were needed to reinforce KSA gains.

<u>Workforce</u>

Some of the barriers to maintaining gains realized from this project are more systemic and beyond the control of either CDC or implementing partners. Multiple interviewees and project documents described challenges related to inadequate staffing, namely the labs being understaffed and only having one or two persons trained in specific diagnostic procedures. For example, during a site visit to a west African country after a training, implementing partner staff discovered that while a national lab regularly collects samples from patients with respiratory symptoms and can run the differential diagnosis, testing was delayed because a single technician was responsible for testing for hepatitis, HIV and influenza and did not have the capacity to add additional testing to their workload.

Some interviewees and project documentation noted gaps in staff management, particularly issues around senior-level staff not recognizing and leveraging the more junior-level staff members' skills and abilities, preventing them from exercising their skillset in the laboratories. This lack of recognition, combined with lower salaries and wages from country-funded labs, contributes to the high staff turnover observed in many countries. Several interviewees and project documentation noted that laboratory staff members would often leave their country labs upon completing the trainings and workshops, taking their enhanced skill set to other multilateral agencies and nonprofit organizations that offered higher pay.

> *"…One more aspect probably worth noting is that there's a rapid turnover of staff in some of these countries, which means that once you have a very good person who is trained, he may leave and you have to start again. This aspect, we cannot really control because it's really up to those countries to manage their staff. But this was one of the aspects we experience, not in all countries, but in some of them." – Implementing Partner Interviewee*

> *"Once people in country get this experience, learn these new skills, and get proficient in all these tests, they move on to different jobs with better pay. And so there's a lot of turnover in the laboratories that are trying to establish these programs. And so it becomes an endless cycle of training, new people. Then they leave and you have to find someone else who can do the job well, and that's been a barrier." – CDC Interviewee*

> *"Sometimes, mostly those people that are trained under and don't have to be paid very well, and then after their training they look for an international, to go out of*

the country because they need the good salaries." – Beneficiary Laboratory Interviewee

Country-specific requirements created additional staffing challenges. For example, in Kenya, government laboratories only hire staff members that have a certificate issued by a specific group, limiting the number of people eligible for those positions.

"It's the Kenya Medical Technician Technology (?) group and basically that group regulates who can work in a lab and who can't. And you have to have a certificate from that group to get a laboratory job in the government. But the certificate costs $100, which is a lot of money for people here in Kenya. So that if people work in research laboratories, they tend to not have that certificate because it's too costly to get. And that policy really limits who can work in the lab. Even if you have a PhD, if you don't have that certificate you can't work in a government laboratory." – CDC Interviewee

Policies and Infrastructure

There were also barriers to successful project implementation related to laboratory-level infrastructure, practices, and policies. In some countries, governments only approve and fund a few centralized labs, resulting in a limited number of laboratories nationwide that have the capacity needed to test specific pathogens while maintaining containment and biosecurity protocols.

"…there isn't regional lab in capacity to do virology. It would be more efficient to have regional laboratories in capacities to do the first diagnostic (with Rapid Diagnostic Tests) and [the central laboratory] to do confirmation of samples, research and recommendations. Today the transport of samples from regions to [the central laboratory] and other labs is very difficult." – Implementing Partner Document

Site visits revealed that, despite being trained in how to use the IRR system, several national labs had not yet registered successfully for the IRR and did not have the supplies needed to perform testing.

"The role of a lab in the surveillance is very important, but our difficulties that we are not able every time to do some activities because of a lack of

material reactive reagent and training." - Beneficiary Laboratory Interviewee

Country-level policies sometimes placed limitations on the procurement of reagents. For example, in one country, reagents must have expiration dates at least a year in the future, which limited the types of available reagents the laboratory could invest in to build their capacity. Further complications often arise when countries receive reagents but do not have the space to store them appropriately. Additionally, many laboratories do not have biorepositories or other effective specimen storage areas or outlined procedures for specimen storage and management.

Several key informant interviewees noted issues with maintaining equipment and supplies, as the country laboratories do not have the funding necessary to maintain and repair the equipment provided to them as a part of these activities, rendering this equipment useless after a few years.

"You have also the problem of maintenance of the materials. Where you have something which out of service, they cannot just fix it." – Implementing Partner Interviewee

Other interviewees and project documentation noted that the labs did not have the proper equipment and supplies for pathogen detection or sample sequencing, leading to massive delays in outbreak response times.

"In [country], we do not have sequencing machines, and now that we are in the COVID outbreaks, we have to send samples out of [the country] to be sequenced." - Beneficiary Laboratory Interviewee

<u>Sustainability</u>

Some interviewees were concerned that once the supply and equipment dissemination through the project ceased, the laboratories would be unable or unwilling to maintain the capacity if the projects did not align with the ministries of health existing priorities.

"The reagents, those people are now obtaining most of them, the reagents, directly from the CDC. I don't know how this will be sustained." – Implementing Partner Interviewee

"For a lot of Ministries of Health, they see lots of partners come in to [the] country, implement a project for one, two or three years. But if they haven't totally bought in from the beginning, if the project doesn't actually address one of their priorities then it's not going to be sustainable. It's not going to have lasting impact" – CDC Interviewee

CONCLUSIONS AND RECOMMENDATIONS

This evaluation of the processes, outputs, outcomes, and impacts of the GHS Laboratory Capacity Building Projects was intended to help understand and answer five research questions selected by CDC NCIRD and APHL:

- Describe the context for the GHS Laboratory Capacity Building Projects and the overarching strategy.
- How much money did the CDC invest in NCIRD GHS Laboratory Capacity Building Projects?
- Describe how the GHS Laboratory Capacity Building Projects amplified and dampened CDC NCIRD goals and priorities?
- Describe how NCIRD GHS Laboratory Capacity Building Projects amplified and dampened country program goals and priorities?
- What can we learn about how to improve project implementation at CDC and partner organizations beyond the process evaluation already completed?

SGNL distilled these research questions into four themes – Overall Strategy, Understanding the Investment, Alignment with Goals and Priorities, and Project Implementation – and organized the conclusions and recommendations within these themes in the following section.

CONCLUSIONS

Overall Strategy

The Capacity Building Projects were relatively successful at achieving "easy wins" of providing necessary items to conduct surveillance activities to laboratories, increasing workforce competency to perform surveillance, and influencing laboratory policies and practices to maintain the improvements. However, staff, stuff, spaces, and systems must be maintained, and sustainable maintenance requires shifts in culture. The general strategy of going after "easy wins" may be inherently flawed. A few key informant interviewees mentioned the challenge of sustainability, especially with regard to talent, technology, and politics.

> *"When there is a new pathogen or something, we have old techniques and there are new techniques arriving on the market ... Help us improve the*

technical level of the laboratory. The same thing has to be done with human resources. Every year the refreshment of the training has to happen... I think that the three main things for us was funds that have to be mobilized very quickly, the strengthening of the laboratory capacity, equipment, reagents, and all those things, and the strengthening of human resources capacity. I think that if all of this are ready every time, if all of these are, that working on every time, we'll not be late every time when there will be an outbreak." – Beneficiary Laboratory Interviewee

"And yes, sadly, I don't know for sustainability … when you train people you're based on people. So, if they're not here or if they are not trained, because the training you have to do it and do it and do it again. You have to... It's a continual process even for the same person." – Implementing Partner Interviewee

"We have major challenges within the Ministry of Health around sharing of information and sharing of data between different partners within the government. … I don't think that any kind of CDC funded project on its own, can fix that. That's really a long-term effort that really requires a culture change and not just implementation of a project." – CDC Interviewee

Future projects must strike a balance between providing "quick fixes" that will provide short-term gains and consulting and aligning with those with power and authority to cultivate policy, system, and infrastructure changes.

Understanding the Investment

The Capacity Building Projects did not appear to suffer from a lack of funding, and the implementing partners successfully completed numerous activities. However, determining the NCIRD's investment (i.e., the initial funding amounts and actual expenses) with confidence is not possible with the information provided to SGNL. Understanding the investment requires accounting for budgeted funding, received funding, expenses, and funds carried forward from year to year for CDC, APHL, and IP. The information received for the cost analysis was not comprehensive (e.g., lacked data about initial funding amounts of IP, lacked expenses for many reported implementation partner activities). Furthermore, the analysis excludes, at the direction of CDC and APHL, the costs associated with salaries, operations, overhead, and equipment necessary for CDC, APHL, and IP to plan and implement the Capacity Building Projects. These

cost categories likely amount to a considerable portion of the investment. At best, SGNL's analysis was limited to considering funding and expenses for a selection of the Capacity Building Projects activities and not a thorough analysis of CDC's entire financial investment.

To understand the investment, one must also consider if the right amount of funding was provided to implement necessary and beneficial activities on a realistic timeline with good effect. Interviewees described challenges associated with receiving large amounts of money that needed to be spent quickly without a firm strategy.

> *"I have to say that things [were] a little rocky, at least on the CDC side, when this was all kicking off. Because there was a whole lot of money up for grabs. But it wasn't quite understood what expectations were attached to that money or how it could and could not be spent. So, if there was better planning for funding upfront, I think the money could have been used a little more efficiently." – CDC Interviewee*

> *"At the beginning there was a large bowl of some money that was rolled out on the heels of Ebola funding. And it was way too much money for the [*Capacity Building Project*] activities that were designed. And everyone knew that, or at least APHL knew that, maybe not some of the early folks at CDC. But I think they're just, honestly, trying to find homes for the money. And so, those activities, they were earmarked for certain things, but like I said they were not perfectly designed." – Implementing Partner Interviewee*

> *"I would like more clearly defined project goals at the outset, but that's not realistic. It's not realistic given the way we work, given the way federal appropriations happen when you might get this bucket of money that has to be spent really quickly and they're trying to obligate it to APHL, and we're going to figure out details later things change." – Implementing Partner Interviewee*

In addition to tracking the investment, the Capacity Building Projects lacked an overarching mechanism for monitoring and evaluation. While each implementing partner conducted some level of data collection on outputs and outcomes, methods and metrics were not consistent and no effort was taken to measure the "dose" of activities received by each participating country, laboratory, or individual. The implementing partners also experienced difficulty achieving high response rates when data collections occurred outside of trainings (i.e., when the respondents were not physically handed a survey to

complete before departing an activity). Finally, the monitoring and evaluation strategy lacked strategies for determining progress toward mid- and long-term outcomes.

Alignment with Stakeholder Needs and Priorities

The evaluation indicates that the Capacity Building Projects had a positive impact on a number of the short- and mid-term outcomes identified by NCIRD and APHL in the logic model. First, pre/post tests indicate that the trainings generated small gains in knowledge, skills, and abilities, and the high pass rates on the EQA challenges demonstrate the necessary laboratory capacity to detect specific non-influenza respiratory pathogens of interest. SGNL's survey (self-reported) and key informant interviews (perceived) confirm the gains in capacity. Second, the data (self-reported) show that most laboratories updated their organizational policies and practices to reflect the knowledge and skills gained via training and learned to make adjustments to protocol based on the equipment, supplies, and workforce available. While laboratory supplies and equipment were procured by implementing partners and distributed to central laboratories successfully, attempts to monitor use of the supplies and equipment were not successful. Similarly, the push to register laboratories to receive reagents through the IRR was successful, but there was no data to indicate how many specimens were tested using the reagents or if laboratories maintained their reagent supply after the initial distribution

In general, offsite trainings that included theory and practice followed by onsite practice and coaching seemed to generate positive outcomes and high participant satisfaction. This approach also benefited the implementing partners because it allowed them to more easily identify teachable moments to encourage self-assessment and asset-based troubleshooting.

While the implementing partners reported that a number of the later activities were successful because they were responsive to laboratories' stated needs, the overall impact of the projects might have been increased if all projects were designed based on expressed laboratory needs from the outset. That said, it is worth noting that multiple interviewees mentioned that non-influenza respiratory pathogens were not a focus for most participating laboratories prior to COVID-19, so SGNL might infer that this family of pathogens might not have been a priority.

"I'm not sure that - especially for the viral diseases - the countries necessarily wanted the capacity as visualized in the IRR draw downs, but I think that's one of the challenges. I think with COVID, we'll see more of a change because countries do want to expand their respiratory disease surveillance because it's apparent that that's the necessary thing in right now outside of influenza." – CDC Interviewee

"I would not say that [non-influenza respiratory pathogens] are priority pathogens for the government. And I would say that even influenza is probably not as high a priority as it should be." – CDC Interviewee

Program Implementation

The rapid initiation of the Capacity Building Projects did not permit sufficient time for planning. Both NCIRD and the implementing partners felt a sense of urgency to submit a budget and activities to secure the available funds. In many cases, this resulted in a mismatch between the budget amounts and the actual costs of activities. Rather than developing a strategic approach to increasing the capacity of the participating laboratories, the partners found themselves trying to come up with additional ways to invest the funds.

The materials and support provided to participating laboratories appear to be based primarily on the perceptions of CDC staff. In other words, the laboratories' self-defined priorities and strategic plans did not seem to drive decision-making, and the laboratories did not seem to be partners in the design process. While relying on CDC perceptions of laboratory KSA and material needs might be sufficient for identifying and satisfying short-term goals, long-term, systemic gains are not possible when laboratory leaders are not engaged in assessment, prioritization, and strategizing. The pilot test of the assessment tool conducted in Cameroon allowed the laboratory staff to participate in an objective assessment of their laboratory's strengths and weaknesses. Likewise, tabletop exercises, like the ones conducted by IP in Senegal, Cote d'Ivoire, and Cameroon, also provide opportunities for the laboratory staff to actively engage in assessment activities.

RECOMMENDATIONS

The following recommendations were developed based on an analysis and findings across all of the designated research areas. The recommendations have been organized into themes but are not prioritized. Individual recommendations were also provided from our survey of respondents regarding additional support needed to improve their capacity to detect pathogens and contribute to the identification and control of outbreaks.

Synthesized Recommendations from SGNL Interviews and Analysis

Overall Strategy

- Liaise with beneficiary health and laboratory leadership at the outset of program planning.
- Identify and coordinate with other efforts targeting laboratories.
- Identify metrics for mid- and long-term outcomes (e.g., creation of regional reference centers, reflection of laboratory needs in MOH and country budgets/policies, shifts in university training programs).

Understanding the Investment

- Implement practices at the programmatic level to more easily record budgeted funding, received funding, expenses, and funds carried forward year to year.
- Leverage external monitoring activities (e.g., e-SPAR[1], JEE assessments, WHO outbreak reporting) to assess long-term impacts.
- Explore contractual and social mechanisms for enforcing participation in monitoring and evaluation activities.
- Document agreed-upon priorities, goals, and performance metrics for participating laboratories
- Develop core questions regarding achievement of common learning objectives and participant experience for inclusion in activity evaluations.
- Develop standard evaluation approaches (e.g., data collection methods, participant identifiers, timing of follow-ups, time to complete, use of incentives) for use by all implementing partners.

[1] Electronic State Parties Self-Assessment Annual Reporting Tool (e-SPAR) is a web-based platform proposed to support State Parties of the International Health Regulations (IHR) to fulfil their obligation to report annually to the World Health Assembly (WHA) on the implementation of capacity requirements under these Regulations and to encourage the transparency and mutual accountability between States Parties towards global public health security, under the WHO IHR Monitoring and Evaluation Framework. The tool includes a section of laboratory capacity and appears to contain data from 2010 to the present. The tool is located here: https://extranet.who.int/e-spar/#capacity-progress.

- Explore options for online performance monitoring systems to measure individual, laboratory, and country metrics and online repositories for data storage.

Alignment with Stakeholder Needs and Priorities

- Assess public health laboratory workforce competencies (i.e., the knowledge, skills and abilities necessary for public health laboratory professionals to deliver core services efficiently and effectively) for participating laboratories in order to 1) establish training cohorts based on competency level, 2) justify invitations based on need, not seniority, and 3) develop tailored capacity building plans.
- Assess public health laboratory capabilities and capacity (e.g., count and characterization of "stuff, staff, space, systems" (CDC, 2020)) in order to develop tailored capacity building plans.
- Engage with laboratory leaders to review their laboratory's assessment results to generate shared understanding of assets and vulnerabilities.
- Engage with laboratory leaders in the design phase to tailor capacity building plans to meet their perceived needs and strategic priorities.
- Consult with ministries of health to align capacity building plans with their strategic priorities to improve buy-in and increase sustainability.

Program Implementation

- Consult with CDC Country Office staff to identify how initiative complements, duplicates, or conflicts with contemporaneous activities.
- Work collectively with all implementing partners to design and implement crosscutting project elements (e.g., learning curriculum, performance management, participant communication).
- Identify points of contacts and communication protocol for each country to ensure culturally and politically appropriate outreach and account for staff turnover.
- Develop short, mid, and long-term learning objectives for all learning activities using a model like blooms taxonomy.[2]
- Establish multi-modal learning pathways (e.g., didactic courses, hands-on exercises, peer coaching, expert mentorship) for training cohorts.
- Ensure all capacity building materials are available in appropriate languages and reading comprehension levels and in accessible formats.
- Design capacity building activities that cultivate peer-to-peer learning and sharing.
- Assess technological capabilities of laboratorians from participating countries in order to determine how appropriate coursework can be delivered via synchronous and asynchronous online learning.
- Expand course offerings to include development of SOPs, continuous quality improvement, people management, scientific writing, and bioinformatics.

[2] For more on blooms taxonomy, see https://tips.uark.edu/using-blooms-taxonomy/.

- Identify appropriate implementing partners for activities, especially procurement and supply.

Individual Recommendations from Country Participants

SGNL's survey of training participants included a question about additional areas of need. Fifty-nine individuals from 22 countries responded to this question. Several respondents expressed the need for additional training in molecular diagnosis, additional pathogen detection techniques using different types of equipment and supplies, outbreak response procedures, sequencing, laboratory quality management, sample transport systems, biosafety topics, and scientific writing. Respondents requested more individual or country lab-specific attention, highlighting the value of mentorships and site visits. The table in Appendix E provides the individual responses by country.

APPENDIXES

Appendix A – Evaluation Plan

EVALUATION OF A GLOBAL HEALTH SECURITY PUBLIC HEALTH LABORATORY CAPACITY BUILDING INITIATIVE

Evaluation Plan
April 17, 2020

GLOBAL HEALTH SECURITY PROJECT

RATIONALE

According to the CDC, global health security is the existence of strong and resilient public health systems that can prevent, detect, and respond to infectious disease threats, wherever they occur in the world. The Ebola epidemic of 2014 exposed major weaknesses in the world's collective capacity for preventing, detecting, and responding to biologic threats. The Global Health Security Agenda (GHSA), launched in 2014, aims to address global vulnerability to public health threats, by building safe, secure, and strong laboratories, ensuring a well-trained and well-equipped workforce, encouraging multi-sectoral collaboration, creating reliable and sensitive real-time disease surveillance systems; and standing up command structures to coordinate an effected and focused response. In the United States, the Centers for Disease Control and Prevention (CDC) works directly with partner country governments to strengthen public health systems and reduce the risk of infectious disease outbreaks.

GOALS

Since 2016, the Association of Public Health Laboratories (APHL) has collaborated with the CDC National Center for Immunization and Respiratory Disease (NCIRD) to build public health laboratory capacity to detect and respond to respiratory disease outbreaks in alignment with the GHSA. The GHS project was intended to provide "quick wins" for building national laboratory capacity. Two overarching objectives guided a variety of project activities: (1) build and sustain laboratory capacity for pathogen detection and outbreak response and (2) improve specimen transport quality and efficiency. Over four years, dozens of countries across Africa and Asia received diagnostic kits, external quality assessment (EQA) panel reviews, support for packaging and shipping specimens, training on laboratory skills, and other capacity building assistance. Institute Pasteur (IP) was also a partner in implementation.

TIMELINE

Federal funding for NCIRD's GHS Project was allocated in 2015, and implementation via APHL and IP kicked off in 2016. While activities continued during 2020, only those completed by calendar year 2019 will be included in the evaluation.

LOGIC MODEL

Assumptions

- JEE establishes global standards for laboratory capacity
- Targeted countries were the best fit for "quick wins"
- CDC HQ and Country Offices had interest and resources to take action
- APHL and IP were trusted sources for capacity building activities
- CDC agenda/priorities aligned with Country MOH agendas/priorities

Context Over Project Period

- APHL and IP now have CDC cooperative agreement specific to GHSA
- Country and laboratory capacity varies
- CDC has had two new directors since GHSA established
- New president/administration brought shift in how CDC agenda was framed (if not shift to actual agenda) – "a threat anywhere is a threat everywhere"
- Variation in internal and external measures of project success

Inputs	Outputs (Activities, Products)	Outcomes/Impacts		
		Short Term	Medium Term	Long Term*
● International Reagent Resources (IRR) ● CDC (funding, subject matter expertise, strategy) ● Laboratories in Asia and Africa ● APHL (management, subject matter expertise)	● External quality assessment (panel and results) ● Workforce development (in-person trainings) ● Provision of equipment and supplies (specimen transport, reagents) ● Capacity Building Assistance (outbreak	● Equipped to transport, receive, maintain, and store specimens ● KSA to ship specimens domestically and internationally ● Equipped with supplies and equipment for specific	● Laboratories are providing reliable data to external partners ● Laboratories are contributing to evidence base/scientific community ● Laboratories have implemented policy and practice	● Laboratories are self sufficient ● Decrease in disease burden ● Improved quality of surveillance ● Increase in timeliness of outbreak response ● Increase in global health security

● Institute Pasteur (management, subject matter expertise) ● Supplies, equipment, EQA panels ● Previously developed tools/materials	response consultations, Measles/rubella self-assessment tool, E-learning modules for writing, transport) ● Peer Support ("Mentorship program", Discussion forum for writing, transport)	respiratory pathogen testing ● KSA to use test kits to perform testing according to quality standards ● KSA to detect pathogens of interest ● KSA to implement quality improvement activities based on EQA results	changes based on GHS Project activities ● Laboratories have implemented packaging and shipping supplies into specimen transport systems ● Increase in JEE scores (unlikely to get for this project period as each country only has one score)	*not in eval scope

GHS PROJECT RETROSPECTIVE EVALUATION

OVERVIEW

APHL contracted with SGNL Solutions (SGNL) to conduct an inventory and analysis of the collective GHS activities funded by NCIRD and implemented by APHL and IP between 2016 and 2019. SGNL will employ basic quantitative and qualitative research methods to describe the GHS project investment, showcase how GHS activities advanced stakeholder goals and priorities, and understand how to improve future efforts.

STAKEHOLDERS

Org	People	Project Role	Evaluation Role	How to Engage
CDC NCIRD	Susan Hiers Jill Woodward	Funder Apply results	• Review work products • Provide access to data • Participate in data collection	Regular emails and phone calls
APHL	Kelly Wroblewski, Stephanie Chester Liz Toure Evaluation staff	Implementation Apply results	• Review work products • Provide access to data • Participate in data collection	Regular emails and phone calls
IP	TBD	Implementation	• Provide existing data	Access via CDC
IRR	TBD	Supply Implementation	• Provide existing data	Access via CDC
QCMD	TBD	EQA Implementation subcontractor (project period complete)	• Provide existing data	Access via APHL
CDC Country Office	CDC in-country staff	Liaison	• Prime labs for evaluation activities • Participate in key informant interviews • Provide data/information	Access via CDC
Country Ministry of Health (MOH)	TBD	Beneficiary	None	Not Applicable
Country Labs	TBD	Participant (workforce trainings to individual staff)	• Participate in key informant interviews • Complete surveys • Provide data/information	Access via CDC
CDC Leadership	Division Director CDC Director	Apply results	None	Not Applicable

RESEARCH QUESTIONS

SGNL, APHL, and CDC developed a set of core evaluation questions for the GHS project evaluation project.

1. Describe the context for the GHS projects and the overarching strategy.
2. How much money did the CDC invest in NCIRD GHS activity implementation?
3. Describe how NCIRD GHS activities amplified and dampened CDC NCIRD global center goals and priorities (e.g., build strong lab systems, improve sustainability and accessibility to quality laboratory diagnostics for under resourced countries). *FYI these were developed after the APs were implemented.
4. Describe how NCIRD GHS activities amplified and dampened country program goals and priorities?
5. What can we learn about how to improve project implementation at CDC and partner organizations beyond the process evaluation already completed?

DATA INVENTORY

SGNL designed and conducted a data inventory and gap analysis. The purpose of the data inventory was to catalog and assess the qualitative and quantitative information sources made available by APHL and CDC NCIRD. The purpose of the gap analysis was to determine what additional information was needed to answer the research questions. The Gap Analysis Brief was previously provided to CDC and APHL.

RESEARCH APPROACH

Using the research questions, logic model, and gap analysis, SGNL developed a mixed-methods retrospective evaluation plan. Given the current stresses on the public health system, the approach is designed to maximize data collection while minimizing burden on key stakeholders. We will adapt our approach based on the impact of COVID-19 on stakeholders' availability to participate.

Because the data available for the project are not uniform across activities in timing or measures, it is not possible to easily conduct a pre-post outcomes assessment. Instead, the aim of the research approach is the describe the GHS project, how it aligns with complementary efforts, and the benefits for stakeholders. In addition, SGNL seeks to elucidate successes and challenges in order to improve future initiatives.

SGNL will conduct primary data collection and perform analyses of secondary data to assess select impact and outcomes of the GHS initiative. SGNL will provide summary data across all participating labs when possible. SGNL will collaborate with CDC and APHL to select five to seven labs for more details impact and outcome case studies. The methods and measures are summarized below. Drafts of the data collection strategies are provided in the appendix.

Summary of Primary Data Collection

Method	Measures	Respondents
Key Informant Interview (90 minutes)	Questions related to project initiation and design, alignment with national priorities, funding/resource allocation, and barriers/facilitators	CDC
Key Informant Interview (90 minutes)	Questions related to project implementation, alignment with country priorities, impacts/outcomes, and barriers/facilitators	CDC Country Office
Key Informant Interview (90 minutes)	Questions related to project participation, alignment with lab priorities, impacts/outcomes, and barriers/facilitators	Select Labs
Key Informant Interview (90 minutes)	Questions related to project design and implementation, resource allocation, and barriers/facilitators	APHL
Online Survey (~15 minutes)	Questions related to participation, impacts/outcomes, and experience	All individuals who attended trainings
Literature Search	Review of literature for publications from participating labs	Not Applicable

Summary of Secondary Data Analysis Methods

Data Source	Analysis/Synthesis
Budgets	Total cost
Concept Notes & Annual Reports	Project description and context
Training/TA Pre/Post Surveys and Reports	Participation rates, impact on individual KSA, and satisfaction with trainings/TA
JEE Results	Description of lab capacity
Lab Policies (pending collection)	Changes to lab policy based on capacity building assistance and resources provided
IRR Drawdown	Uptake of materials and supplies
Materials Procurement and Distribution Documentation	Uptake of materials and supplies

Synthesis and Reporting

SGNL will code, synthesize, and summarize the qualitative and quantitative data to answer the research questions. SGNL will review the preliminary findings with APHL and CDC NCIRD to facilitate synthesis and interpretation for specific stakeholders and audiences. SGNL will prepare a final evaluation report in MS Word layout/format without professional graphic design. SGNL will be available to consult with APHL on the development of collateral materials (e.g., infographics, project briefs, webinars).

Literature Review Methods

SGNL will research and compile peer-reviewed literature, books, dissertations, conference proceedings, and other relevant documents using the following information.

Search Parameters	Date Range: 2016 to Present Countries: TBD Authors: TBD Institutions: TBD
Databases	PubMed
Search Engines	Google, Google Scholar
Key Words and MeSH Terms	TBD

Key Interview Scripts

Thank you for agreeing to do this interview. My name is [NAME], and I'll be talking with you today. [Introduce other project staff on the phone if needed.]

This project is being funded by the Association for Public Health Laboratories (APHL) in partnership with the CDC.

The purpose of this interview today is to understand the impact of the Global Health Security (GHS) Acceleration Projects (APs) in the context of laboratory gains.

The interview will last about [60-90 minutes] hour.

You read and signed the consent form that was sent to you. Do you have any questions about it?

- We are recording this interview. Is that ok?
- We do not intend to attribute stories and quotes to individuals, but will include the organization type and country.
- At any time during our conversation, you can let me know if you have any questions or if you would rather not answer any specific question. You can also stop the interview at any time for any reason.
- Please remember that we want to know your perspectives and that there are no right or wrong answers.

Questions

CDC	APHL	Country Offices	Labs
Background ● I'd like to begin by asking you some questions about your role in the GHS Project implementation. ○ What was your position at [CDC/APHL/IP]? ○ What were your major responsibilities in that position as they related to GHS Project? ● Next I would like to discuss the implementation of the GHS Project. ○ What were the activities designed for each strategy and why were they selected? ▪ How were the activities developed over time? ▪ Were there interim goals to monitor the progress towards the desired outcomes? ○ How were the labs chosen at the outset? ▪ How did the initiative align with the lab lifecycle? ○ What external forces helped/hindered the implementation? ○ Were any changes or edits implemented during the project, and if so, what were	Context / Background ● I'd like to begin by asking you some questions about your role in the GHS AP implementation. ○ What was your position at [CDC/APHL/IP]? ○ What were your major responsibilities in that position as they related to GHS Project? ● Next I would like to discuss the implementation of the GHS Project. ○ What were the activities designed for each strategy and why were they selected? ▪ How were the activities developed over time? ▪ Were there interim goals to monitor the progress towards the desired outcomes? ○ How were the labs chosen at the outset? ▪ How did the initiative align with the lab lifecycle? ○ What external forces helped/hindered the implementation? ○ Were any changes or edits implemented during the project, and if so, what were	Context/ Background ● How were labs chosen at the outset? ● Which GHS Project saw the greatest impact? NCID Goals and Priorities ● I would like to discuss how APs amplified or dampened CDC NCIRD global center goals and priorities. ○ What were the global center goals and priorities? ○ Did the APs help achiev	Context/ Background ● Which GHS Project were implemented in your lab? ○ How were the activities developed over time? ○ Which activities led to increased knowledge among staff members? ○ Which activities led to improved lab policies? ● How many members from your lab participated in APs? ○ How was information learned in training disseminated across lab personal? ▪ Prompt: What did these trainings look like? Who particip

they and what was the outcome? ▪ Which activities saw the greatest impact? NCID Goals and Priorities ● I would like to discuss how APs amplified or dampened CDC NCIRD global center goals and priorities. ○ What were the global center goals and priorities? ○ Did the APs help achieve global center goals and priorities? ▪ Prompt: were there gains in terms of lab system strengthening or sustainability and accessibility to quality diagnostics? Country program goals and priorities ● Were there any ISO/JEE metrics that were not improved after activities were implemented? ○ What could be done in the future to target and improve these metrics? ○ Was information obtained through the workshops and trainings brought back to other laboratory workers/ were changes implemented across the laboratory workforce? ▪ If not, what can be done to ensure that this information is	they and what was the outcome? ▪ Which activities saw the greatest impact? NCID Goals and Priorities ● I would like to discuss how APs amplified or dampened CDC NCIRD global center goals and priorities. ○ Did the APs help achieve global center goals and priorities? ▪ Prompt: were there gains in terms of lab system strengthening or sustainability and accessibility to quality diagnostics? Country program goals and priorities ● Were there any ISO/JEE metrics that were not improved after activities were implemented? ○ What could be done in the future to target and improve these metrics? ○ Was information obtained through the workshops and trainings brought back to other laboratory workers/ were changes implemented across the laboratory workforce? ▪ If not, what can be done to ensure that this information is reaching laboratory workers that did not	e global center goals and priorities? ▪	ated? NCID Goals and Priorities ● I would like to discuss how APs amplified or dampened CDC NCIRD global center goals and priorities. ○ Did the APs help achieve global center goals and priorities? ▪ Prompt: were there gains in terms of lab system strengthening or sustainability and accessibility to quality diagnostics? Gaps/Barriers ● Finally, I would like to discuss any gaps or barriers identified during the GHS AP implementation timeline ○ If we have this opportunity

reaching laboratory workers that did not personally participate in program activities? ○ How can laboratory capacity be improved in resource limited settings? ▪ What could be done to minimize the time, money, and effort needed to implement practices that would meet ISO/JEE metrics? ▪ How can laboratory personnel participate in ongoing trainings/stay informed of changing guidelines and recommendations? Funding ● Now I would like to discuss GHS AP funding. ○ Where did the funding come from? ○ What was the total CDC NCIRD budget for each funding year? ▪ What was distributed to APHL? To IP? ○ What constraints or limitations were place on funding? ▪ Prompt: in terms of timeline, topics, type of activity, etc.	personally participate in program activities? ○ How can laboratory capacity be improved in resource limited settings? ▪ What could be done to minimize the time, money, and effort needed to implement practices that would meet ISO/JEE metrics? ▪ How can laboratory personnel participate in ongoing trainings/stay informed of changing guidelines and recommendations? Funding ● Now I would like to discuss GHS AP funding. ● How did [APHL/IP] use the funding allocated to them? ○ Prompt: how was the funding allocated across broad strategy "buckets" Gaps/Barriers ● Finally, I would like to discuss any gaps or barriers identified during the GHS AP implementation timeline ○ What lessons learned should be considered when seeking to do similar activities in the future?		again, what should we prioritize? ○ What do you believe is the biggest gap/barrier that your laboratory faces? ▪ What could be done to mitigate this gap/barrier?

Gaps/Barriers ● Finally, I would like to discuss any gaps or barriers identified during the GHS AP implementation timeline ○ What lessons learned should be considered when seeking to do similar activities in the future? ○ If we have this opportunity again, what should we prioritize? ○ How should we address past and remaining gaps?	○ If we have this opportunity again, what should we prioritize?		

		Exposure to GHS Project ● What did the labs gain in terms of staff, stuff, space, and systems? ○ Has the lab's capacity increased since AP implementation? Gaps/Barriers ● Finally, I would like to discuss any gaps or barriers identified during the GHS AP implementation timeline ○ What gaps/barriers did	

		you encounter during AP implementation? ▪	

Closing

- Is there anything else that you would like to add or other areas that we didn't discuss but you think are important?
- Thank you for your time and participation in this interview. The information that you provided to us will be very helpful in this project.
- We will be in touch if we have any questions about your responses.

**Following the interview, send the participant an email to thank them for participating and request access to data they mentioned and/or for introductions to people they mentioned.

Training Participant Survey Questions

1. Please indicate the activities in which you participated.
   [List of activities by name, location, and date]

2. Indicate the extent to which you agree with each statement below. [Likert Scale]
   [generated based on response to Q1]
   - As a result of [Training Title], I am better able to ship specimens inside my country.
   - As a result of [Training Title], I am better able to ship specimens outside my country.
   - As a result of [Training Title], I am better able to use test kits according to quality standards.

3. Did you do anything transfer the knowledge you gained from the trainings to other employees who were unable to attend the in-person trainings.
   - Yes
   - No
   - Not sure

   [If yes] Please describe how you shared what you learned.
   [Free response box]

4. Did your lab make any changes to its policies or protocols based on participating in the trainings? Please select all that apply.
   - Yes
   - No
   - Don’t know

   [If yes] Please describe how you shared what you learned.
   [Free response box]

5. Have you published or submitted for publication any peer-reviewed papers sine 2016?
   [If yes] Please describe.

[Free response box]

6. What additional support do you need to improve your capacity to detect pathogens and contribute to the identification and control of outbreaks?
   [Free response boxes for knowledge, skills, supplies, equipment, other]

Appendix B – Gap Analysis Brief

EVALUATION OF A GLOBAL HEALTH SECURITY
PUBLIC HEALTH LABORATORY CAPACITY BUILDING INITIATIVE
Gap Analysis Brief
2020 ,March 27

BACKGROUND

The GHS public health laboratory evaluation focuses on answering five core research questions.

1. Describe the context for the GHS projects and the overarching strategy and activities.
2. How much money did the CDC invest in NCIRD GHS activity implementation?
3. Describe how NCIRD GHS activities amplified and dampened CDC NCIRD global center goals and priorities?
4. Describe how NCIRD GHS activities amplified and dampened country program goals and priorities?
5. What else can we learn about how to improve project implementation at CDC and partner organizations (beyond the process evaluation already completed)?

In order to design an evaluation strategy, SGNL designed and conducted a data inventory and gap analysis. The purpose of the data inventory was to catalog and assess the qualitative and quantitative information sources made available by APHL and CDC NCIRD. The purpose of the gap analysis was to determine what additional information was needed to answer the research questions.

METHODS

APHL provided SGNL with access to a collection of documents that provide formative, process, and impact data for the activities implemented as part of the global health security laboratory capacity building project. The collection consisted of 82 documents across 15 succinct activities. The documents covered a range of information, including:

- Concept notes and proposals,
- Pre-, post-, and six-month survey data for training activities,
- EQA panel results,
- Budgets, invoices, receipts,
- Supply inventories, and
- Activity and annual reports.

SGNL created an excel inventory tool to systematically assess the content, completeness, and fit of each data source. Each document was assessed individually for the variables listed in the table below.

Variable	Definition
Source ID	Input the source ID assigned by SGNL
Document Name	Input the file name
Document Type	Describe the information collection methodology/information type (e.g., pre/post, interview, count, description)

Time period data collected	Describe when the information was collected
Respondents	Name the entity that completed the tool or provided the information (e.g., individual, lab, organization)
Administrator	Name the entity that administered the tool/collected the data or created the document.
Measurement/assessment	List what was measured/assessed/described in the document
Source type	Indicate if this is a primary or secondary information source
Data storage location	Indicate where the information is stored
Standard for comparison	Indicate if there is a standard for comparison (i.e., a widely accepted/expected/desired outcome)
Data availability	Indicate if SGNL has access to the information
Issues	List any issues or concerns with the information source (e.g., quality, completeness)

The SGNL team received training on how to use the inventory tool. Then, each reviewer completed the tool for all documents associated with one activity. The team collectively reviewed and reconciled the results to improve interrater reliability. All of the documents were assigned a unique ID by SGNL and randomly assigned to reviewers to input into the inventory tool. The complete data inventory spreadsheet is available for review.

GAP ANALYSIS

After completing the inventory, SGNL conducted a gap analysis to ascertain the extent to which the research questions could be answered with the information available and what additional information is needed. The table below demonstrates how the available data aligns with research questions.

Research Question	**Information Sources**
Describe the context for the GHS projects and the overarching strategy and activities.	● IRR contract expansion (03_01) ● NCIRD meningitis annual reports (14_01; 14_02; 14_03) ● NCIRD annual reports (14_04; 14_05; 14_06)
How much money did the CDC invest in NCIRD GHS activity implementation (initial amount and actual expenses)?	● QCMD EQA Proposal (2_03) ● Acceleration Project Concept Development IRR Contract Expansion_NCIRD (3_01)

	● Lab capacity (Guinea) budget, budget update, purchase orders (04_02; 04_03; 04_01; respective) ● Lab Impact Workshop_Johannesburg 2018_Budget Tracking (05_04) ● Atlanta 2017 Bacterial Meningitis Budget (6_06) ● Budget for Year 1 - Training lab budget (08_04) ● Acceleration Project Concept Development Multiple Diagnostics_NCIRDLABGHS (9_01e) ● Packaging-Shipping_MasterWorkbook (10_14) ● Budget Summary Vietnman shipping training 2017 (Hanoi) (11_11) ● Workshop Contractor Final Revised Project Budget - 2019 International Scientific Writing Workshop (12_05)
Describe how NCIRD GHS activities amplified and dampened CDC NCIRD global center goals and priorities?	● GHSA annual reports (2016, 2017, 2018 (15_02; 15_03; 15_01, respectively) ● NCIRD annual reports (14_04; 14_05; 14_06) ● Impact workshop (05_01; 05_05) ● Meningitis workshop (06_02; 06_03) ● Molecular training (08_01)
Describe how NCIRD GHS activities amplified and dampened country program goals and priorities.	● Senegal JEE (15_04) ● GHSA annual reports (2016, 2017, 2018 (15_02; 15_03; 15_01, respectively) ● EQA (02_01; 02_02) ● 2016 NCIRD workshop summary (01_01) ● Pre- and post-test summary (01_02) ● individual countries impact assessments (01_03 [folder]) ● IP/CDC/NCIRD training (08_07) ● Country dashboard (03_02) ● Meningitis workshop (06_05) ● Packaging and shipping materials (10_14) ● Packaging and shipping workshop [Uganda] (11_01; 11_06), [Vietnam] (11_10) ● Scientific workshop (12_01; 12_03)

What else can we learn about how to improve project implementation at CDC and partner organizations?	● Workshop summary reports (05_02; 06_02) ● 2016 NCIRD workshop summary (01_01)

NEXT STEPS

The gap analysis revealed that additional information is needed to complete the evaluation. The information needs for which SGNL believes there are existing secondary sources are listed below, by partner/source. In addition, SGNL will design primary data collection methods to collect information that cannot be obtained via secondary sources.

CDC
- RFPs/NOAs related to initiative
- NCIRD annual workplans related to initiative
- NCIRD annual reports related to initiative

APHL/IP
- Any remaining workplans/budgets for activities
- Documentation of distribution of procured materials
- Summary data for non-training/non-material activities (e.g., peer groups, toolkits)
- Identification of individual respondent, survey questions, and/or raw data for select trainings (see table below)

Other
- JEE reports by participating lab/country
- 2017 EQA results by participating lab
- IRR drawdown by participating lab
- WHO surveillance compliance by country (source: WHO website or CDC Country Offices)

Missing Data by Training/Workshop

Training/Workshop	Identification of individual respondents	Survey questions	Raw data
Molecular training on respiratory viruses)	08_01 – identification of individual responses for 4 labs (follow up): Benin, Togo, Mauritania, RDC 08_03 - identification of individual responses for 10 countries (baseline data): Benin; Burkina Faso; Cameroon; Cote d'Ivoire; Guinee; Mali; Mauritania; RDC; Senegal; Togo	08_01 – questions for follow up survey 08_05 - template of baseline survey	Not provided
Outbreak laboratory response workshop	Not provided		
Meningitis training	06_02 summary report of pre/post and 6 month follow up for 8 countries: Bangladesh; Gambia; Ghana; India; Liberia; Nigeria; Sierra Leone; Togo	06_02 pre/post test, 6mo follow up questions	06_05 raw data for pre/post, but countries unidentified
CDC Division of Viral Diseases (DVD) molecular training	01_01 summary report for 8 countries: Bangladesh; Burkina Faso; Cameroon; Cote d'Ivoire; Pakistan; Senegal; Uganda; Vietnam	01_03 post-training assessments for 7 countries: Bangladesh; Burkina Faso (2); Cameroon; Senegal; Uganda; Vietnam	01_02 raw data, but countries unidentified
Bacteriology and molecular diagnostic training for meningitis	Not provided		
Laboratory impact meeting	05_02 summary report for 22 countries: Bangladesh; Benin; Burkina Faso; Cameroon; Cote d'Ivoire; DRC; Ethiopia; Ghana; Guinea; Guinea-Bissau; Indonesia; Liberia; Mali; Mauritania; Niger; Nigeria; Pakistan; Senegal; Tanzania; Togo; Uganda; Vietnam	Not provided	Not provided
Scientific writing workshop	12_03 summary report for 10 countries: Benin; Gambia; Guinea; Kenya; Mali; Nigeria; Senegal; Sierra Leone; Togo; Uganda	Not provided	12_01 - Raw pre/post test scores, but countries unidentified
Meningitis training in Kankan Guinea 2018	Not provided		
Uganda Packing and Shipping Workshop	Not provided	11_05 survey questions	11_01, 11_02 scanned in surveys; no excel sheet
Vietnam Packing and Shipping Workshop	11_10 summary data; no countries identified	11_09 survey questions	Not provided

Appendix C – Final Data Collection Tools (Surveys and Interview Script)

Training Participant Survey
Email Invitation—English Version

Subject line: SGNL Solutions Invitation: Survey of APHL and IP Laboratory Training Impact

Dear [participant],

We are contacting you because our records indicate that you participated in one or more of the laboratory training activities offered by the Association of Public Health Laboratories (APHL) and Institut Pasteur between 2016 and 2020.

In collaboration with APHL and the US Center for Disease Control and Prevention (CDC), SGNL Solutions is conducting a survey of training participants to assess the impact of the trainings on public health laboratory capacity to detect and respond to respiratory disease outbreaks. We will also use the information gathered to improve future initiatives. We would greatly appreciate your participation in this survey.

The survey will take you around 15 minutes to complete. Your answers will be kept strictly confidential and will be reported publicly only in aggregate with other responses.

Please complete the survey by [Date 3 weeks from launch]. Click this link to begin: [link].

If you have any questions, please email me at lstrack@sgnl.solutions.

Thank you,

Lindsay Strack
Senior Research Analyst/Consultant
SGNL Solutions
www.sgnl.soltuions

TRAINING PARTICIPANT SURVEY QUESTIONS

SGNL Solutions is conducting a survey of Association of Public Health Laboratories (APHL) and Institut Pasteur training participants to assess the impact of the trainings on public health laboratory capacity to detect and respond to respiratory disease outbreaks. We will also use the information gathered to improve future initiatives.

The survey will take you around 15 minutes to complete. Your answers will be kept strictly confidential and will be reported only in aggregate.

1. Please indicate the activities in which you participated.

- € CDC molecular training (RT PCR Assays) | July 2016 | Georgia, USA
- € Molecular training on respiratory viruses | March 2017 | Yaoundé, Cameroon
- € Packaging and shipping training | March 2017 | Entebbe, Uganda
- € Packaging and shipping training | June 2017 | Vietnam
- € Outbreak Response Workshop | July 2017 |Dakar, Senegal
- € Bacteriology and molecular diagnostic training for meningitis | Sept. 2017 | Georgia, USA
- € Outbreak Response Workshop | September 2017 | Abidjan, Cote d'Ivoire
- € Meningitis training | February 2018 | Paris, France
- € Outbreak Response Workshop | February 2018 | Yaoundé, Cameroon
- € Bacteriology and molecular diagnostic training for meningitis | May 2018 | Minnesota, USA
- € Bioinformatics training | Sept. 2018 | Paris, France
- € Bacteriology and molecular diagnostic training for meningitis | Oct. 2018 | Georgia, USA
- € Meningitis training | Oct./Nov. 2018 | Georgia, USA
- € Scientific writing workshop | July 2019 | Dakar, Senegal

2. Indicate the extent to which you agree with each statement below.

If selected from Q1	Display
● Molecular training on respiratory viruses | March 2017 | Cameroon ● CDC molecular training (RT PCR Assays) | July 2016 | Georgia	*I am better able to use molecular testing methods to detect non-influenza respiratory viruses.*
● Outbreak response workshop | July 2017 | Senegal ● Outbreak response workshop | Sept. 2017 | Cote d'Ivoire ● Outbreak response workshop | Feb. 2018 | Cameroon	*I am better able to create an operational plan that includes measures that must be taken in the context of an epidemic.*
● Meningitis training | Feb. 2018 | Paris	*I am better able to use laboratory methods to identify agents involved in acute bacterial meningitis.*
● Packaging and shipping training | March 2017 | Uganda ● Packaging and shipping training | June 2017 | Vietnam	*I am better able to transport and handle specimens.*
● Bacteriology and molecular diagnostic training for meningitis | Sept. 2017 | Georgia	*I am better able to detect and serotype meningitis pathogens.*

● Bacteriology and molecular diagnostic training for meningitis | May 2018 | Minnesota ● Bacteriology and molecular diagnostic training for meningitis | Oct. 2018 | Georgia	
● Scientific writing workshop | July 2019 | Senegal	*I am better able to prepare existing data for manuscript publication.*
● Meningitis training | Oct./Nov. 2018 | Georgia	*I am better able to detect bacterial meningitis pathogens, including Streptococcus pneumoniae, and Haemophilus influenza.*
● Bioinformatics training | Sept. 2018 | Paris	*I am better able to prepare samples for next generation sequencing and analyze and exploit next generation sequencing results.*

3. Did you transfer the knowledge you gained from the trainings to other employees who were unable to attend the in-person trainings?
    - o Yes
    - o No
    - o Not sure

3a. Please describe how you shared what you learned in the training with your colleagues.

_____

4. Did your lab make any changes to its policies or protocols based on participating in the trainings?
    - o Yes
    - o No
    - o Not sure

4a. Please describe the changes to policies or protocol.

_____

5. Have you published or submitted for publication any peer-reviewed papers since 2016?
    - o Yes
    - o No
    - o Not sure

5a. Please provide a citation for your publication.

_____

6. What additional support do you need to improve your capacity to detect pathogens and contribute to the identification and control of outbreaks?

   _____

French Version

Invitation par courrier électronique

Objet : Invitation de SGNL Solutions : Enquête sur l'impact la formation en laboratoire de l'APHL et du partenaire d'exécution

Cher\Chère [participant (Centers for Disease Control and Prevention)],

Nous vous contactons car nos dossiers indiquent que vous avez participé à une ou plusieurs des activités de formation en laboratoire proposées par l'Association des laboratoires de santé publique (APHL) et l'Institut Pasteur entre 2016 et 2020.

En collaboration avec l'APHL et les Centres pour le contrôle et la prévention des maladies (CDC), SGNL Solutions mène une enquête auprès des participants aux formations afin d'évaluer l'impact des formations sur la capacité des laboratoires de santé publique à détecter et à répondre aux épidémies de maladies respiratoires. Nous utiliserons également les informations recueillies pour améliorer les initiatives futures. Nous vous remercions de votre participation à cette enquête.

L'enquête vous prendra environ 15 minutes. Vos réponses resteront strictement confidentielles et ne seront rendues publiques que sous forme agrégée avec les autres réponses.

Veuillez répondre à l'enquête avant le [. Date 3 semaines après le lancement]. Cliquez sur ce lien pour commencer : [lien].

En cas de questions, veuillez m'envoyer un courriel à lstrack@sgnl.solutions.

Cordialement,

Lindsay Strack
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QUESTIONS DE L'ENQUETE AUPRES DES PARTICIPANTS A LA FORMATION

SGNL Solutions mène une enquête auprès des participants aux formations de l'Association des laboratoires de santé publique (APHL) et de l'Institut Pasteur afin d'évaluer l'impact des formations sur la capacité des laboratoires de santé publique à détecter et à répondre aux épidémies de maladies respiratoires. Nous utiliserons également les informations recueillies pour améliorer les initiatives futures.

L'enquête vous prendra environ 15 minutes. Vos réponses resteront strictement confidentielles et ne seront communiquées que sous forme agrégée.

7. Veuillez indiquer les activités auxquelles vous avez participé.
    - € Formation moléculaire sur les virus respiratoires | mars 2017 |Yaoundé, Cameroun
    - € Atelier de riposte aux épidémies | juillet 2017 | Dakar, Sénégal
    - € Atelier de riposte aux épidémies | septembre 2017 | Abidjan, Côte d'Ivoire
    - € Formation sur la méningite | février 2018 | Paris, France
    - € Atelier sur la riposte en cas d'épidémie | février 2018 | Yaoundé, Cameroun
    - € Formation sur la méningite | Octobre/novembre 2018| Géorgie, États-Unis
    - € Formation en bio-informatique | septembre 2018 | Paris, France
    - € Formation moléculaire par le CDC (essais PCR RT) | juillet 2016 | Géorgie, États-Unis
    - € Formation sur l'emballage et sur l'expédition | mars 2017 | Entebbe, Ouganda
    - € Formation sur l'emballage et sur l'expédition | juin 2017 | Vietnam
    - € Formation en bactériologie et en diagnostic moléculaire de la méningite | septembre 2017 | Géorgie, États-Unis
    - € Formation en bactériologie et en diagnostic moléculaire de la méningite | mai 2018 | Minnesota, États-Unis
    - € Formation en bactériologie et en diagnostic moléculaire de la méningite | octobre 2018 | Géorgie, États-Unis
    - € Atelier de rédaction scientifique | juillet 2019 | Dakar, Sénégal

8. Indiquez dans quelle mesure vous êtes d'accord avec chaque affirmation ci-dessous.

Si sélectionné à partir de la première question	Affichage
● Formation moléculaire sur les virus respiratoires | mars 2017 | Cameroun ● Formation moléculaire par le CDC (essais PCR RT) | juillet 2016 | Géorgie	*Je suis mieux en mesure d'utiliser des méthodes de tests moléculaires pour détecter les virus respiratoires non grippaux.*

● Atelier sur la riposte en cas d'épidémie | juillet 2017 | Sénégal ● Atelier sur la riposte en cas d'épidémie | septembre 2017 | Côte d'Ivoire ● Atelier sur la riposte en cas d'épidémie | février 2018 | Cameroun	*Je suis mieux en mesure de créer un plan opérationnel qui incluant des mesures qui devant être prises dans le contexte d'une épidémie.*
● Formation sur la méningite | février 2018 | Paris	*Je suis mieux en mesure d'utiliser des méthodes de laboratoire pour l'identification des agents impliqués dans la méningite bactérienne aiguë*
● Formation sur l'emballage et sur l'expédition | mars 2017 | Ouganda ● Formation sur l'emballage et sur l'expédition | juin 2017 | Vietnam	*Je suis mieux en mesure de transporter et de manipuler des échantillons.*
● Formation en bactériologie et en diagnostic moléculaire de la méningite | septembre 2017 | Géorgie ● Formation en bactériologie et en diagnostic moléculaire de la méningite | mai 2018 | Minnesota ● Formation en bactériologie et en diagnostic moléculaire de la méningite | octobre 2018 | Géorgie	*Je suis mieux en mesure de détecter et d'effectuer le sérotypage des pathogènes de la méningite.*
● Atelier de rédaction scientifique | juillet 2019 | Sénégal	*Je suis mieux en mesure de préparer les données existantes pour la publication des manuscrites.*
● Formation sur la méningite | Octobre/novembre 2018| Géorgie	*Je suis mieux à même de détecter les agents pathogènes de la méningite bactérienne, notamment le Streptococcus pneumoniae, et la grippe hémophilique.*
● Formation en bio-informatique | septembre 2018 | Paris	*Je suis mieux en mesure de préparer des échantillons pour le séquençage de nouvelle génération et d'analyser et d'exploiter les résultats du séquençage de nouvelle génération.*

9. Avez-vous transmis les connaissances que vous avez acquises lors des formations à d'autres employés n'ayant pas pu assister aux formations en personne ?
    - Oui

- Non
- Incertain

3a. Veuillez décrire comment vous avez partagé avec vos collègues ce que vous avez appris pendant la formation

_____

10. Votre laboratoire a-t-il apporté des modifications à ses politiques ou protocoles en fonction de sa participation aux formations ?
    - Oui
    - Non
    - Incertain

4a. Veuillez décrire les changements apportés aux politiques ou au protocole.

_____

11. Avez-vous publié ou soumis pour publication des documents évalués par des pairs depuis 2016 ?
    - Oui
    - Non
    - Incertain

5a. Veuillez fournir une citation pour votre publication.

_____

12. De quel soutien supplémentaire avez-vous besoin pour améliorer votre capacité à détecter les agents pathogènes et à contribuer à l'identification et au contrôle des épidémies ?

Key Informant Interview Script

<u>Opening</u>

Thank you for agreeing to do this interview. My name is [NAME], and I'll be talking with you today. [Introduce other project staff on the phone if needed.]

This project is being funded by the Association for Public Health Laboratories (APHL) in partnership with the Centers for Disease Control (CDC).

The purpose of this interview today is to understand more about how the NCIRD's accelerator projects were implemented and the impact of the Global Health Security Acceleration Projects in the context of laboratory gains.

- [Use individual profile to remind them of what pieces of the project they touched.]

I'd like to share a few details about the interview.

- The interview will last about [60 minutes].
- We are recording this interview. Is that ok?
- We intend to attribute stories and quotes by organization type and country but will not reference individual names.
- At any time during our conversation, you can let me know if you have any questions or if you would rather not answer any specific question. You can also stop the interview at any time for any reason.
- Please remember that we want to know your perspectives and that there are no right or wrong answers.

Do you have any questions about the interview?

Questions

CDC Staff	APHL/IP Staff	CDC Country Office Staff	Select Laboratory Leaders
● I'd like to begin by asking you some questions about your role within your organization. ○ What was/is your position at CDC NCIRD? ○ What were your major responsibilities in that position as they related to GHS Project? ○ What were CDC NCIRD overall goals and priorities related to GHS? ○ What were the long-term goals for this laboratory	● I'd like to begin by asking you some questions about your role within your organization. ○ What is/was your position at [APHL/IP]? ○ What were your major responsibilities in that position as they related to GHS Project? (note: some worked on few, some many) ○ In your own words, what was the overarching goal of the GHS Project? ● Next I would like to discuss the	● I'd like to begin by asking you some questions about your role within your organization. ○ What is/was your position? ○ What are/were your major responsibilities? ○ To what extent are you aware of the NCIRD Accelerator GHS projects to build laboratory capacity. ▪ Prompt with summary as needed) ○ How did you interact with CDC NCIRD, IP, and APHL? ○ Thinking back over the last few years, what were your	I'd like to begin by asking you some questions about your role with the laboratory. ○ What is/was your position? ○ What are/were your major responsibilities? ○ When did you first learn about the CDC GHS laboratory projects? ○ The project activities started in 2016. What do you recall about your staff's participation in the activities? ○ Prompt with project description if needed. ● Next I'd like to ask you some questions about the impact of the GHS project(Centers for Disease Control and Prevention).

focused GHS Project? ○ Were there any formal or informal interim goals to monitor the progress? ● [OD only] Now I would like to discuss GHS AP funding. ○ Where did the funding come from? ○ What constraints or limitations were place on funding? ▪ Prompt: in terms of timeline, topics, type of	implementation of the GHS Project. (link to inventory spreadsheet) ○ Which activities was your organization responsible for implementing? (confirm using SGNL records) ○ To what extent were you able to decide how to allocate the funding you received? ○ To what extent were you able to design the activities for each strategy? ▪ How did your approach change	goals for the laboratories? ▪ How did these projects align with those goals? ● Next I'd like to ask you some questions about the impact of the GHS projects. ○ How did the laboratories' understanding of the role of the lab in a surveillance system shift over time (obtaining specimen, getting it to lab, testing it, getting results to surveillance, making decisions to respond)? ○ How did the laboratories' capacity (e.g., equipment, KSA) to transport	○ How did the laboratories' understanding of the role of the lab in a surveillance system shift over time (obtaining specimen, getting it to lab, testing it, getting results to surveillance, making decisions to respond)? ○ How did the laboratory's capacity (e.g., equipment, KSA) to transport (domestically/internationally), receive, maintain, and store specimens change over the project period (2016-2019)? ▪ What contributed to those changes?

activity, etc. ● Next I would like to discuss the implementation of the GHS Project. ○ Why did CDC opt to work with APHL and IP? ○ How did CDC decide who would implement which activities? ○ What activities were selected and why? ▪ Probe for topics and methods of learning	over time? ▪ How did you measure success for the activities? ● Probe by type ○ What external (things outside of your control) forces helped/hindered the implementatio	(domestically/internationally), receive, maintain, and store specimens change over the project period (2016-2019)? ▪ What contributed to those changes? ▪ Where did you think the activities contributed to those changes? ○ How did the laboratories' capacity (e.g., supplies, KSA) to perform testing for [list pathogens relevant to country based on training records or non-flu viral respiratory] according to quality standards change	○ How did the laboratory's capacity (e.g., supplies, KSA) to perform testing for [list pathogens relevant to country based on training records or non-flu viral respiratory] according to quality standards change over the project period (2016-2019)? ▪ What contributed to those changes? ▪ Prompt for specific pathogens based on participation records ○ How did the laboratory's capacity (e.g., KSA) to detect pathogens

○ How did the selection or focus of the activities shift over time? ○ How were the labs chosen for participation in project activities? ○ What external forces helped/hindered the implementation of project activities? ▪ Prompt for each type of activity ○ How did the broad strategies or focused activities change during	n of project activities? ▪ Prompt: local politics, staff turnover, travel restrictions, outbreaks, vendor issues, partner issues, supply chain issues, financial constraints ○ How did the broad strategies or focused activities	over the project period (2016-2019)? ▪ What contributed to those changes? ▪ Prompt for specific pathogens based on participation records. ▪ Which pathogens were a priority for the country? ○ How did the laboratories' capacity (e.g., KSA) to detect pathogens of interest [tailor to specific trainings or non-flu viral respiratory for short] change over the project period (2016-2019)?	of interest [tailor to specific trainings or non-flu viral respiratory for short] change over the project period (2016-2019)? ▪ What contributed to those changes? ▪ Prompt for specific pathogens based on participation records. ▪ Has this capacity been sustained? For which pathogens? ▪ Are labs able to connect with CDC SMEs on relevant

the project? Why? ○ What would you do differently as the CDC if you do this project again? ▪ Probe: lessons learned re: staffing, budgets, timing, partnerships, procurement, implementation ○ In what ways did the project not meet your expectations?	change during the project? Why? ○ What would you do differently if you do this or a similar project again? ▪ Probe: lessons learned re: staffing, budgets, timing, partnerships, procurement, implementation ○ In what ways did the project	▪ What contributed to those changes? ▪ Prompt for specific pathogens based on participation records ○ Did the laboratories implement any quality improvement activities based on the EQA for respiratory pathogens provided by QCMD over the project period (2016-2019)? (make sure they know which one we are talking about) ○ How did the laboratories' ability to provide reliable and quality surveillance data to	assays to troubleshoot issues? ○ Did the laboratories implement any quality improvement activities based on the EQA for respiratory pathogens provided by QCMD over the project period (2016-2019)? If so, describe. (make sure they know which one we are talking about) ○ How did the laboratory's ability to provide reliable and quality surveillance data to public health agencies change over the project period (2016-2019)? ▪ What contributed

○ In what ways did the project meet or exceed your expectations? ● Finally, think back to the CDC's GHSA. What gaps remain in terms of laboratory capacity?	not meet your expectations? ○ In what ways did the project meet or exceed your expectations?	public health agencies change over the project period (2016-2019)? ▪ What contributed to those changes? ○ Did the laboratories implement any policy or practice changes based on participation in GHS project activities? ▪ Prompt for publishing, packaging/shipping, pathogen detection, quality improvement based on EQA, shift in preparation for JEE, etc ○ How did the laboratories' ability	to those changes? ▪ Are additional pathogens of interest able to be reported to MOHs? ○ How did the laboratories' ability to share what they've learned (via publication, conferences) change over the project period (2016-2019)? ○ Did the laboratory implement any policy or practice changes based on participation in GHS project activities? ▪ If so, describe. ▪ Prompt for publishing, packaging/sh

		to share what they've learned (via publication, conferences) since 2016? ○ In what ways are the laboratories more self-sufficient since 2016? ○ In what ways have the laboratories contributed to improvements in the timeliness of outbreak response since 2016? ○ In what ways have the laboratories contributed to improvements in the quality of disease surveillance since 2016? ● Finally I'd like to ask you to provide feedback on GHS AP projects. ○ What would you do differently if you do	ipping, pathogen detection, quality improvement based on EQA, shift in preparation for JEE, etc ○ In what ways have the laboratories contributed to improvements in the timeliness of outbreak response since 2016? ○ In what ways have the laboratories contributed to improvements in the quality of disease surveillance since 2016? ● Finally I'd like to ask you to provide feedback on the project (Centers for Disease Control and Prevention).

		this or a similar project again? ○ In what ways did the project not meet your expectations? ○ In what ways did the project meet or exceed your expectations? ○ What gaps remain for laboratory capacity to detect pathogens of interest? ○ In what way do regional activities assist laboratory capacity building efforts? ○ Did trainees provide guidance or training materials back to the lab?	○ In what ways did the project (Centers for Disease Control and Prevention) not meet your expectations? ○ In what ways did the project (Centers for Disease Control and Prevention) meet or exceed your expectations? ○ What gaps remain for laboratory capacity to detect pathogens of interest? ○ What challenges have you experienced in sustaining training endpoints?

Closing

- Is there anything else that you would like to add or other areas that we didn't discuss but you think are important?
- Thank you for your time and participation in this interview. The information that you provided to us will be very helpful in this project.
- We will be in touch if we have any questions about your responses.

**Following the interview, send the participant an email to thank them for participating and request access to data they mentioned and/or for introductions to people they mentioned.

Appendix D – Literature Search Bibliography

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Appendix E — Response to Survey Question Asking What Additional Support is Needed to Improve Their Capacity to Detect Pathogens and Contribute to the Identification and Control of Outbreaks

Country	Number of survey respondents	Responses
Bangladesh	1	● Continuous training and support in reagents, consumables and equipment
Benin	3	● Follow-up training, NGS training for further characterization with bioinformatics ● The provision of reagents for carrying out analyzes ● Need for training using the RT-PCR technique
Burkina Faso	4	● More knowledge and skills in identification of new strain of disease pathogens like COVID-19, gene sequencing of new pathogens and Laboratory Quality Management in regard to the outbreak. ● Bioinformatics training ● The training at Georgia was primarily on conventional bacteriological aspects. Advanced training on molecular epidemiological tools including performing sanger sequencing, NGS and analysis of sequence data will be very useful in surveillance and outbreak investigations ● Certification of PSMs; Ability to source diagnostic kits or order primers; Training on advanced molecular methods; Controls / Reference standards
Cameroon	3	● Further training in surveillance and molecular laboratory diagnostic techniques. Reagents and logistics for

		diagnostic testing. Additional refresher training workshops to discuss and share best practices. ● Advanced training course on pathogens causing meningitis ● Training for: outbreak response; whole genome sequencing; respiratory virus detection
Cote d'Ivoire	3	● Need sequencing trainings for better understanding of sequence changes due to viruses coinfection ● Free kit and reagent ● More training especially practical and in the fields of bioinformatics and scientific writing
Gambia	3	● Support the improvement of working environments, especially infrastructure, advocate at the level of government officials so that they support national public health laboratories in terms of equipment and reagents, financially motivate laboratory staff because of laboratory work is very difficult, requires exact results and therefore a motivated and balanced staff. Support laboratories in the implementation of quality so that they are accredited. ● We will need support in terms of renewing certain equipment, broadening the range of diagnostics for monitoring meningitis and not just looking for 3 bacteria (Spn, Nm, Hi). To have a training in quality management in bacteriology lab. ● Renewal of the IATA Certificate Accessibility of an NGS sequencing platform Support for waste management Support for a Biobank
Ghana	1	● Improvement of the technical platform and very good training in Bioinformatics

Guinea	3	● We look forward to attending training courses in diagnostic techniques, bioinformatics and serology. Thank you for your support. ● I need to reinforce my bacteriology Unit ● I think refresher training needed for us and also for the newcomers. I attend shipment training for viruses but not for bacteria. So sometimes I became confused. Though I'm virologist but in an Institute, there are several Departments.
Guinea-Bissau	2	● PCR machine and primers and probes ● I am sure as a Microbiologist, an aspiring researcher, good and sound working knowledge in molecular microbiology including sequencing, will help me a lot in contributing and improving my ability/capacity in pathogen detection/identification for control of outbreaks. As with a good background in applied (field) epidemiology, having a sound working knowledge in molecular (micro) biology, will enhance my bench skills in pin-pointing to the causative agents for outbreaks hence recommend control measures, which in turn may help in advice for right vaccine development.
India	1	● Recycling on sample transportation and on the new technics in molecular diagnosis
Indonesia	2	● I need training in Phylogenomics which would help me detect and track outbreaks of meningitis ● Sharing of updated protocols on regular basis
Mali	3	● How to /detect/examine specimens on a large scale 2. Analysis of NGS ● Practical training in diagnostic techniques, including PCR.

		• Equipment such as PLCs to have greater detection capacity; Training in the use of new technologies
Mauritania	1	• I need training in molecular diagnosis. This will help me participate actively in precise diagnosis of other diseases.
Niger	1	• Support the National Public health Laboratory and lab network with trainings, reagents, consumables and access to standards
Nigeria	4	• The additional support we will need to improve our work will be more training and mentor-ship thanks • Equipment (automatons) to speed up the diagnosis in the event of an epidemic or pandemic, as currently with the covid (we do manual extractions which are long and with the risk of contamination) • Need for diploma training • We need a biosafety equipment and facilities such as a BSL-3 safety cabinet and a P3 lab to handle high risk pathogens. We have automated nucleic acid extractors (Easymag and Qiacube) and need reagents to increase testing output. We need more training on detection of pathogens particularly in analysis of Taqman Array Card (TAC) and RT-PCR assays.
Pakistan	3	• Laboratory reagents and consumables Outbreak investigation Data management • Reagents for influenza virus tests. • We need molecular diagnostic kit for meningitis and 2X universal master mix
Senegal	3	• Strengthen our diagnostic capacity in molecular biology • Logistic is faced with the rupture of stock of materials and consumables. lack of equipment for molecular

		biology. the transport circuits work with difficulty especially in the rainy eopcas. ● I want to publish all the work for the surveillance of non influenza viruses. We will appreciate if we can get support on genotyping this viruses and more respiratory viruses
Sierra Leone	3	● Training on molecular diagnosis of bacterial meningitis. ● To get more skills and on hands training with the provision of reagents/supplies to detect priority pathogens for outbreak. ● The need for additional support to improve our ability to detect pathogens and to assist in the identification and control of epidemics is: 1. Material and reagent support 2. Staff training 3. Equipment maintenance
Tanzania	3	● At this we need support for the meningitis examination. We are currently developing JE surveillance, we also intend to detect meningitis. We will be greatly helped by technical assistance related to meningitis laboratory procedures. ● NGS-based training, and NGS implementation, to help produce in-house antigens ● We wish agreement from our leader because we only run Realtime PCR for verification method
Togo	3	● Need for training using the RT-PCR technique ● Training on detection of pathogens using other molecular techniques such as: Sequencing to meet up with the increasing number of emerging and reemerging infectious diseases especially in developing countries 2. Analysis and troubleshooting 3. Primer Design 4. Vaccine development

		• Protocol and Reagents
Uganda	3	• I think it will be very helpful if I can join more workshop to gather more knowledge, which will help to identify or detect pathogens and control outbreak. • Funding to buy reagents and equipment • Our lab is responsible for respiratory bacteria. These years, we usually have outbreaks like whooping cough in 2018 and Diptheria in this year. The situation is getting difficult when pandemic COVID-19 is happening. To improve capacity in detecting pathogens we need to enhance knowledge, practice, SOP, reagents, and machine to support the identification of bacteria. Our lab is the national lab so we need another lab to assess our capacities via PT or EQA.
Vietnam	6	• Our department is divided 2 departments so we only use vitek MS to detect pathogen now • We need reagent support and additional training on writing scientific papers to better showcase the knowledge gained • Improve lab data management • Further support in publishing results. A writing group would be beneficial • Readily available Laboratory supplies contribute a lot in pathogen detection and control of outbreaks. More the supplies should be provided, Provision of more equipment used in sample processing and testing for instance PCR machines, thermocyclers, pipettes, centrifuges Refresher training and capacity building for the staff. Routine checks or visits by an external body to ensure that standards are adhered to

		• Refresher's training, onsite follow up supervisory visits, updated protocols on new testing methods used

Appendix F – Codebook

Logic Model

Inputs	Outputs (Activities, Products)	Outcomes/Impacts		
		Short Term	Medium Term	Long Term*
● International Reagent Resources (IRR) ● CDC (funding, subject matter expertise, strategy) ● Laboratories in Asia and Africa ● APHL (management, subject matter expertise) ● Institute Pasteur (management, subject matter expertise) ● Supplies, equipment, EQA panels ● Previously developed tools/materials	● External quality assessment (panel and results) ● Workforce development (in-person trainings) ● Provision of equipment and supplies (specimen transport, reagents) ● Capacity Building Assistance (outbreak response consultations, Measles/rubella self-assessment tool, E-learning modules for writing, transport) ● Peer Support ("Mentorship program", Discussion forum for writing, transport)	● Equipped to transport, receive, maintain, and store specimens ● KSA to ship specimens domestically and internationally ● Equipped with supplies and equipment for specific respiratory pathogen testing ● KSA to use test kits to perform testing according to quality standards ● KSA to detect pathogens of interest ● KSA to implement quality improvement activities based on EQA results	● Laboratories are providing reliable data to external partners ● Laboratories are contributing to evidence base/scientific community ● Laboratories have implemented policy and practice changes based on GHS Project activities ● Laboratories have implemented packaging and shipping supplies into specimen transport systems ● Increase in JEE scores (unlikely to get for this project period as each country	● Laboratories are self sufficient ● Decrease in disease burden ● Improved quality of surveillance ● Increase in timeliness of outbreak response ● Increase in global health security *not in eval scope

			only has one score)	

Research Questions

SGNL, APHL, and CDC developed a set of core evaluation questions for the GHS project evaluation project.

1. Describe the context for the GHS projects and the overarching strategy.
2. Describe how NCIRD GHS activities amplified and dampened CDC NCIRD global center goals and priorities (e.g., build strong lab systems, improve sustainability and accessibility to quality laboratory diagnostics for under resourced countries). *FYI these were developed after the APs were implemented.
3. How much money did the CDC invest in NCIRD GHS activity implementation?
4. Describe how NCIRD GHS activities amplified and dampened country program goals and priorities?
5. What can we learn about how to improve project implementation at CDC and partner organizations beyond the process evaluation already completed?

Preliminary Codes

Purpose **-** Description of goals and priorities

- NCIRD
- Country Labs
- APHL

Implementation Barriers/Facilitators – Description of challenges to implementation with fidelity (i.e., intended process) and good effect (i.e., intended outcomes)

- Communication
- Coordination
- Country Workforce
- Evaluation
- Funding
- Partner Organizations
- Politics
- Procurement
- Timeline

Outcomes **-** Examples of advancements in laboratory capacity and performance

- Decrease in disease burden
- Equipped to transport, receive, maintain, and store specimens
- Equipped with supplies and equipment for specific respiratory pathogen testing
- Improved quality of surveillance
- Increase in global health security
- Increase in JEE scores
- Increase in timeliness of outbreak response
- KSA to detect pathogens of interest
- KSA to implement quality improvement activities based on EQA results

- KSA to ship specimens domestically and internationally
- KSA to use test kits to perform testing according to quality standards
- Laboratories are contributing to evidence base/scientific community
- Laboratories are providing reliable data to external partners
- Laboratories are self-sufficient
- Laboratories have implemented packaging and shipping supplies into specimen transport systems
- Laboratories have implemented policy and practice changes based on GHS

Remaining Gaps - Commentary about remaining capacity/capability gaps at any level (country laboratories, partner organizations, or CDC)

Preliminary Tags

Activity - Tag to indicate commentary about specific activity

- EQA - Performed challenges to the laboratories' quality management systems by providing a set of samples for testing and a report of results.
- IRR - Provided laboratories with reagents, test kits, and information for studying and detection of viruses
- P&S - Provided supplies to pack and ship specimen and training/exercises to practice packaging and shipping
- Training - Provided training on how to do specific laboratory tests (and a few other random things, like publishing)

Country - Tag to indicate commentary about a specific country

Quote - Tag to indicate passage with potential to be used as a full quote in report narrative

Context – Description of the context for the GHS projects and the overarching strategy

Appendix G: Case Examples

CASE EXAMPLE 1: BENIN

> "We can say that during 2016 to 2020 our performance is better because since 2018, we begin to test Meningitis bacterial by PCR, and then it is very fast, and we are able to send the response to epidemiological team and this help them to take a decision….in 2019, last year, we had an epidemic in a region in the North of the country, Banikoara, and it is our capacity testing for PCR who help us to know what is passing." *-Benin Laboratorian*

The National Public Health Laboratory of Benin is a division of the Department of Pharmacy, Drug and Diagnostic Exploration within the Ministry of Health. It is a national public laboratory with a technical and administrative staff assigned by the state. The laboratory specializes in medical biology with units in Bacteriology (bacteriological diagnosis of cholera, shigellosis, and bacterial meningitis), Immunology (viral serology activities like rotavirus, measles, and yellow fever), Biochemistry, and Parasitology. An appendix of the LSNPB in Cotonou was equipped during the Ebola outbreak to do the diagnosis of Hemorrhagic viral fever.

The Joint External Evaluation (JEE), a consolidation of the World Health Organization (WHO) International Health Regulations (IHR) 2005 Monitoring and Evaluation Framework and the Global Health Security Agenda country assessment tool, is an objective, voluntary, independent peer-to-peer multisectoral assessment of a country's health security preparedness and response capacity across 19 technical areas.

A 2017 JEE revealed that funding was severely lacking to execute Benin's national plan for detection and reporting of antimicrobial-resistant pathogens, and no health-specific legal framework existed to comply with the IHR. Challenges specific to laboratories included lack of quality assurance, weak protection of workers against contamination, and logistical problems with packaging and transport of specimens. There were also no standard operating procedures for approving and reporting international public health emergencies to the WHO. In addition, Institut Pasteur conducted an assessment mission in Benin to evaluate the possibility initiating biological surveillance of respiratory pathogens. At that time, the National Public Health Laboratory did not have real-time PCR or conventional PCR device capability.

CDC's National Center for Immunization and Respiratory Disease (NCIRD) collaborated with the Association of Public Health Laboratories (APHL) and Institut Pasteur (IP) to design and implement the GHS Laboratory Capacity Building Projects (hereinafter "Capacity Building Projects"). The Capacity Building Projects address two core aims: (1) build and sustain laboratory capacity for pathogen detection and outbreak response and (2) improve specimen transport quality and efficiency. From 2016 to 2020, dozens of countries across Africa and Asia received infectious disease diagnostic test kits through the International Reagent Resource (IRR), external quality assessment (EQA) panel reviews, support for packaging and shipping specimens, training and workshop sessions to develop laboratory skills, and other capacity building assistance.

As a high-risk, non-Ebola affected country in West Africa following the 2014-2015 outbreak, Benin was selected as a candidate for the Capacity Building Projects.

Staff from the National Public Health Laboratory of Benin participated in the following activities.

- Respiratory Viruses Basic Training (Cameroon, July 2016)
- Packaging and Shipping Training (Uganda, March 2017)
- Bacteriology and Molecular Diagnostic Training for Meningitis – French (USA, September 2017)
- Site Visit from IP (September 2017)
- Meningitis Training (France, Spring 2018)
- Laboratory Impact Workshop (South Africa, July 2018)
- International Laboratory Scientific Writing (Senegal, July 2019)
- Received 19 cooler kits
- Received Arktek kit
- Ordered 27 items from the IRR

Benin experienced a number of gains in laboratory capacity during the Capacity Building Projects. Testing capacity improved, specifically for meningitis. Since 2018, the national laboratory has been able to test for bacterial meningitis using PCR, resulting in a much shorter turnaround time for results. The laboratory shortened the timeframe for providing meningitis test results to two days, and the lab can process more than 50 tests per day. This allows laboratorians to more rapidly inform the epidemiological team to improve their decision-making. For example, a 2019 meningitis epidemic in northern Benin was quickly detected and monitored because of the new PCR testing ability. Staff also reported an improved ability to test for rubella, measles, and yellow fever.

In addition to the knowledge, skills, and abilities acquired via the five trainings attended, staff reported that training attendance led to the creation of standard operating procedures for activities such as cleaning and sanitizing and developed a standard workflow. The laboratory also improved its ability to transport and store specimens. For example, staff developed a strategy where peripheral labs send specimens to the regional labs and then on to the national lab. If there is an issue with the transport, someone will take a car and go directly to the regional level to collect the specimen. National lab staff who participated in the Capacity Building Projects authored eight publications with topics ranging from pediatric bacterial meningitis to antimicrobial resistance of sexually transmitted infections to molecular diagnostic practices.

Staff at the national laboratory reported a number of challenges related to physical equipment, infrastructure, and logistics. Some surveillance activities are difficult to implement because of a lack of reagents, equipment, and training. Specifically, in 2018, the laboratory had a PCR machine in disrepair, which resulted in a decrease in testing capacity. In addition, the laboratory experienced a ten-month delay in receiving its cooler kits.

National laboratory staff requested additional training in bioinformatics, RT-PCR techniques, and specimen transport and infrastructure improvements (e.g., testing platforms, reagents). In addition, training opportunities for regional laboratories would enhance national capacity.

CASE EXAMPLE 2: CAMEROON

> "In Cameroon, one of the labs which are involved in the surveillance is the Center Pasteur of Cameroon. They performed the conventional bacteriology, but they were missing a lot of samples, positive samples. When they implemented the PCR, and they started to use the PCR in the diagnostic, they increased and improved the diagnostic." - *Implementing Partner*

The Centre Pasteur du Cameroon Measles and Rubella laboratory is located in Yaoundé, Cameroon. The laboratory's mission is to support measles and rubella surveillance and diagnostic activities, which include measles and rubella IgM serological assays, real-time PCR, and genotyping. The laboratory space and equipment are shared with other public health programs for diseases such as polio and influenza.

The Joint External Evaluation (JEE), a consolidation of the World Health Organization (WHO) International Health Regulations (IHR) 2005 Monitoring and Evaluation Framework and the Global Health Security Agenda country assessment tool, is an objective, voluntary, independent peer-to-peer multisectoral assessment of a country's health security preparedness and response capacity across 19 technical areas.

A JEE process in 2017 determined that Cameroon's public health surveillance infrastructure had limited capacity to detect outbreaks. Staffing across public health infrastructure was insufficient, and Cameroon's workforce development plan was limited in implementation. The assessment also noted insufficient coordination across sectors and a lack of written documentation and procedures. Both a national multi-sector capacity building strategy and specimen transport and transfer system for rapid confirmation of outbreaks were deemed essential.

CDC's National Center for Immunization and Respiratory Disease (NCIRD) collaborated with the Association of Public Health Laboratories (APHL) and Institut Pasteur (IP) to design and implement the GHS Laboratory Capacity Building Projects (hereinafter "Capacity Building Projects"). The Capacity Building Projects address two core aims: (1) build and sustain laboratory capacity for pathogen detection and outbreak response and (2) improve specimen transport quality and efficiency. From 2016 to 2020, dozens of countries across Africa and Asia received infectious disease diagnostic test kits through the International Reagent Resource (IRR), external quality assessment (EQA) panel reviews, support for packaging and shipping specimens, training and workshop sessions to develop laboratory skills, and other capacity building assistance.

As a GHSA partner country, Cameroon was selected as a candidate for the GHS Laboratory Capacity Building Projects. Staff from the Centre Pasteur du Cameroon participated in the following activities.

- Respiratory Viruses Basic Training (Atlanta, July 2016)
- Regional Respiratory Viruses Basic Training (Cameroon, March 2017)
- Packaging and Shipping Training (Uganda, March 2017)
- Pilot test of Laboratory Assessment Tool (August 2017)
- Bacteriology and Molecular Diagnostic Training for Meningitis – French (USA, September 2017)
- Outbreak Investigation Workshop (February 2018)

- Meningitis Training (France, Spring 2018)
- Laboratory Impact Workshop (South Africa, July 2018)
- Bioinformatics Training (France, September 2018)
- International Laboratory Scientific Writing (Senegal, July 2019)
- Received 20 cooler kits

- Ordered 53 items from IRR
- Received laboratory equipment
- Submitted viral and bacterial results for two EQA cycles

Cameroon experienced a number of gains in laboratory capacity during the Capacity Building Projects. Laboratory staff atttended six trainings and reported that they passed along knowledge gained to other staff in their lab by organizing their own trainings on topics like the spread of cholera, sample transport of COVID-19, and the molecular diagnostics process for meningitis.

The 2018 measles and rubella capacity assessment identified a number of strengths, including the provision of weekly surveillance reports to the WHO, detailed standard operating procedures, proper biosafety equipment and laboratory space, and successful IgM and real-time PCR testing for measles and rubella. In addition, staff reported systematic implementation of confirmation of meningitis results and updates to documentation requirements for international sample transport. Most notably, laboratorians in Cameroon demonstrated diagnostic capacity enhancements by detecting a serogroup of meningitis that they previously thought was not present in the country, serogroup X of *Neisseria meningitis*.

Laboratories who participating the Capacity Building Projects published 22 articles in peer-reviewed journals across a wide spectrum of topics, including surveillance, early detection, whole-genome sequence analysis, and practical tests for tuberculosis, as well as relevant disease areas including influenzas, Rift Valley Fever, Arboviruses, Enterovirus D, Measles, and antimicrobial resistance.

While participation in the Capacity Building Projects increased bacteriology laboratorians understanding of the importance of their role in surveillance, poor coordination between Cameroon's Ministry of Health and the laboratories led to confusion about roles for surveillance. The laboratory's manual extraction techniques limited the number of specimens it could test. Laboratories identified the availability of reagents as the biggest obstacle to fulfilling their responsibilities.

National laboratory staff requested additional training (e.g., new techniques in molecular diagnostics, scientific writing) and access to reagents and consumables.

CASE EXAMPLE 3: PAKISTAN

> "They started….training the people related to this field to come to our hospital, and we got them trained. And now, finally, there is a lot [more] awareness among the people and in the different regions. They are enough trained to know what is the biosafety? What is the biosecurity? How to wear the PPE, what are the SOPs? I think so much more, especially after this COVID-19." -*Pakistan Laboratorian*

The Public Health Laboratories Division of Pakistan's National Institute of Health provides laboratory support to public and private sectors for timely detection, prevention and control, of infectious diseases during outbreaks and epidemics. This division serves as the only WHO Collaborating Center for Research and Training in Viral Diagnostics in Pakistan. The laboratory also provides surveillance programs on influenza and bacterial meningitis. Notably, surveillance in Pakistan has benefited from a long-standing CDC Field Epidemiology Training Program that focuses on outbreak investigation and surveillance.

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A 2016 JEE found critical needs for expanded multi-sectoral communication and coordination and recommended developing a five-year country roadmap to strengthen their capabilities. They also identified a need to establish strong surveillance and a tiered public health laboratory system, potentially modeled on the devolution of Pakistan's healthcare system, where much of the implementation is led by the provinces.

CDC's National Center for Immunization and Respiratory Disease (NCIRD) collaborated with the Association of Public Health Laboratories (APHL) and Institut Pasteur (IP) to design and implement the GHS Laboratory Capacity Building Projects (hereinafter "Capacity Building Projects"). The Capacity Building Projects address two core aims: (1) build and sustain laboratory capacity for pathogen detection and outbreak response and (2) improve specimen transport quality and efficiency. From 2016 to 2020, dozens of countries across Africa and Asia received infectious disease diagnostic test kits through the International Reagent Resource (IRR), external quality assessment (EQA) panel reviews, support for packaging and shipping specimens, training and workshop sessions to develop laboratory skills, and other capacity building assistance.

As a GHSA partner country, Pakistan was selected as a candidate for the Capacity Building Projects. Staff from the Public Health Laboratories Division participated in the following activities.

- Respiratory Viruses Basic Training (Cameroon, July 2016)
- Packaging and Shipping Training (Vietnam, April 2017)
- Laboratory Impact Workshop (South Africa, July 2018)
- Received 5 cooler kits
- Ordered 33 items from IRR

Pakistan experienced a number of gains in laboratory capacity during the Capacity Building Projects. After staff attended two trainings, they were able to train their peers on fast-track diagnostics, how to expand influenza surveillance to other respiratory diseases, and international transportation and shipment guidelines. For example, transport technicians from different districts were trained transport samples in line with temperature requirements and biosecurity guidelines and changes in protocol were made to require specimen shipment to be inspected and approved by an IATA certified shipment expert.

Pakistan developed a National Laboratory Policy and a Biosafety Policy in 2017. All laboratories are currently operating under this national policy, but there are plans to develop provincial policies that are more tailored to the specific region and lab staff and capacity. Because they were already trained on RT-PCR for influenza, one laboratory in Gilgit, Pakistan was able to pivot quickly to COVID-19 testing, processing nearly 80% of the country's COVID-19 testing as of May 2020.

Laboratorians that participated in Capacity Building Project activities authored six publications in recent years. Article topics covered the characterization of molecular epidemiology of respiratory syncytial virus in children and immunophenotypic and genetic analyses and diverse disease areas, including pneumonia, influenza, RSV and lower respiratory tract infections, and Dengue fever.

Pakistan's difficult geography remains a challenge. Mountainous terrain and weak cellular signals are a barrier to specimen transportation and timely communication. Conducting trainings at the provincial level involves substantial travel time and coordination. While testing capacity has improved, laboratories are still limited by the availability of reagents and other supplies.

National laboratory staff requested additional training in quality control, quality assurance, biosafety, and biosecurity and infrastructure enhancements such as backup PCR machines.

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