Workshop on strengthening laboratory services for antimicrobial resistance (AMR) surveillance in leprosy

14–15 November 2022

Schieffelin Institute of Health – Research and Leprosy Centre (SIHRLC)
Karigiri, Vellore, India
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## Acronyms and abbreviations

<table>
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<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AMR</td>
<td>antimicrobial resistance</td>
</tr>
<tr>
<td>BU</td>
<td>Buruli ulcer</td>
</tr>
<tr>
<td>DNA</td>
<td>deoxyribonucleic acid</td>
</tr>
<tr>
<td>EQA</td>
<td>external quality assurance</td>
</tr>
<tr>
<td>GLP</td>
<td>Global Leprosy Programme</td>
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<tr>
<td>GLASS</td>
<td>Global Antimicrobial Resistance Surveillance System</td>
</tr>
<tr>
<td>HARP</td>
<td>a database of Hansen's disease Antimicrobial Resistance Profiles</td>
</tr>
<tr>
<td>ILEP</td>
<td>International Federation of Anti-leprosy Associations</td>
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<tr>
<td>IQC</td>
<td>internal quality control</td>
</tr>
<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
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<tr>
<td>LPA</td>
<td>line probe assay</td>
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<tr>
<td>LAMP</td>
<td>loop-mediated isothermal amplification</td>
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<tr>
<td>LPEP</td>
<td>leprosy post-exposure prophylaxis</td>
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<tr>
<td>MDT</td>
<td>multidrug therapy</td>
</tr>
<tr>
<td>MFA</td>
<td>mouse foot pad assay</td>
</tr>
<tr>
<td>MFP</td>
<td>mouse foot pad</td>
</tr>
<tr>
<td>MB</td>
<td>multibacillary</td>
</tr>
<tr>
<td>NTD</td>
<td>neglected tropical disease</td>
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<tr>
<td>NGS</td>
<td>next generation sequencing</td>
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<tr>
<td>NSP</td>
<td>national strategic plan</td>
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<tr>
<td>PCR</td>
<td>polymerase chain reaction</td>
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<tr>
<td>PEP</td>
<td>post-exposure prophylaxis</td>
</tr>
<tr>
<td>QC</td>
<td>quality control</td>
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<tr>
<td>SNP</td>
<td>single nucleotide polymorphism</td>
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<tr>
<td>SIHRLC</td>
<td>Schieffelin Institute of Health – Research and Leprosy Centre</td>
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<tr>
<td>SOP</td>
<td>standard operating procedure</td>
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<tr>
<td>SDR</td>
<td>single-dose rifampicin</td>
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<tr>
<td>TAG</td>
<td>technical advisory group</td>
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<tr>
<td>TB</td>
<td>tuberculosis</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>WGS</td>
<td>whole genome sequencing</td>
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Executive summary

The WHO Global Leprosy Programme (GLP) reviewed the leprosy situation globally at a consultation in June 2021 [see Report of the virtual Consultation on antimicrobial resistance (AMR) in leprosy, New Delhi, India, 14–17 June 2021] involving laboratory experts and programme managers. It identified the need for developing or strengthening linkages of leprosy programmes with designated diagnostic sites or laboratories, and those between diagnostic laboratories and reference laboratories.

The Consultation, organized by WHO, highlighted the importance of quality control in AMR surveillance testing and mainstreaming of AMR surveillance in the Global Antimicrobial Resistance Surveillance System (GLASS). The Seventeenth Meeting of the WHO Technical Advisory Group (TAG-Leprosy), held on 29 November–1 December 2021, endorsed these suggestions from the consultation meeting. It recommended holding discussions with designated testing and reference laboratories to develop quality assurance techniques for testing drug resistance in leprosy.

In continuation to this, WHO organized a “Workshop on strengthening laboratory testing procedures for antimicrobial resistance (AMR) surveillance in leprosy” at SIHRLC, Karigiri, Vellore, India, on 14–15 November 2022, involving country programme managers, laboratory experts, International Federation of Anti-leprosy Associations (ILEP) and WHO members. The objectives of the meeting were to review the testing methods available to detect AMR in leprosy, encompassing the emerging evidence on testing procedures that included field-friendly methodology, and to strengthen and facilitate linkages between clinical reference laboratories and designated testing centres for quality assurance with regard to testing. This meeting was expected to develop global templates for AMR testing with a special focus on quality assurance.

The inaugural address was delivered by Dr V.R. Pemmaraju, Acting Team Lead, WHO Global Leprosy Programme, on behalf of Dr Poonam Khetrapal Singh, WHO Regional Director for South-East Asia. It emphasized the need for understanding and implementing AMR tests in general and those for leprosy in particular. The guests of honour – Mr Kumaravel Pandian, District Collector, Vellore, Professor Emmanuel le Cambau, member of the WHO Technical Advisory Group (TAG) and Professor of Bacteriology, School of Medicine, University Paris Cité, and Dr P.G. Bhanumathy, Director, Public Health, Vellore district – addressed the participants, underlining the need for surveillance of AMR in leprosy and its integration into other programmes for neglected tropical diseases (NTDs).

The keynote address was delivered by Dr Daniel Argaw Dagne, Coordinator, NTDs, WHO headquarters (WHO HQ). Dr Dagne spoke about the criticality of protecting the efficacy of the limited number of antimicrobials available for treating NTDs and the need to develop strategies to prevent or avert development of AMR while monitoring drug efficacy, implementing surveillance mechanisms for monitoring resistance, and developing new, safe and effective treatments to sustain the gains and achieve the targets of the Global NTD Roadmap 2021–2030.

There were 10 technical sessions, which started with updates on the historical evolution of AMR surveillance for leprosy during the past 14 years and the global situation on AMR, along with currently available guidance for AMR surveillance. The second session covered the recent advances in AMR testing, which included whole genome sequencing and Deeplex® Myc-Lep assay. There were also presentations on some forthcoming field-friendly technologies for AMR testing. Facility tours, covering leprosy clinics and the AMR testing laboratory, were arranged for the participants. Following the tours, the participants’ feedback session, focusing on the current global AMR templates, was conducted; this included mapping of clinical sites, diagnostic facilities and designated referral facilities at national and international levels. These activities concluded Day 1.
The sessions on Day 2 included an overview of the existing quality assurance procedures in the tuberculosis (TB) programme and the Global Antimicrobial Resistance Surveillance System (GLASS). The participants were divided into groups to discuss the modalities for establishing linkages between clinical and laboratory facilities and referral laboratories to strengthen quality assurance. They were also encouraged to provide inputs to the quality assurance templates. Finally, the perspectives of the leprosy programme managers and their suggestions for the national plans were obtained.

The workshop concluded with the following recommendations:

1. The technical guide should be reviewed, updated and converted into e-training modules for facilitating capacity-building and implementation of AMR surveillance.
2. For improving laboratory quality assurance, WHO, WHO collaborating centres and other partners should support countries to implement quality management systems at designated treatment facilities, testing facilities and reference laboratories.
3. Develop quality indicators for surveillance of AMR in leprosy.
4. Qualified SOPs from other disease models can be referenced for quality assurance in AMR and the reference laboratory should follow a quality management system.
5. Countries are encouraged to implement surveillance of AMR in leprosy, include it in their AMR national action plans and report to GLASS (this will be facilitated by WHO).
6. Introducing or re-introducing skin smear examination at designated clinical and treatment facilities will help in easily following the selection criteria for AMR screening.
7. Countries, implementing leprosy post-exposure prophylaxis (LPEP), should include for AMR surveillance all multibacillary (MB) cases occurring after the intake of rifampicin or any other antibiotic as leprosy prophylaxis, in addition to 10% of new MB cases and all MB relapse cases.
8. In addition to 10% of new MB cases, those MB cases, who have received post-exposure prophylaxis in the past, should (all) be included for AMR surveillance.
9. Clinical management of leprosy patients, detected with resistance, should be improved.
   - AMR-positive reports should be communicated to clinicians in a timely manner for further management.
   - Mapping out such patients is encouraged in order to identify associations with clinical, demographic and geographical locations.
   - Treatment outcomes need to be recorded for follow-up.
   - National programmes are encouraged to support implementation of second-line treatment, where required.
10. The templates for quality assurance at diagnostic testing and clinical facilities need to be included in the new, revised and updated technical guide.
11. Develop a common and easy-to-use platform to adequately identify mutations that are known to confirm AMR in leprosy.
12. Keep watch on the progress of new tests and innovative technologies to detect AMR in leprosy.
1. Introduction

Multidrug therapy (MDT) has been the main treatment regimen for over four decades now. It consists of three antibiotics: dapsone, rifampicin and clofazimine. Resistance to dapsone was widely present before the introduction of MDT. Combined resistance to dapsone and rifampicin has been reported. Resistance to ofloxacin (a second-line drug) has also been reported in some countries. WHO, in collaboration with ILEP, has been supporting AMR surveillance in 20 countries through sentinel surveillance centres. A few countries routinely investigate AMR while others have expressed interest in undertaking regular AMR surveillance. The WHO Global Leprosy Programme (GLP) has published an updated version of *A guide for surveillance of antimicrobial resistance in leprosy: 2017 update* ([https://apps.who.int/iris/rest/bitstreams/1137285/retrieve](https://apps.who.int/iris/rest/bitstreams/1137285/retrieve)).

The WHO GLP further reviewed the situation during a consultation meeting in June 2021 ("Report of the virtual consultation on antimicrobial resistance in leprosy, New Delhi, India, 14–17 June 2021"), involving laboratory experts and programme managers. The role of partner organizations was acknowledged as many laboratories involved in AMR surveillance were funded and supported by members of ILEP. The need for developing or strengthening linkages of leprosy programmes with designated diagnostic sites or laboratories, and between diagnostic laboratories and reference laboratories was highlighted. The consultation meeting also recommended development of quality control at each step of conducting AMR surveillance, such as specimen collection, extraction of DNA, polymerase chain reaction (PCR) test, gene sequencing, and mouse foot pad testing for validation of new mutations and standardization. Mainstreaming of AMR surveillance work in GLASS, organized by WHO, was also emphasized during the meeting.

The WHO Technical Advisory Group (TAG-Leprosy) in its Seventeenth Meeting (29 November–1 December 2021) endorsed the conclusions and recommendations of the consultation meeting and recommended discussions with designated testing and reference laboratories to develop quality assurance techniques for testing drug resistance in leprosy.

The recommendations from the consultation, held in December 2021, included developing a network of laboratories, facilitating linkage with national programmes and introducing quality assurance methods for strengthening surveillance of AMR in leprosy. The national leprosy programmes that have demonstrated interest in improving coverage of AMR surveillance, diagnostic laboratories, supporting countries and reference laboratories across the world, experts in leprosy and AMR surveillance and partners will be invited to discuss ways of strengthening AMR surveillance at successive meetings on the subject.

Emerging evidence on new testing methods and improving the current tests and laboratory procedures, followed in AMR surveillance, were discussed.

2. Objectives of the workshop

2.1 The Objectives of the workshop were to:

1. review the available testing methods to detect AMR in leprosy, including emerging evidence on testing procedures, using field-friendly methodology; and
2. strengthen and facilitate linkages between clinical reference laboratories and designated testing centres for quality assurance with regard to testing.
3 Expected outcomes

3.1 The expected outcomes of the workshop were to:

1. global templates on conducting AMR developed; and
2. a template for quality assurance for AMR testing developed.

4 Proceedings of the workshop

4.1 Opening session

Dr Jerry Joshua, Director, Schieffelin Institute of Health – Research and Leprosy Centre (SIHRLC), Karigiri, welcomed all dignitaries and participants. All dignitaries lit lamps to start the inaugural programme.

Dr V.R. Pemmaraju, Acting Team Lead, WHO Global Leprosy Programme, delivered the opening address on behalf of Dr Poonam Khetrapal Singh, WHO Regional Director for South-East Asia, emphasizing the need for understanding and implementing AMR tests in general and those for leprosy in particular. Dr Poonam Khetrapal Singh's address highlighted the following:

Of the two basic tenets that had helped in leprosy control since the early 1980s, the first involves detection of cases early, before deformities develop. The second deals with treating those cases with MDT. Together, these two strategies have proved to be highly effective, reducing new cases from more than 5 million annually in the early 1980s to less than 200 000 every year at present.

AMR is one of the foremost global public health and development threats to humanity. It is associated with an estimated 4.95 million deaths across the world every year. Since 2014, preventing and combating AMR has been one of the eight Flagship Priorities in the South-East (SE) Asia Region. Even before the COVID-19 pandemic, AMR was projected to potentially reduce the GDP of low-income countries by 5% and push up to 28 million people into poverty by 2050. There is an urgent need to maintain the focus on preventing, detecting, treating and combating AMR in leprosy, addressing the current surveillance and laboratory challenges, not to mention the inadequate access to point-of-care testing, suboptimal linkages between clinical units and testing laboratories, and lack of integration with the Global Antimicrobial Resistance and Use Surveillance System (GLASS).

She concluded by encouraging participants to review the available testing methods to detect AMR in leprosy, including emerging evidence on testing procedures that can be carried out in the field; to strengthen quality assurance methods and create linkages between reference laboratories and designated testing centres for quality assurance; and to better collaborate with testing centres with reference laboratories, with the aim of facilitating current capacity-building and quality assurance activities.

Mr Kumaravel Pandian, District Collector, Vellore, delivered the inaugural address and highlighted the important role education plays in society’s progress towards well-being. He wished participants a profound deliberation during the workshop on further improvements, issues and challenges to AMR testing and how the problems could be resolved.

Dr Daniel Argaw Dagne, Coordinator, NTDs, WHO headquarters, Professor Emmanuele Cambau, member of the WHO Technical Advisory Group and Professor of Bacteriology, School of Medicine, University Paris Cite, and Dr P.G. Bhanumathy, Director, Public Health, Vellore district, also addressed the participants, emphasizing the need for AMR surveillance in leprosy and its integration into other NTD programmes.
4.2 Technical session 1

This session was chaired by Professor Emanuelle Cambau and co-chaired by Dr Paul Saunderson, Technical Advisor, American Leprosy Missions.

The session commenced with a brief overview of the objectives and outcomes of the workshop, presented by Dr V.R. Pemmaraju of WHO GLP.

Dr Dagne, Coordinator for NTDs at WHO headquarters, presented an overview of antimicrobial use and the AMR threat with regard to NTD medicines.

The WHO NTD Prevention and Control Department approaches NTD control through preventive chemotherapy, integrated vector management and intensified innovative disease management. Dr Dagne elaborated on the list of medicines used for treating various NTDs and the status of their drug resistance. He dwelt on the following points:

1. Most NTD programmes depend on different medicines to scale up interventions for control, elimination and eradication of these diseases.

2. It is critical to protect the efficacy of the limited number of antimicrobials by reinforcing collaboration with various sectors and closely monitoring the use of these medicines in both humans and animals.

3. NTD programmes should be supported to develop strategies to prevent or avert development of AMR, monitoring drug efficacy, implementing surveillance mechanisms for monitoring resistance, and developing new, safe and effective treatments to sustain the gains and achieve the Global NTD Roadmap 2021–2030 targets.

Professor Emmanuelle Cambau, from the Mycobacteriology Laboratory at the French National Reference Centre for Mycobacteria, a member of the WHO TAG on leprosy, shared her experience spanning 14 years in AMR surveillance of leprosy. She narrated the evolution of AMR testing for leprosy and its global expansion, starting from 2008. Currently, 19 countries are covered. The 2021 report indicated results from 3452 (8%) patients tested for *M. leprae* strains with at least one case of resistance (R): 51 were found to have *M. leprae* strains resistant to rifampicin, 49 to dapsone and three to oflaxacin; and four had strains resistant to more than one antimicrobial. She deliberated on the technical and operational issues in AMR testing and reiterated that robust quality assurance mechanisms are needed to be built into the surveillance systems.

Professor Cambau also recommended strengthening linkages between sentinel sites and laboratories, further testing resistance to other drugs, such as clarithromycin, used in treatment and PEP++, and clofazimine, and creating a database platform for microbiological results.

Dr Pemmaraju presented the global situation in AMR surveillance and the current guidance on AMR surveillance for national leprosy programmes. He highlighted the issues, challenges and strategic importance of AMR in reaching the goals of zero leprosy by 2030. He explained the significance of AMR as one of the key components of Strategic Pillar 1 of the Global Leprosy Strategy 2021–2030. He informed the participants about the WHO guidelines on AMR testing for leprosy, which were updated in 2017. The participants were apprised of the objectives, case definitions and organizational set-up at the national level and the monitoring of AMR testing. The focus was on operationalizing the global templates that were developed in 2021. Emphasis was also placed on strengthening laboratory services; incorporating quality assurance systems; discussing clinical management of resistant cases; exploring possibilities of networking among laboratories; sharing country experiences; and identifying possibilities for integration into the wider AMR agenda.
4.3 Technical session 2

In this session, different countries were invited to present their data on AMR surveillance. The following countries presented their current AMR scenarios.

Table 1. Reported resistance in relapse cases

<table>
<thead>
<tr>
<th>Country</th>
<th>Presenter</th>
<th>Reporting period</th>
<th>Testing method used</th>
<th>No. of samples tested</th>
<th>Dapsone–R</th>
<th>Rif–R</th>
<th>Of–R</th>
<th>More than one drug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>Dr Amrish Shah Bin Osman, National Public Health Laboratory</td>
<td>2015–2022</td>
<td>Mouse foot pad assay (MFA) and line probe assay (LPA)</td>
<td>192</td>
<td>21</td>
<td>5</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Madagascar</td>
<td>Dr Tahinamandrandranto Rasamoelina, Centre d’Infectiologie Charles Mérieux</td>
<td>2017–2021</td>
<td>Sanger sequencing and line probe assay</td>
<td>182</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nepal</td>
<td>Dr Rabindra Baskota, Chief, Leprosy Control Division</td>
<td>2017–2021</td>
<td>MFA*</td>
<td>72</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>Dr Vu Tuan Anh, Quyhoa Leprosy – Dermatology Hospital, MoH</td>
<td>2017–2021</td>
<td>Sequencing</td>
<td>06**</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brazil</td>
<td>Ciro Martins Gomes, Ministérida Saúdedo Brasil</td>
<td>2018–2020</td>
<td>Sequencing</td>
<td>1183</td>
<td>14</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

*Sequencing results pending, hence reported only on the basis of MFA.
**52 samples from new patients were also tested. None found resistant.

The major challenges/issues, brought out by the country presentations, included lack of funding to support the AMR work and absence of a proper surveillance system (not fully integrated into the national programme). Technical limitations, such as limited technical capacity for sequencing, long turnaround time for sequencing, laborious procedures for MFP and no proper quality assurance, were pointed out by country presenters.

4.4 Technical session 3

In this session of the workshop, new evidence on AMR testing and surveillance was put forth by various delegates.

Dr Madhusmita Das, Scientist, SIHRLC, Karigiri, spoke about the recent evidence on AMR testing – review of published literature. She presented an overview of the current scenario of anti-leprosy drug resistance and anti-leprosy drugs. She mentioned bedaquiline (a new drug), which has shown bactericidal activity in mice experiments and is found to be like moxifloxacin and rifampicin, and for which clinical trials have been initiated.

She also told the audience about other genes, which can be responsible for drug resistance, such as gyrB, rpoC, rpoA, gene nth, efflux pump system and LipU gene. She highlighted the recent advances in detection of AMR to anti-leprosy drugs, such as line
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probe assay, a commercial kit GenoType Leprae DR, whole genome sequencing (WGS), nested PCR/sequencing and Taqman SNP genotyping assay, Deeplex Myc-Lep (Genoscreen), LAMP method, HARP database (for AMR resistance profiles), field-friendly PCR biomeme franklin™ thermocycler and Minion platform (portable) nanopore sequencing USB device.

An update on whole genome sequencing was presented by Dr Pushpendra Singh, Scientist, ICMR-NIRTH, Jabalpur, on behalf of Dr Charlotte Avanzi, Scientist, Colorado State University. They informed the participants about identification of mutations in ribD, fadD9 and nth genes, found to be associated with drug-resistant strains. They said further studies and validation are warranted to see if these genes are linked with drug resistance or responsible for compensatory effect. If not, what is the impact of these mutations on *M. leprae* physiology? Do they make any clinical impact?

Although whole genome sequencing can be expensive for routine work, there are a lot of advantages of WGS in the framework of drug resistance surveillance in high resolution for identification of new markers. The presenter pointed out some of the advantages of WGS and suggested the following:

- Research for a better understanding of the molecular mechanism of resistance of the leprosy bacilli and molecular epidemiology (especially considering the plans for PEP).
- Empower national laboratories with DNA extraction methods, PCR and drug-resistance surveillance workflow (rapid field results).
- Save some aliquot of the sample/DNA for quality control and genome sequencing as part of the next generation sequencing (NGS) expertise.
- Feedback needs to be based on WGS data and development of PCR to perform onsite genotyping (research project). This partnership was implemented in Madagascar (Foundation Merieux, Antananarivo) and is currently being carried out in Tanzania (NIMR, Mwanza, Dr Safari/Dr Kasang) and Benin (CDTLUB, Pobé, Dr Johnson/Dr Marion).

Following the WGS update, Dr Sofie Braet, Institute of Tropical Medicine Antwerp, Belgium, presented the new method, Deeplex Myc-Lep, for testing antimicrobial resistance in leprosy. She put forth the data on the observational study of leprosy patients in Anjouan, Moheli, Madagascar, also known as the ComLep Study. Out of 1199 patients, identified from 2017–2020, Deeplex Myc-Lep was carried out for 260 biopsies. For dapsone, folP1 was targeted, for fluoroquinolones, gyrA and gyrB were aimed at and for rifampicin, RpoB, CtpC and Ctpl were targeted for testing drug resistance. Apart from these known genes, the hypermutable gene nth was also targeted. CtpC and Ctpl genes are transporter-encoding genes in which mutations were found in strains that were rifampicin-resistant.

Seven patients were found with gyrB mutation, spatially clustered and of the same genotype which is likely to be phylogenetic mutation. Asp521 is located away from the drug-binding pocket and does not interact with other residues in the conformation, unlikely to cause resistance to fluoroquinolones.

### 4.5 Technical session 4

A clinical and laboratory site visit to SIHRLC was arranged for all participants of the workshop. They visited the histopathology laboratory, the smear laboratory, the animal laboratory and the molecular biology laboratory.

The participants were happy to see all facilities. They interacted with laboratory personnel and their queries were answered.
Following the site visit, the participants engaged in bilateral meetings between countries and reference laboratories for establishing linkages and strengthening their AMR surveillance systems. Day 1 of the workshop ended with these bilateral meetings.

The second day of the workshop was chaired by Professor Emanuelle Cambau and co-chaired by Dr Daniel Argaw Dagne.

4.6 Technical session 5

The technical session started with a recap of the presentations on the first day of the workshop, with Dr Aparna Srikantam, Director, LEPRA Society, and Dr Itu Singh, Senior Scientist with TLM India, elaborating on the significant takeaways from each session.

Dr Sundeep Chaitanya, Research Director, American Leprosy Missions, shared his experiences in developing the Buruli Ulcer BU-Labnet, a network of laboratories in West African countries, where Buruli ulcer is endemic.

The BU-LABNET is a network of laboratories involved in PCR-based diagnosis of Buruli ulcer, endemic in the African Region, and committed to utilizing standardized testing protocols, covering external quality assurance programmes and sharing knowledge between member laboratories. The objective is to reach quality Buruli ulcer PCR diagnosis in the African continent and allow for integration of other skin NTDs, utilizing molecular diagnostic platforms for case confirmation. The network also acts as a channel for collaborative research, aimed at a multicentric evaluation of new tools and technologies for effectively diagnosing skin NTDs. Dr Chaitanya also put emphasis on improving quality diagnosis by ensuring that all laboratories in the network utilize standardized procedures for PCR-based diagnostic of Buruli ulcer and implementing an external quality assurance (EQA) programme for PCR laboratories in the network through a centralized coordinating system.

4.7 Technical session 6

Dr Madhusmita Das of SIHRLC, Karigiri, provided the global AMR templates to all participants. The participants’ feedback regarding AMR templates was discussed and agreed upon for further modifications. The following are the suggestions:

**Flowchart 1 (Scenarios 1 and 2):**

- to add skin biopsy along with slit skin smear at the designated treatment facility (Level 1);
- to also perform internal quality control for PCR and sequencing at the designated testing facility (Level 2); and
- to include reporting to the regional leprosy programme in the flowchart.

**Flowchart 1A:**

- objectives to be framed.

**Flowchart 2:**

- a separate inclusion criterion to be added for patients, who have received PEP.

**Flowchart 3:**

- Transportation will be carried out by the designated courier or airlines, whichever is feasible, and country guidelines for transportation are to be ensured.
4.8 Technical session 7

Following the feedback received from all participants for the global AMR template, Dr Raynal Squires, AMR Focal Point, WHO Regional Office for the Eastern Mediterranean (WHO-EMRO), delivered a presentation on quality assurance – existing systems and procedures (TB control and GLASS). He highlighted a few important aspects of the quality assurance procedures for TB, which can serve as a model to adapt for quality assurance for AMR in leprosy. This includes training and competence assessment; instrument verification; equipment maintenance; method validation; quality control (QC); lot testing/batch testing; external quality assessment (EQA), which includes proficiency testing; blind re-checking; and onsite supervision and quality indicator monitoring.

He suggested a few elements to consider for leprosy QA, such as:

- collection of phenotypic testing data by GLASS;
- structural advantage for leprosy AMR testing;
- PCR advantage;
- qualified SOPs (e.g. PulseNet);
- a WHO collaborating centre as the gatekeeper for laboratory quality aspects (clinical, testing, data); and
- quality indicators.

4.9 Technical session 8

A group discussion and a breakout session on “Linkages between clinical facilities, testing laboratory and reference laboratory to strengthen quality assurance” was led by Professor Emmanuelle Cambau. She initiated the session by providing an overview of the significant points of discussion noted below.

1. Monitoring of AMR results provided to patients and clinicians:
   - steps to be taken, from patient selection to results given; and
   - checklist for monitoring.

2. Verification of organization and personal capacities at clinical facilities:
   - steps taken to ensure reliability of results.

3. Organization and personal capacities at the laboratories:
   - personal and staff operating; and
   - organization and connections with the clinical facilities and between the laboratories.

4. Quality controls: Internal and external quality controls (IQC):
   - description
   - frequency of use
   - results
   - evaluation
   - information.

5. Other suggestions, if any.
The participants were divided into three groups.

<table>
<thead>
<tr>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr Line-Marlene Ganlonon, Benin</td>
<td>Dr Selfu Girma, Ethiopia</td>
<td>Dr Emmerson Gale S.V. Vista</td>
</tr>
<tr>
<td>Ms Radia Sabouni</td>
<td>Dr Amri Kingalu, Tanzania</td>
<td>Mr Amrish Shah Bin Osman</td>
</tr>
<tr>
<td>Dr Ahmed Mohamed Nabil Ramadan</td>
<td>Dr Marianela Martinez Falcon</td>
<td>Dr Jose Guillemot Pereira</td>
</tr>
<tr>
<td>Dr Estelle Marion</td>
<td>Dr Jose Guillemot Pereira</td>
<td>Dr Vu Tuan Anh</td>
</tr>
<tr>
<td>Dr Alexandre Tiendrebeogo</td>
<td>Dr Paul Sauderson</td>
<td>Dr Sutthisak Ngamwahiraporn</td>
</tr>
<tr>
<td>Professor Emmanuelle Cambau</td>
<td>Professor Kiochi Suzuki</td>
<td>Dr Sundeep Chaitanya</td>
</tr>
<tr>
<td>Dr Laetitia Gahimbare</td>
<td>Dr Itu Singh</td>
<td>Dr Pushpendra Singh</td>
</tr>
<tr>
<td>Dr Yves Thierry Barogui</td>
<td>Dr Deanna Hegge</td>
<td>Dr Aparna Srikantam</td>
</tr>
<tr>
<td>Dr Raynal Squires</td>
<td>Dr D. Mikita</td>
<td>Mr Divya Rana</td>
</tr>
<tr>
<td></td>
<td>Dr Marcelo Galas</td>
<td>Mr Tadesse Tesfaye</td>
</tr>
<tr>
<td></td>
<td>Ms Aya Tobiki San</td>
<td>Dr Rabindra Baskota</td>
</tr>
</tbody>
</table>

4.10 Suggestions on discussion points from the participants

**Surveillance:**
- patient diagnosed with MB leprosy with more than five lesions or nodules as one of the inclusion criteria;
- mandatory informed patient consent form to be collected from the patient; and
- only a skilled/trained health-care worker competent to perform skin biopsy or slit skin smear for collection of samples.

**Transporting a sample to the designated testing facility:**
- SOPs in place for sampling and storage of samples;
- duly filled-in requisition forms along with the samples;
- mandatory transportation form (including feedback to evaluate the courier services);
- SOPs in place to organize international shipping (includes customs clearance), following respective country guidelines for transportation of biological materials; and
- designated testing facility to provide feedback on confirmation of receipt and quality of sample (intact packaging, no spilling) to the courier services and the designated treatment facility.

**Quality assurance for laboratory results:**
- standardized results with a known format (e.g. date, authorized signature).

**Results to the clinicians to include:**
- SOPs for receipt of laboratory results. (e.g. result receipt confirmed, printed and filed); and
- clinician course of action for the patient after the receipt of results is recorded and communicated to the designated testing facility.
**Capacity-building for clinical competency:**
- Clinicians need to be trained in relevant AMR background.
- The clinic/hospital should maintain at least two staff members competent to collect samples.
- A programme to train and evaluate clinicians is needed.

**Laboratory competency:**
- Samples to be voluntarily sent to the reference laboratory to verify results;
- Blinded samples from the reference laboratory to be sent to designated testing facilities;
- In case of non-conformities, designated testing facilities to evaluate and take corrective actions; and
- Performance indicators to be provided by the Global Leprosy Programme.

Following suggestions and discussions, a template for quality assurance for designated testing facility and designated treatment facility was developed by all participants; it is provided as annexures at the end of this report.

### 4.11 Technical session 9

The final session focused on the perspectives of national leprosy programme managers with regard to introducing/scaling up AMR surveillance in the national strategic plans (leprosy). It was facilitated by Dr Daniel Dagne, Dr Subbanna Jonnalagada, Medical Officer, WHO Global Leprosy Programme, and Dr Sundeep Chaitanya.

The discussion topics included the following:

1. What are the existing capacities and structures for conducting AMR surveillance (leprosy), including laboratory capacity, in the country?
2. What are the major challenges you expect to conducting AMR surveillance in your country?
3. Please mention the measures that can be taken to:
   - Strengthen the capacities and structures for effective implementation of AMR surveillance for leprosy in the country; and
   - Carry out various quality assurance tasks for AMR surveillance and indicate how they can be harmonized with the National Strategic Plan (leprosy).

Dr Dagne provided an overview of the need for countries to be vigilant for AMR in leprosy among the NTDs. He stressed that the country programmes need to take the right steps now for implementation and WHO can provide the technical assistance for the same.

The summary of the discussions is presented below.

**Thailand**

Dr Sutthisk Ngamwachiraporn, National Programme Manager for Leprosy from Thailand, informed the participants that they have limited resources for leprosy and are interested to start AMR surveillance in leprosy, with technical support from WHO for building the staff capacity and the technical guidance to establish the AMR leprosy network in the country.
Malaysia

Dr Amrish Shah bin Osman from Malaysia said they have the capacity and facilities for dealing with AMR in leprosy. Through consultations with dermatologists, skin smears and skin biopsies for testing AMR in leprosy are carried out at three testing centres, linked with 18 hospitals across the country. There is a national reference laboratory. Malaysia does not have an external quality assurance programme and has requested WHO support in this regard.

The major problem faced involves procurement of LPA kits for sequencing. There is need for building staff capacity and organizing meetings to gear up for rolling out AMR in leprosy rollout. Malaysia reiterated that they want to be part of the AMR surveillance network.

Philippines

Dr Emmerson Vista from the National Reference Laboratory of Philippines said that the AMR programme is in place for other programmes but not for leprosy at present. The National Reference Laboratory is in Manila. The challenge is to have resources and coordinate with various stakeholders, including the government and the private sector. They are interested in taking on AMR in leprosy in near future with WHO technical support and guidance. He mentioned that they are familiar with the work of the Cebu Skin Clinic in Philippines, run by American Leprosy Mission, and will coordinate.

Nepal

Dr Rabindra Baskota informed the participants that Nepal is one of the high-burden leprosy countries and the Ministry of Health and Population is committed to working towards zero leprosy in the country by 2030. In this regard, Nepal recently developed a National Strategic Plan and the AMR in leprosy roadmap is part of the Strategic Pillar 3. At present, there is no technical expertise in the department. There is also no National Reference Laboratory for PCR sequencing in the country. The TLM Research Centre, Anandaban, carries out AMR testing, and EQA is with the Tokyo laboratory (at the Leprosy Research Centre of the National Institute of Infectious Diseases, Tokyo, Japan).

The plan is to roll out single nucleotide polymorphism (SNP) pillar 3 for AMR in leprosy surveillance with capacity-building and laboratory strengthening.

Viet Nam

Dr Vu Tuan Anh from Viet Nam said that they do not have the National Reference Laboratory with the sequencing facility. There is resource constraint and the AMR laboratory network needs to be established in the country. WHO was requested to provide technical support in this regard.

Egypt

Dr Ahmed Mohammed Nabil Ramadan from the Ministry of Health of Egypt informed the participants that the leprosy programme is working well in the country. Coordination between leprosy clinics and laboratories needs to be strengthened though. AMR is not mentioned in the National Strategic Plan. They are interested in being a part of the AMR leprosy network and require resources and technical support to strengthen the laboratory network with staff capacity-building.

At the end of all technical sessions, the following conclusions and recommendations were drafted.
5. Conclusions

(1) Although a low rate of resistance to antibiotics, used in treatment of leprosy, had been observed so far, an effective AMR surveillance needs to be developed and implemented to prevent the spread of the strains that are resistant to rifampicin, dapsone and ofloxacin.

(2) In addition to the two categories of leprosy cases targeted for AMR surveillance, i.e. new MB cases for primary resistance and relapse MB cases for secondary resistance, a third category should be included for both primary and secondary resistance, comprising MB cases, who have previously received leprosy post-exposure prophylaxis (LPEP), especially those who have received single-dose rifampicin (SDR).

(3) Interactions with GLASS are noted and integrating AMR surveillance for leprosy with GLASS is encouraged.

(4) Learning from other disease models, such as Buruli ulcer and skin NTDs (BU-LABNET), can help develop laboratory networks for AMR surveillance with regard to leprosy.

(5) Templates for quality assurance at diagnostic testing and clinical facilities were framed.

(6) Countries are in different stages of implementing AMR and expressed the need for strengthening health staff and linkages with reference laboratories to establish external quality assurance for AMR testing.

(7) Diagnostic testing facilities and designated treatment facilities are encouraged to join the AMR surveillance network, informing their corresponding national programme managers and WHO (country/regional and global offices). Diagnostic testing facilities should be tightly linked with designated treatment facilities and both coordinated by national programmes.

(8) While reporting AMR surveillance results, all diagnostic testing/clinical facilities are requested to communicate with their respective national programmes, the WHO Country Office and the Regional Office. This is to ensure effective reporting and monitoring. The flowcharts will be modified accordingly.

(9) Global templates of flowcharts for implementing AMR surveillance should also include internal quality assurance.

(10) There are difficulties in analysing sequencing data and a common platform to identify mutations more easily is required.

6. Recommendations

(1) The technical guide should be reviewed, updated and converted into e-training modules for facilitating capacity-building and implementation of AMR surveillance.

(2) For improving laboratory quality assurance, WHO, WHO collaborating centres and other partners should support countries to implement quality management systems at designated treatment facilities, designated testing facilities and reference laboratories.

(3) Develop quality indicators for AMR surveillance for leprosy.

(4) Qualified SOPs from other disease models can be referenced for quality assurance in AMR and the reference laboratory should follow a quality management system.

(5) Countries are encouraged to implement AMR surveillance for leprosy and include this in their AMR national action plans and report to GLASS (this will be facilitated by WHO).
(6) Introducing or re-introducing skin smear examination at designated clinical and treatment facilities will help in easily following the selection criteria for AMR screening.

(7) Countries, implementing LPEP, should include for AMR surveillance all MB cases occurring after intake of rifampicin or any other antibiotic as leprosy prophylaxis, in addition to 10% of new MB cases and all MB relapse cases.

(8) In addition to 10% of new MB cases, MB cases, who have received post-exposure prophylaxis in the past, should (all) be included in AMR surveillance.

(9) Clinical management of leprosy patients, detected with resistance, should be improved.
   
   (a) AMR-positive reports should be communicated to clinicians in a timely manner for further management.
   
   (b) Mapping out such patients is encouraged to identify associations with clinical, demographic and geographical locations.
   
   (c) Treatment outcomes need to be recorded for follow-up.
   
   (d) National programmes are encouraged to support implementation of second-line treatment, where required.

(10) The templates for quality assurance at diagnostic testing facilities and clinical facilities need to be included in the new, revised and updated technical guide.

(11) Develop a common and easy-to-use platform to adequately identify mutations, known to confirm AMR in leprosy.

(12) Keep watch on the progress of new tests and innovative technologies to detect AMR in leprosy.
Annex 1

Programme schedule and Agenda

Background:
The World Health Organization organized a global consultation on strengthening AMR surveillance with regard to leprosy in June 2021. During the consultation, the linkages between the leprosy programme and testing laboratories were highlighted and the need for standardizing testing methods was discussed. The recommendations from the consultation included developing global templates for conducting AMR and quality assurance for AMR.

WHO organized a “Workshop on strengthening laboratory testing procedures for antimicrobial resistance (AMR) surveillance for leprosy” at Karigiri, Vellore, India, on 14–15 November 2022.

The objectives of the Workshop were to:
1. review the available testing methods to detect AMR in leprosy, covering the emerging evidence on testing procedures, including field-friendly methodology; and
2. strengthen and facilitate the linkages between clinical reference laboratories and designated testing centres for quality assurance on testing.

Expected outcomes:
1. global templates on conducting AMR surveillance developed; and
2. a template for quality assurance for AMR testing developed.

Agenda

<table>
<thead>
<tr>
<th>Opening session</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcome: Dr Jerry Joshua, Director, SIHRLC, Karigiri</td>
</tr>
<tr>
<td>Opening address: Dr Poonam Khetrapal Singh, WHO Regional Director for South-East Asia Region</td>
</tr>
<tr>
<td>Overview of AMR surveillance for NTDs: Dr Daniel Dagne, Coordinator NTD/WHO HQ</td>
</tr>
<tr>
<td>Inaugural address of the Chief Guest: District Collector, Vellore</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objectives and expectations of the workshop – Dr V.R. Pemmaraju, GLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Technical session – update on AMR surveillance in leprosy control</td>
</tr>
<tr>
<td>• AMR surveillance for leprosy – 14-year experience – Professor Emmanuelle Cambau</td>
</tr>
<tr>
<td>• Global situation in AMR surveillance and current guidance on AMR surveillance to national programmes – Dr Pemmaraju, GLP</td>
</tr>
<tr>
<td>2. AMR surveillance for leprosy – presentation by the countries invited</td>
</tr>
<tr>
<td>Country presentations – Brazil, India, Madagascar, Malaysia, Nepal, Viet Nam</td>
</tr>
</tbody>
</table>
### 3. Technical session: New evidence on AMR testing and surveillance

Recent evidence on AMR testing – review of published literature – Dr Madhusmita Das

- Update on whole genome sequencing: Dr Charlotte Avanzi
- Deeplex-mycLep – Ms Sofie Braet/ Professor Emmanuele Cambau
- Field-friendly innovations in testing for AMR surveillance – Professor Suzuki

### 4. Technical session: Clinical and laboratory site visits

**Visit to clinical facilities and laboratories** – clinical facilities, histopathology, smear laboratory, animal laboratory and molecular biology

Bilateral meetings, countries, NGOs, laboratories – group discussion between countries and reference laboratories
Annex 2

List of participants

Country representatives

Dr Line-Marlene Ganlonon  
National Leprosy Programme  
MoH, Porto Novo, Benin

Dr Selfu Girma  
National Leprosy Programme  
Addis Abeba, Ethiopia

Dr Tahinamandranko Rasamoelina  
Leprosy Programme  
Antananarivo, Madagascar

Dr Amri Kingalu  
Ministry of Health  
Dodoma, U R Tanzania

Dr Ciro Martin Gomes  
NTD Control Programme  
Brasilia, Brazil

Dr Jose guilemmot Pereira  
Brunelli  
Paraguay

Dr Marianela Martinez Falcon  
Especialista del Microbiologia  
Cuba

Dr Ahmed Mohamed Nabil Ramadan  
National Leprosy Programme  
Cairo Egypt

Ms Radia Sabouni  
Ministry of Health  
Rabat, Morocco

Dr Rabindra Baskota  
National Leprosy Programme  
Kathmandu, Nepal

Dr Sutthisak Ngamwahiraporn  
National Leprosy Programme  
Bangkok, Thailand

Mr Amrish Shah Bin Osman  
Ministry of Health  
Kaula Lumpur Malaysia

Dr Emmerson Gale S V Vista  
Department of Health  
Philippines

Dr Vu Tuan Anh  
National Leprosy-Dermatology Hospital  
Ministry of Health  
Viet Nam

Technical experts and partner agencies

Dr Paul Saundersen  
American Leprosy Missions  
Alisund, Norway

Professor Kiochi Suzuki  
Tokyo University  
Tokyo, Japan

Dr Pushpendra Singh  
ICMR  
Jabalpur, India

Dr Sundeep Chaitanya  
American Leprosy Missions  
Cambridge United Kingdom

Dr Madhusmita Das  
SIHR & LC  
Karigiri, India

Dr Aparna Srikantam  
BPHRC, Lepra Society  
Hyderabad, India

Dr Itu Singh  
Stanley Brown laboratories  
TLMTI, New Delhi, India

Dr Charlette Avanzi  
United States of America

Dr Deanna Hegge  
Ananda Ban Hospital  
Kathmandu, Nepal

Dr D Mikita  
Tokyo, Japan

World Health Organization

Dr Daniel Argaw Dagne  
Coordinator NTD PCT  
WHO HQ

Dr V.R. Pemmaraju  
Global Leprosy Programme  
WHO Regional Office for South-East Asia

Dr Subbanna Jonnalagada  
Global Leprosy Programme  
WHO Regional Office for South-East Asia

Dr Laetitia Gahimbare  
AMR focal point  
WHO AFRO

Dr Yves Thierry Barogui  
Focal point for NTDs  
WHO AFRO

Dr Raynal Squires  
AMR focal point  
WHO EMRO

Mr Subhash Chand  
Global Leprosy Programme  
WHO Regional Office for South-East Asia

WHO TAG for leprosy

Professor Emmanuelle Cambau  
National reference center for mycobacteria and resistance to antimycobacterial agents  
Paris, France

Dr Jerry Joshua  
Director SIHR & LC  
Karigiri, India

Mr Tesfaye Tadesse  
Adis Abeba.  
Ethiopia

Observers

Ms Aya Tobiki  
Sasakawa Health Foundation  
Tokyo, Japan
Annex 3

Template for quality assurance for designated testing facility

Country:

Name of the laboratory:

Name of the person in charge:

Name of the reference centre:

Table 1. Help in quality assurance for resistance testing in leprosy: Internal controls

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Internal controls</th>
<th>Frequency to be tested or indication</th>
<th>Answer of the laboratory</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is a PCR negative control prepared in-house (e.g. DNA-free water)?</td>
<td>Each experiment</td>
<td>• Yes</td>
<td>If yes – please comment If no- please specify</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Is a PCR positive control prepared in-house (e.g. known positive sample/M. leprae control DNA)?</td>
<td>Each experiment</td>
<td>• Yes</td>
<td>If yes – please comment If no – please specify</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Is there a critical review of the results of AMR testing?</td>
<td>Every 10 experiments; at least once a year</td>
<td>• Yes</td>
<td>If yes – some/partial If no- please specify</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Are you using control positive samples with known positive mutation(s) in the target genes?</td>
<td>At least once a year</td>
<td>• Yes</td>
<td>• Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No</td>
<td>• No</td>
</tr>
</tbody>
</table>

Note: Plasmid controls for positive AMR strain

Table 2. Help in quality assurance for resistance testing in leprosy: External controls

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Internal controls</th>
<th>Frequency to be tested or indication</th>
<th>Answer of the laboratory</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Was a set of blinded samples sent by the reference centre?</td>
<td>Yearly for at least one negative, one sensitive and one resistant sample (any drug)</td>
<td>• Yes</td>
<td>If yes – please comment If no – please specify</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Is there a set of samples shared between different laboratories (international and national)?</td>
<td>Within a country or within a geographical region or within laboratories with the same reference laboratory/ every other year</td>
<td>• Yes</td>
<td>If yes – please comment If no – please specify</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• No</td>
<td></td>
</tr>
<tr>
<td>SI No.</td>
<td>Internal controls</td>
<td>Frequency to be tested or indication</td>
<td>Answer of the laboratory</td>
<td>Comments</td>
</tr>
<tr>
<td>--------</td>
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<td>--------------------------------------------------------------------------</td>
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<tr>
<td>3</td>
<td>Are samples randomly chosen, sent to the reference laboratory for comparing results?</td>
<td>e.g. samples yearly</td>
<td>• Yes</td>
<td>If yes – some/ partial If no – please specify</td>
</tr>
<tr>
<td>4</td>
<td>Review of results with other laboratories or reference laboratories, including sequencing data</td>
<td>Yearly, online (once a year meet to review)</td>
<td>• Yes</td>
<td>If yes – please comment If no – please specify</td>
</tr>
</tbody>
</table>
Annex 4

Template for quality assurance for designated treatment facility

**Country:**

Name of the designated treatment/clinical facility

Name of the person in charge:

**Table 1. Help in quality assurance for resistance testing in leprosy:**

<table>
<thead>
<tr>
<th>SI No.</th>
<th>Steps for monitoring</th>
<th>Items</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Selection of patient</td>
<td>Patient diagnosed for MB leprosy with skin lesions (nodules preferably) with consent</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Clinical form</td>
<td>Contains ID, surveillance no., new case/retreatment data and includes all patients, who have received PEP</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sampling</td>
<td>Personal staff, trained and skilled</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Transportation</td>
<td>Contract and being evaluated, IATA competent, if international</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Turnaround time</td>
<td>Time to reach the laboratory and time to receive the results</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Results</td>
<td>• Received</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Read</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Report in the file</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Changed treatment or not</td>
<td></td>
</tr>
</tbody>
</table>
Workshop on strengthening laboratory services for antimicrobial resistance (AMR) surveillance in leprosy

14–15 November 2022
Hosted by: SIHRLC, Karigiri, Vellore, India

Group photograph of the participants at the Workshop
Workshop on strengthening laboratory services for antimicrobial resistance (AMR) surveillance in leprosy
14–15 November 2022

Schieffelin Institute of Health – Research and Leprosy Centre (SIHRLC)
Karigiri, Vellore, India