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COLLEGE OF HEALTH SCIENCES

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Assessment of Laboratory Equipment Maintenance Practice and Associated Challenges in selected public Hospitals Addis Ababa, Ethiopia

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This is to certify that the thesis prepared by **Daniel Melkamu**, entitled:

Assessment of Laboratory Equipment Maintenance practice and associated Challenges in selected public Hospitals Addis Ababa, Ethiopia and submitted in partial fulfillment of the requirements for Master of Science degree in Clinical Laboratory Sciences (Laboratory management and Quality assurance specialty track) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abbreviations

AAU	Addis Ababa University
BMET	Biomedical Engineering Technicians
CM	Corrective Maintenance
DC	Data Collector
DREC	Department research and ethics committee
EM	Equipment Maintenance
FMoH	Federal ministry of health
IPM	Inspection and Preventive Maintenance
PI	Principal Investigator

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Abstract:

Background: Laboratory equipment maintenance practices are one of the key interventions to minimize equipment down time and service interruptions in public hospital. This study focused on the strategies of laboratory equipment maintenance practices for improving maintenance of laboratories equipment at public hospitals in Addis Ababa for effective service delivery.

Objective: This study aimed to assess laboratory equipment maintenance practice and associated challenges in selected public hospitals present in Addis Ababa, Ethiopia.

Methods: A descriptive cross sectional survey supported with qualitative data collection methods were conducted at 12 public hospitals in Addis Ababa from May 2021 to July 2021. A convenient sampling technique was used for the quantitative part and Criterion based purposive sampling technique was followed to select participants for the qualitative data collections. A pre-tested structured self-administered questionnaire was used to collect the quantitative data and semi structured in-depth interview guides and check lists were used to collect the qualitative data. The questionnaire was returned and the data was analyzed by using SPSS Version 20 software and the result was presented in tables, figures and graphs.

Result: A total of 48 respondents, 24 respondents from the quantitative and 24 respondents from the qualitative part were participated from 12 public health hospitals found in Addis Ababa, The findings showed that 95.8% equipment preventive maintenance practices takes place in their departments however, the practice of corrective maintenance was found to be 42.7%. Lack of spare parts and lack of trained biomedical engineers were the major laboratory equipment maintenance challenge which accounts about 29.2 % and 25% respectively. Age of the machine, work load and carelessness of the worker which is 45.8%, 33.3% and 12.5%, respectively were the major laboratory equipment failures among public hospital in Addis Ababa.

Conclusion: The study shows that preventive maintenance practices take place for laboratory equipment among public hospitals in Addis Ababa. The study also showed that corrective maintenance practices were not carried out for most of the equipment's and the majority of laboratory equipment was out of service due to lack of spare parts and lack of well-trained biomedical engineer. Age of the machine and work load were also the major laboratory equipment failures. Therefore availing spare parts and arranging training for biomedical engineers to improve the technical skill with continuous training is recommended.

Key words: Maintenance challenges, preventive and corrective maintenance practice.

1. Introduction

1.1 Background

Laboratory equipment is widely utilized for the diagnosis and treatment of patients. It is an asset that directly improves the quality of life for many people (1). Laboratory equipment requiring calibration, maintenance, repair, pre service user training and documenting all the activities are usually managed by engineers. It's also requires scheduled and unscheduled maintenance during its useful life (2). The laboratory should ensure that laboratory equipment is kept in working condition, and is safe, accurate, and reliable and operates at the required level of performance effectively (3). Lack of proper maintenance of laboratory equipment leads to equipment downtime, reduces the level of equipment performance, and wastes costs and resources. In this concern, it is essential that hospitals administrative should focus on effective and quick maintenance for laboratory equipment (4)

Laboratory equipment management systems should be characterized by formal policies, processes and procedures for selection, qualification, validation, maintenance, calibration, troubleshooting, decommission and record keeping. These systems prove that a laboratory selects equipment that meets its needs; and maintains it in a state that produces reliable test results; and documents its processes sufficiently for internal and external oversight(5). Equipment maintenance has different types: Inspection and Preventive Maintenance (IPM) and corrective maintenance (CM) (6). Effective management of equipment maintenance and repairs shall be planned and implemented using appropriate maintenance schedule to keep the equipment safe and functional according to basic functional specifications (7,8).The most common cause of laboratory equipment downtime is improper maintenance, planning, and management (9,10) It is necessary to establish and regulate a system to solve the problem of improper maintenance and incorrect use of laboratory equipment(11).The final goal of laboratory equipment maintenance is trust and safety. It should always be safe for both patients and users (12). Preventive maintenance can extend the life of equipment and generate significant savings of unnecessary maintenance cost (13). Responses to equipment repair requests are late or never take place, due to lack of attention from the staff, or lack of routine preventive maintenance training. Even preventive maintenance takes place; there is often no documentation of how or when preventive maintenance takes place. Every laboratory needs to establish and regulate a system for routine preventive maintenance to ensure reliability of results and to extend and

maintain the life of equipment. New employees and newly employ laboratory personnel often receive minimal exposure to equipment policies, pre service training prior to assign routine work (14).

More than 50% of laboratory equipment in resource-poor settings is not functional (15). The shortage of functional laboratory equipment has a horrific effect on healthcare in resource-poor settings. Certainly one of the most common causes of laboratory equipment being out-of-service is the shortage of spare parts including reagent packs, and the system of the equipment either closed or open. However, a large quantity of out-of-service equipment does not require consumables (16).There is evidence that much of this laboratory equipment is out-of-service because of the lack of Trained Biomedical Engineering Technicians (BMET). If the problem is the lack of trained professionals, then the solution would be training of the professional (16).

Maintenance is required for laboratory equipment because the efficiency and quality of laboratory results is reduced over time and the machines may fail more often. To function regularly over a longer period of time, it is necessary to be properly maintained (17). This is especially important for those systems that can cause failure relatively often, which disable the regular operation of the system, but with proper maintenance methods they can be avoided (18). According to studies, the cost of maintenance can reach 15-40% of the product cost, depending on the manufacturing industry(19).Therefore maintenance does not only aim to keep the equipment in a state of working order but also plays a decisive role in achieving production goals with optimum cost of ownership and maximum productivity.

1.2 Statement of the Problem

Laboratory equipment plays a vital role in the diagnosis, monitoring and treatment of patient in a health care. A maintenance program of laboratory equipment is crucially important not only to assure that the equipment is maintained at its best condition but also to eliminate any failures or breakdown occurred during its operations (20).

A study conducted in 60 resource-poor hospitals located in 11 nations in Africa, Europe, Asia, and Central America, showed that the most commonly mentioned equipment maintenance challenges are lack of spare parts, and lack of highly trained technician, unreliable schedule systems for equipment, high equipment breakdowns and shortage of manpower (22).

In most developing countries lack of spare parts, reagents, trained biomedical equipment maintenance technicians are in short supply, thus even minor equipment failures, lack of training for routine preventive maintenance, even in facilities where preventive maintenance is carried out, there is often no documentation of how or when preventive maintenance takes place. New employees of laboratory technology graduates often not receive minimal exposure to equipment policies. Equipment is easily damaged, disrupting services. This is also true for our country Ethiopia (25).

The importance of laboratory equipment maintenance practice, unfortunately, has not been paid enough attention, especially in developing countries including Ethiopia, a number of studies have been conducted on medical equipment maintenance management until now, but no studies have provided comprehensive framework for laboratory equipment maintenance practice and associated challenges in Ethiopia. This study aimed to assess the views of experts on laboratory equipment maintenance practice and associated challenges with the purpose of designing a possible ways to enhance and improve the understanding of equipment maintenance in selected public hospitals in Addis Ababa Ethiopia (27).

1.3 Significance of the Study

The main purpose of this study was to assess the effective preventive and correction maintenance practice implementations for improving maintenance of laboratories equipment and identify the challenges that affecting the maintenance of laboratory equipment. The finding of this study will also provide a baseline data and insight concerning the laboratory equipment maintenance practice and associated challenges which are vital for designing appropriate strategies and action plans on resolving the associated challenges. The finding will also provide hospital administrators and other concerned stakeholders with relevant knowledge which is necessary for evidence based equipment maintenance practice and appropriate interventions.

2. Literature review

2.1 Laboratory equipment maintenance practice

Maintenance practices involve preventive maintenance and corrective maintenance. Preventive maintenance is a type of maintenance practice that involves inspection, lubrication, cleaning and testing of equipment used in laboratory. Corrective maintenance is a work carried out to restore including adjustment and repair to meet standards. Corrective maintenance is employed when there is malfunctioning or complete breakdown of the equipment (1). Laboratory equipment requiring calibration, maintenance, and repair, pre service user training and documenting all activities. It's also requires scheduled and unscheduled maintenance during its useful life (2) Lack of proper maintenance of laboratory equipment leads to equipment downtime, reduces the level of equipment performance, and wastes costs and resources. The most common cause of laboratory equipment downtime is improper maintenance, planning, and management (9, 10). It is necessary to establish and regulate a system to solve the problem of improper maintenance and incorrect use of laboratory equipment (11)

2.2 Challenges of Laboratory equipment maintenance practice

A study conducted in manufacturing enterprises at Kosovo, to determine equipment maintenance management the result shows that the most frequent challenges are in electrical and electronic systems with 69%, with 26% mechanical and 5% hydraulic and pneumatic. Thus the main equipment failure are improper current supply, which is 44%, age of machines is 22%, carelessness of workers 17%, heavy load 13%, and other factors 4 %.The main factors influencing good equipment maintenance management is the use of maintenance management software. This shows that, the greatest need for expert and staff training is in maintaining electrical and electronic systems (21).

A cross sectional study was conducted in hospitals affiliated to Iran University of Medical Sciences at Iran, to assess maintenance and cost of medical equipment. The result showed that 60% of medical devices in hospitals affiliated to medical sciences universities had not been given pre service training for the staff, thus the most frequent challenges are repair and maintenance services 29.6%, Supply of equipment 26.1%, inspection and service training aspects 14.1 %. Almost 24% of the total amounts of the hospitals' budget are allocated for incurred expenses of

supply, repair and technical training of medical equipment. This shows that the hospital administrative need to prepare pre service training for medical equipment managements (22).

A systematic review conducted in 60 resource-poor hospitals located in 11 nations in Africa, Europe, Asia, and Central America, on 2010 by Robert Malkin Allison Keane to assess Evidence-based approach to the maintenance of laboratory and medical equipment in resource-poor settings shows that most of laboratory and medical equipment in resource-poor settings is out-of-service. The most common reasons are a lack of spare parts and a lack of highly trained technicians. Out of 2,849 equipment-repair requests (of which 2,529 were out-of-service medical equipment) from 60 resource-poor hospitals 1,821 pieces of medical equipment were placed back into service, or 72%, without requiring the use of imported spare parts. Of those pieces repaired, 1,704 were sufficiently documented to determine what knowledge was required to place the equipment back into service. Of the total of 1,704 documented, repaired pieces, 1,132 were put back into service using one of the 107 identified skills. In other words, 66% of the medical equipment placed back into service here, required only knowledge of the identified 107 skills and all of those without importing spare parts. Each of the equipment was analyzed by an engineer or an engineering student and a repair was tested using only locally available materials. This show that the equipment was placed back into service; they were assumed that the engineer's problem solving analysis was correct, and conclude that a the majority of laboratory and medical equipment can be put back into service without importing spare parts and using only basic knowledge (23).

A descriptive study conducted in Kitwe Central Hospital, Nchanga North Hospital and Ronald Ross Hospital at Zambia to assess the effectiveness of equipment maintenance practices in public hospitals notified that there is a high rate of equipment unavailability attributed by high failure rates due to unreliable schedule systems for equipment maintenance, high equipment downtime and shortage of maintenance personnel. As a result of these challenges, only 24% from the respondents agreed the health service delivery was good, while 76% agreed it was not good. 84% of the respondents in the maintenance department agreed the maintenance practices used in the maintenance of the equipment were giving a lot of challenges while 16% were not sure (24).

A review conducted in Sub-Saharan Africa on 2012, to evaluate Laboratory equipment maintenance critical bottleneck for strengthening health systems in sub-Saharan Africa shows the advantage and persistent challenges associated with sustaining laboratory equipment

maintenance. They were proposing equipment management policies as well as a comprehensive equipment maintenance strategy that would involve equipment manufacturers and strengthen local capacity through pre-service training of biomedical engineers. Strong country leadership and commitment are needed to assure development and sustained implementation of policies and strategies for standardization of equipment, and regulation of its procurement, donation, disposal, and replacement (25).

Across sectional study conducted in 14 public hospital in Addis Ababa to assess functionality status of medical laboratory equipment and reasons for their malfunction among Public Hospitals in Addis Ababa, 2018., the result shows that the overall functionality status of medical Laboratory equipment was 58.3%. Unavailability of spare parts was the primary reason for malfunction of medical laboratory equipment among public hospitals in Addis Ababa. Lack of spare parts accounts about 39.6% of the non-functionality of medical laboratory equipment followed by installation problem 14.6% and unavailability of reagents 12.5% (26).

The maintenance management of laboratory equipment is not good in developing country. The poor management of laboratory equipment is due to lack of spare parts, lack of reagents, lack of service contracts, and lack of trained Service engineers and absence of scheduled preventive and corrective maintenances. In general, the major causes for the failure of the equipment are due to operating the equipment by untrained laboratory professionals, electric power interruption, and failure to calibrate machines periodically. Hence to decrease frequent laboratory equipment failure, well trained laboratory professional also has a positive impact on performance of the equipment (28).

2.3 Conceptual frame work

A conceptual frame work for the current study which shows the major challenges associated with the laboratory equipment practice.

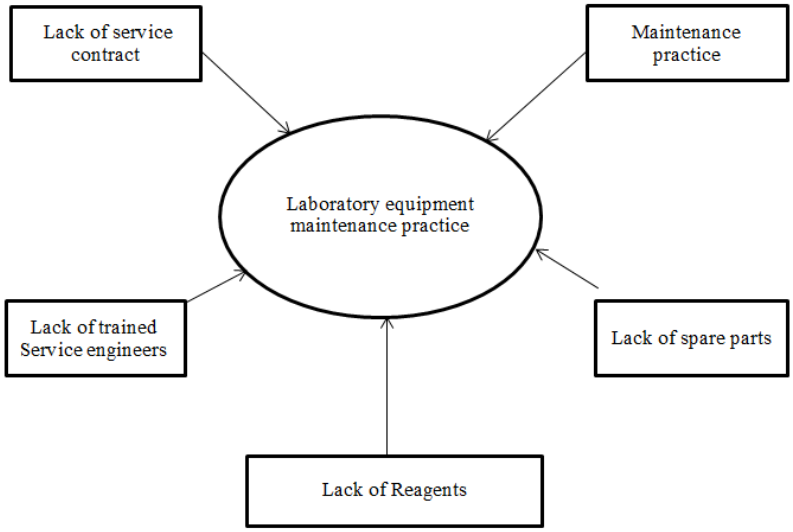


Figure 1**:** *A conceptual frame work to assess laboratory equipment maintenance practice and associated challenges*

3. Objectives

3.1 General Objective

- To assess laboratory equipment maintenance practice and associated challenges in selected public Hospitals present at Addis Ababa, Ethiopia from May 2021- July 2021 G.C

3.2 Specific Objectives

- To assess laboratory equipment maintenance practice in public Hospitals Addis Ababa Ethiopia from May 2021- July 2021 G.C.
- To identify the major challenges of laboratory equipment maintenance in public Hospitals, Addis Ababa, Ethiopia from May 2021- July 2021 G.C.

4. Materials and Methods

4.1 Study area and Period

This study was conducted in Addis Ababa the capital city of the Ethiopia, from May 2021– July 2021. A total of 52 hospitals are found in Addis Ababa, of these 12 are owned by the Public and 40 are under private sectors. All public hospitals (i.e. Black Lion Hospital, St Paul's Hospital Millennium Medical College, Zewditu Memorial Hospital, Yekatit 12 Hospital Medical College, Ras Desta Damtew Hospital, Dagmawi Mlinik II Hospital, Tirunesh Bejing Hospital, Gandi Memorial Hospital, St Peter Hospitals, Alert Hospital, Eka Kotobe Hospital, and Abet Hospital) were included in the current study. In these hospitals different laboratory service is given in these hospitals with a standardized setup and sophisticated equipment.

4.2 Study design

Descriptive cross sectional survey supported with qualitative data collection methods were applied in the current study.

4.3 Population

4.3.1 Source population

Quantitative

All medical laboratory department head and biomedical department heads, working in all public hospital found in Addis Ababa Ethiopia.

Qualitative

Selected medical laboratory professional and biomedical engineer working in all public hospital found in Addis Ababa Ethiopia.

4.3.2 Study population

The study populations for quantitative data collections were medical laboratory department head & biomedical department heads whereas selected senior medical laboratory professional & biomedical engineers, working in the selected public hospital found in Addis Ababa were the study populations in the qualitative data collections

4.4 Inclusion and Exclusion criteria

4.4.1 Inclusion criteria

Quantitative

- Being Medical laboratory and biomedical department heads, in public hospital found in Addis Ababa Ethiopia.

Qualitative

- Being senior medical laboratory professional and biomedical engineers, in public hospital found in Addis Ababa Ethiopia.

4.4.2 Exclusion criteria

- Medical laboratory and biomedical department heads and laboratory professionals who were not cooperative/ volunteer,
- Medical laboratory and biomedical department heads and laboratory professionals who were sick and unable to respond for the questionnaire.
- Medical laboratory and biomedical department heads and laboratory professionals who worked less than one year.

4.5 Study Variables

4.5.1 Dependent variable

The practice of laboratory equipment maintenance**.**

4.5.2 Independent variables

Challenges of laboratory equipment maintenance practice like: - Availability of spare parts, reagents, service contracts, trained service engineers, and service maintenance practice**.**

4.6 Sample size calculation and sampling methods

4.6.1 Sample size determination

Quantitative

- Since the study design for the quantitative part is a cross-sectional survey and size of the source population is manageable all (i.e. 24) Medical laboratory & biomedical department heads were included in the quantitative part.

Qualitative

- Based on the principle of saturation of idea raised from the participants a total of 24 senior medical laboratory professional & biomedical engineers were included in the in-depth interview.

4.6.2 Sampling method

Quantitative

- Convenient sampling technique was used for the quantitative part where all medical laboratory head and biomedical department heads were participated.

Qualitative

- Criterion based purposive sampling technique was followed to select participants for the in-depth interview. Selected senior medical laboratory professional & biomedical engineers were participated.

4.7 Measurement and data collections

4.7.1 Data collection tools and procedure

Quantitative

- A pre-tested structured self-administered questionnaire was used to collect the quantitative data. Questionnaire was designed in a way that to capture the different views of medical laboratory and biomedical department heads. It was developed after reviewing similar literatures and is comprised of closed-ended questions. The quantitative data was collected by the data collectors and the researcher was involved in supervising the overall data collection procedure. The collected data were checked for completeness on daily base.

Qualitative

- Semi structured in-depth interview guides were used to collect information from senior medical laboratory professionals and biomedical engineers. The guide contains an open ended question which used to explore a detailed idea on major challenges of laboratory maintenance practice and the way forwarded. The principal investigator conducted the interview and took the note during the process. Observational check lists were used to assess the general laboratory maintenance practices conducted at each facility. The data

was collected using checklists. This observational review was carried out by data collectors.

4.8 Data Quality Assurance:

Quantitative

- Training was given for quantitative data collectors before the actual data collection date. The questionnaire was also pre-tested on 5% of the sample. Based on the finding appropriate measures were taken on the questionnaire. Data were checked for completeness on daily base before entering in to computer SPSS software.

Qualitative

- The in-depth interview guide was also pre-tested and appropriate modifications were made accordingly.

4.9 Data entry & analysis procedure

Quantitative

- The collected quantitative data was cleaned, coded and entered in to Statistical Package for Social Sciences (SPSS) version 20:00 for analysis. Descriptive analysis was carried out for each variable. Then the result is presented in the form of table and graphs.

Qualitative

- The note book recorded data from in-depth interview was refined and then the written data were coded by two researchers. Then, subsequent pattern formation and thematization were done from the coded data. Finally, some quotes that could explain the context of challenges of laboratory service maintenance practice were identified and presented in the respondents' own words to give more insight accordingly.

4.10 Operational Definitions:

Laboratory equipment maintenance practice: In the current study it is defined as day to day activities which takes place by laboratory personnel's/biomedical engineers.

Preventive Maintenance: in the current study it is defined as an activities which takes place by laboratory personnel's/biomedical engineers for the purpose of maintaining laboratory equipment in satisfactory operating condition before they occur or before they develop into major defects.

Corrective Maintenance: In the current study defined as maintenance activities which take place by biomedical engineers after fault recognition.

Senior medical laboratory professional: In the current study defined as laboratory personnel's who worked greater than one year.

4.11 Ethical considerations

Prior to the actual data collection ethical approvals were obtained from department research and ethics committee (DREC) from the department of medical laboratory science Addis Ababa University. Official support letter was also obtained from Addis Ababa University and Hospitals prior to the study. Verbal informed consent was taken from the participants. The confidentiality of the collected data was assured the respondents' right to refuse or withdraw from participating in the study was fully acknowledged.

4.12 Dissemination of Result

The result of this study will be submitted and presented in open defense to department of medical laboratory Science College of health science, Addis Ababa University as part of MSc thesis. The finding of the current study will also be communicated to all hospitals found under the study Furthermore, effort will also be made to present the paper in scientific conferences and attempt will be done to publish the finding in peer-reviewed journals.

5. Result

A. Quantitative

5.1 Socio demographic characteristics

A total of 12 public hospitals both from federal and Addis Ababa city administration health bureau hospitals were assessed in this study. Among this hospital 24 respondents were participated in the study. Regarding their profession 12 (50%) of the respondents were laboratory department head/laboratory manager and 12(50%) of the respondents were biomedical department heads/biomedical engineers. From the total respondents proportions of male were 18(75%) females were 6(25%). Of the respondents 3(12.5%) had diploma, 14(58.3%) had first degree and 7(29.2%) had second degree (Table 1)

Table 1:- The socio-demographic characteristics of respondents Addis Ababa, Ethiopia 2021

Variables	Category	Number	Percent
Sex	Male	18	75.0
	Female	6	25.0
Age	20-29 years	8	33.3
	30-39 years	13	54.2
	40-49 years	2	8.3
	>=50 years	1	4.2
Educational Status	Diploma	3	12.5
	First degree	14	58.3
	Second degree	7	29.2
	Others	0	0.0
Employment status	Lab professional	12	50.0
	Biomedical engineer	12	50.0
length of years in service	1-4 years	7	29.2
	5-8 years	12	50.0
	9-12 years	2	8.3
	>12 years	3	12.5
what is your responsibility in the department	Lab manager	12	50.0
	Biomedical engineers	12	50.0

5.2 Laboratory equipment maintenance practice

A total of eight questions were asked to assess the laboratory equipment maintenance practice which is implemented in each facility. Based on this almost all of the respondents 23(95.8%) confirmed that for laboratory equipment preventive maintenance procedures takes place in their department. The finding is in lined with the finding *from the observational check list where routine preventive maintenance is performed in all facilities.* However, only 6 (25.0%) of them replied that the recommended preventive maintenance practice (i.e. daily maintenance) is implemented in their department. Moreover, 10(41.7%) respondents confirmed that corrective maintenance procedure was performed for all equipment in their department and 14(58.3%) respondents confirmed that corrective maintenance procedure was not performed in their departments. Majority 22 (91.7%) of them confirmed the availability of equipment service contact information in their department also, almost all 23(95.8%) of them assured the availability of equipment operator manuals in their department.

Table 2 :- Laboratory equipment maintenance practice, public hospitals, Addis Ababa, Ethiopia 2021

Variables	Response	Number	Percent
Trained biomedical engineers	Yes	16	66.7
	No	8	33.3
Are there preventive maintenance procedure takes place in your department for all equipment?	Yes	23	95.8
	No	1	4.2
How often does your department carry-out preventive maintenance?	Daily	6	25.0
	Weekly	5	20.8
	Monthly	5	20.8
	All	8	33.3
Are there corrective maintenance procedure takes place in your department for all equipment?	Yes	10	41.7
	No	14	58.3
How often does your department carry-out corrective maintenance?	Weekly	0	0.0
	Monthly	0	0.0
	Every six month	4	40.0
	After replacing spare parts	6	60.0
Availability of preventive maintenance log sheet	Yes	23	95.8

for all equipment in your department?	No	1	4.2
Availability of equipment service contact information in your department for equipment failure?	Yes	22	91.7
	No	2	8.3
Availability of equipment information sheet that includes Instrument name, Instrument model, Instrument serial No, etc.?	Yes	22	91.7
	No	2	8.3
Availability of equipment operator manuals in the department	Yes	23	95.8
	No	1	4.2

With regard to preventive maintenance practice implementation for laboratory equipment, about 8(33.3%) respondents confirms that preventive maintenance practice implemented as a daily, weekly and monthly manner in their departments. Whereas 6(25%) respondents confirms that preventive maintenance practice implemented as a daily followed by weekly and monthly which is 20.8% respectively.(See Figure 2).

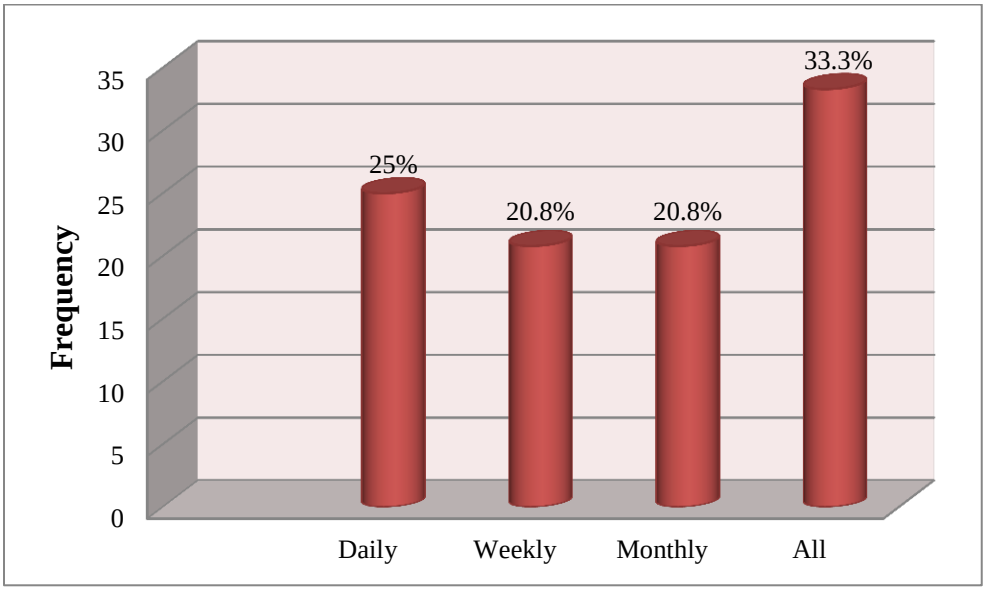


***Figure 2**:- Frequency of preventive maintenance practice, public hospitals, Addis Ababa, Ethiopia, 2021*

Regarding the frequency of corrective maintenance (calibration and verification) procedure implementations, 60% respondents confirms that corrective maintenance practice implemented after replacing spare parts in their departments. Whereas 40% respondents confirm that corrective maintenance practice implementation is takes place every six months. (See figure 3).

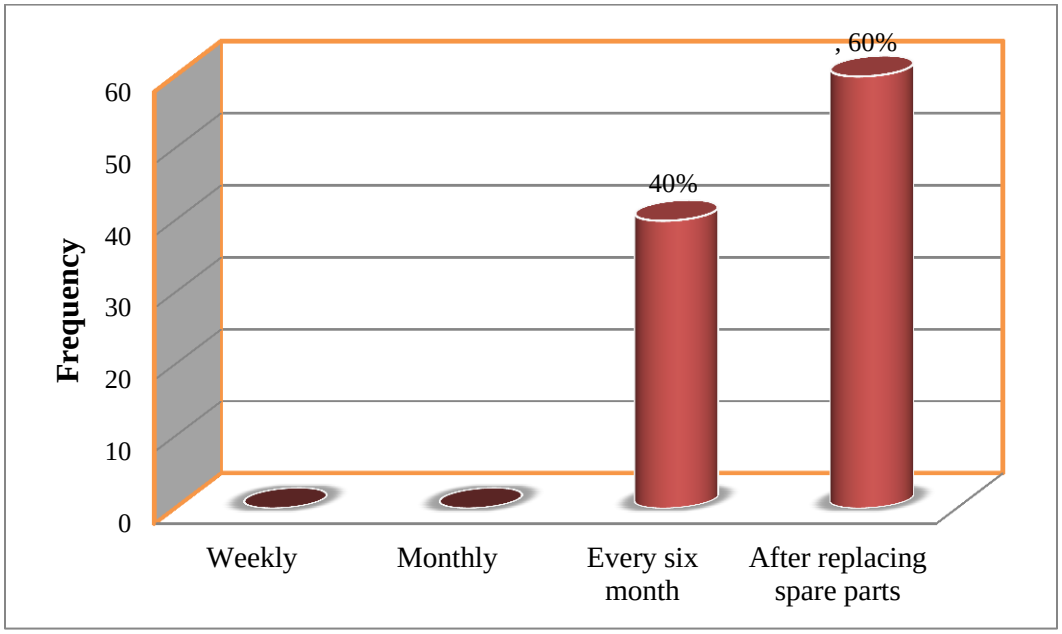


***Figure 3**:- Frequency of corrective maintenance procedure, public hospitals, Addis Ababa, Ethiopia, 2021*

5.3 Laboratory equipment maintenance challenges

Regarding laboratory equipment maintenance challenges, lack of spare parts 7(29.2%) were the major challenge followed by lack of trained biomedical engineers 6(25%), lack of service contract 3(12.5%) and lack of reagents 2(8.3%) respectively. This finding is also supported by the in-depth interview in which *most of the participants replied that lack of spare parts is the leading challenge for laboratory equipment maintenance in their facility*. With regard to the equipment failure 11(45.8%) of the equipment in public hospital fails due to age of the machine, 8(33.3%) failure were work load and 3(12.5%) failure were carelessness of the workers. The majority of the respondents 16(66.7%) had not attending training/workshop on the use and maintenance of the equipment's, 8(33.3%) were attending training on the use and maintenance of the equipment. The replacement policy of laboratory equipment for the hospitals were 13(54.2%) lies on the existing ones are damaged or non- functioning due to lack of spare part/lack of trained engineer and 9(37.5%) replacement policy lies on when the equipment are obsoletes . Most of the hospital had laboratory service agreement 18(75%) whereas 6(25%) had not have service agreement for maintaining the equipment when maintenance is needed (see table 3)

Table 3:- Laboratory equipment maintenance challenges, public hospitals, Addis Ababa, Ethiopia 2021

Variables	Response	Frequency	Percent
What are the major equipment maintenance challenges for the equipment? (more than one answer is possible)	Lack of spare parts	7	29.2
	Lack of reagents	2	8.3
	Lack of trained biomedical engineers.	6	25.0
	Lack of service contract	3	12.5
	Combination of all challenges	6	25.0
What are the major reasons for laboratory equipment failures in your facility?	Age of the machine	11	45.8
	Electrical(improper current supply)	1	4.2
	Carelessness of the workers	3	12.5
	Work load	8	33.3
	Combination of all challenges	1	4.2
Are there backup laboratory procedure/ backup equipment for equipment failure?	Yes	17	70.8
	No	7	29.2

Have you attended training or workshop on the use and maintenance on any of this equipment?	Yes	8	33.3
	No	16	66.7
Does the laboratory have any in- service training on laboratory equipment maintenance? If yes go to the next questions	Yes	24	100.0
	No	0	0.0
How often does the department organize the training?	Occasionally	24	100.0
	Regularly	0	0.0
What is the replacement policy for the equipment?	When the equipment are obsolete	9	37.5
	When the hospital gets fund	1	4.2
	When the existing ones are damaged or non-functioning due to lack of spare part/lack of trained engineer	13	54.2
	Retirement based on expiration of manufacturer's recommended date	1	4.2
Does the laboratory have service agreement for the equipment?	Yes	18	75.0
	No	6	25.0

B. Qualitative

5.4 In-depth interview

In the in-depth interview a total of 24 (i.e. 12 senior laboratory technologists and 12 senior biomedical engineers) were participated. An in-depth interview guide was prepared and used to explore additional ideas from the participants. The interview guide consists of three interview guiding questions that focus on issues about the current status of laboratory equipment maintenance practice in each facility, the major challenges faced during laboratory equipment maintenance and the possible options to improve laboratory equipment maintenance practice in their facility.

Concerning the current status of laboratory equipment maintenance practice in each facility, most of the respondent explain that the laboratory equipment maintenance practice is in their facility could be labeled as poor. *Lack and absence of continuous professional training for biomedical engineers, irregularity in the timing of equipment maintenance and the nature of contractual agreement with the supplier company regarding equipment maintenance* were identified as major themes from the interview for poor maintenance practice.

Regarding the challenges encountered during maintaining laboratory equipment, several opinions were raised by the participants. From these opinions; *Lack of spare parts, Lack of reagent, Lack of trained service engineer, and lack of service contract agreement* were identified as a major theme for the challenges faced on equipment maintenance practice in their respective facilities. As an outliers *limited support from the top management and inadequate budget for equipment maintenance* were mentioned by few of the participants and categorized under minor theme.

Furthermore, the respondents were also interviewed about their opinion concerning the better option (ways) to improve laboratory equipment maintenance practice in their facility. Accordingly, *improving the technical skill of biomedical engineers with continuous training, strengthening the contractual agreement with the supplier, and allocation of appropriate budget for spare parts* and *other materials were taken as major themes from the interview*. Some participants were also mentioned that *absence equipment selection and inspection criteria* in their facility which is taken as a minor theme.

5.5 Observational checklist

Observational checklist was also used to assess the general laboratory maintenance practices conducted at each facility.

In all facilities: equipment are installed and placed as specified in the operator's manuals. Equipment inventory data like name of equipment, manufacturer's contact details, and condition received (new or used), serial number were available in most of the equipment, Service information like contact details of service providers, last date of service, performance maintenance record are readily available in the laboratory room. Manufacturer's operator manuals are found and are readily available to testing staff; routine preventive maintenance report is also recorded on the log sheet. Also daily startup and daily control is performed in all hospitals. However, the observational check list exposed that, in majority of the facilities there higher shortage on spare parts which are used to perform minor repairs. Moreover, non-functioning equipment were either not labeled properly or removed from the laboratory and storage areas. Furthermore, in most of the facilities routine equipment maintenance was not conducted by qualified professionals according to its schedule.

6. Discussion:

The finding of this study shows that the majority 23(95.8%) of the respondents confirms that preventive maintenance practice were implemented among public hospitals in Addis Ababa. However, in this study the of implementation of preventive maintenance practices, 8(33.3%) of respondents indicated that preventive maintenance takes place combinations of daily, weekly and monthly; 6(25%) of preventive maintenance takes place as daily and only 5(20.8%) of preventive maintenance implemented as weekly and monthly practices. Moreover all equipment are installed, equipment inventory data, service contact information and manufacturer manuals are readily available and posted in the testing site during data collections. Based on the result of this study 23(95.8%) of the respondents confirms that preventive maintenance log sheet is available in the department and preventive maintenance report is also recorded on the log sheet. 22(91.7%) of participants indicated that equipment service contact information is available in the department for equipment failure. This finding is in line with the studies conducted in Kitwe Central Hospital, Nchanga North Hospital and Ronald Ross Hospital at Zambia, the result shows that 93.9% of the hospitals had preventive maintenance programs in their departments (24).

With regard to corrective maintenance practice, 14(58.3%) respondents indicated that corrective maintenance practices were not implemented in public hospital found in Addis Ababa. In the majority of facilities there are higher shortages of spare parts which are used to perform minor repairs. Furthermore, in most of the facilities routine equipment maintenance was not conducted by qualified professionals according to its schedule. Lack of spare parts 7(29.2%), lack of trained biomedical engineer 6(25%), lack of service contract 3(12.5%) and lack of reagents 2(8.3%) respectively are the major reason and identified as a major challenges faced during maintaining laboratory equipment in public hospital Addis Ababa. This is also supported by the in-depth interview in which most of the participants replied that lack of spare parts is the leading challenge for laboratory equipment maintenance in their facility. This finding is consistent with a systematic review conducted in 60 resource-poor hospitals located in 11 nations in Africa, Europe, Asia, and Central America, on 2010 by Robert Malkin Allison Keane showed that most of laboratory and medical equipment in resource-poor settings is out-of-service. The most common reasons are a lack of spare parts and a lack of highly trained technicians (23). This shows that the majority laboratory equipment in public hospital was out of service due to lack of

spare parts and absence of continuous professional training for biomedical engineers. The majority of the respondents 16(66.7%) had not attending training/workshop on the use and maintenance of the equipment's; 8(33.3%) were attending training on the use and maintenance of the equipment.

In this study age of the machine, work load and carelessness of the workers which is 11(45.8%), 8(33.3%) and 3(12.5%) respectively were the major laboratory equipment failures among public hospital in Addis Ababa. In contrast with this result study conducted at Kosovo, shows that the most frequent challenges for equipment failures are in electrical and electronic systems with 69%, with 26% mechanical and 5% hydraulic and pneumatic. Thus the main equipment failure are improper current supply, which is 44%, age of machines is 22%, carelessness of workers 17%, heavy load 13%, and other factors 4 % (21).

With respect to in- service training on laboratory equipment maintenance management, this study reveals that laboratories have in- service training on laboratory equipment maintenance prior to service delivery. In contrast with this finding, study conducted in hospitals affiliated to Iran University of Medical Sciences at Iran, the result showed that 60% of medical devices in hospitals affiliated to medical sciences universities had not been given pre service training for the staff, thus the most frequent challenges are repair and maintenance services 29.6%, Supply of equipment 26.1%, inspection and service training aspects 14.1 %(22).

Regarding the replacement policy of laboratory equipment,13(54.2 %) of the respondents confirmed that laboratory equipment is replaced when the existing ones are damaged or non-functioning due to lack of spare part/lack of trained engineer, 9(37.5%) of the respondents agreed that laboratory equipment is replaced when the equipment are obsolete. Furthermore, 2(4.2%) of the respondents agreed when the hospital gets fund and retirement based on expiration of manufacturer's recommended date. According to the findings of this study majority of laboratory equipment was out of service due to lacks of spare parts (29.2%); lack of trained biomedical engineer (25%), lack of service contract (12.5%) and lack of reagents (8.3%). This are the major challenges identified for maintaining laboratory equipment in public hospital in Addis Ababa during the study period. This result is consistence with the study conducted 14 public hospitals found in Addis Ababa, the result shows that lack of spare parts was the primary reason for non-

functionality of medical laboratory equipment among public hospitals which accounts about 39.6% of the non-functionality of medical laboratory equipment during the study period followed by installation problem 14.6% and lack of reagents 12.5% (26). The other findings of this study shows that 70.8% of public hospitals laboratory have back up laboratory procedure for equipment failure, only 29.2% laboratory don't have backup procedure/backup equipment for equipment failures during the study period.

7. Strength and limitations

7.1 Strength

The current study used a mixed data collection methods (i.e. both qualitative and quantitative data collection methods) to explore the challenges of laboratory equipment maintenance which could be taken as a major strength. Additionally the study applied a standard observational checklist to check out the actual performance and maintenance practices conducted in each hospital which could strengthen the finding.

7.2 Limitations

This study was limited only in public hospital found in Addis Ababa, further comprehensive and comparative study needed on private and public owned hospitals; this could be taken as a limitation. In addition, social desirability bias on the quantitative part could also be taken among the limitations of the current study.

8. Conclusion and Recommendations

8.1 Conclusion

In conclusion the findings of the current study revealed that Preventive equipment maintenance procedures were conducted about 95.8% and the practice of corrective maintenance procedure was found to be 42.7%. Lacks of spare parts and lack of trained biomedical engineers were the major laboratory equipment maintenance challenge of corrective laboratory equipment maintenance. Age of the machine, work load and carelessness of the worker were the major laboratory equipment failures among public hospital in Addis Ababa. The majority of laboratory equipment in public hospital was out of service due to lack of spare parts and absence of continuous professional training for biomedical engineers.

8.2 Recommendations

Based on the result the following recommendations are forwarded to the concerned bodies in order to improve laboratory equipment maintenance management system.

- The hospitals management in collaboration with FMoH and funding organizations should exhaustively work on availability of Spare parts
- The hospitals management/administration body should establish a means to maintain nonfunctional equipment's found in each hospital
- The hospitals should facilitate/arrange on job training and continuous professional development scheme for biomedical engineers to improving their technical skill.
- The hospital management/administration body should avail the reagents and the laboratory equipment should have service agreement.
- Finally, the researcher will recommend a comprehensive and comparative study on challenges of laboratory equipment maintenance among private and public owned hospitals

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Annex 1. Information sheet

Title of the Research Project: Assessment of Laboratory Equipment Maintenance practice and associated Challenges in selected public Hospitals present at Addis Ababa, Ethiopia

Principal Investigator: Daniel Melkamu (BSc, MSc candidate)

Name of the Organization: Department of Medical Laboratory Sciences, College of Health Sciences, Addis Ababa University

Introduction

You are invited to participate as a study subject in a research conducted by MSc candidate, from Addis Ababa University. Your participation is voluntarily. The research teams will include one principal investigator, two advisors; from Addis Ababa University Department of medical Laboratory Sciences. Please take as much time as you need to read or listen in the information sheet.

Purpose of the Research Project

We are asking you to take part in this study because we will try to assess laboratory equipment maintenance practice and associated Challenges in selected public Hospitals present at Addis Ababa, Ethiopia

Confidentiality

We respect your privacy and confidentiality. Any information that identifies you will not be shared with anyone else outside the study team. The information we will collect from you as part of the study will be kept in a locked file cabinet, or be protected by a password on the computer only accessible to personnel involved in the study. There is no sensitive issue that you will be asked related with your social desirability but any information that is obtained in connection with this study and that can be identified with you will remain confidential.

Potential benefits to subjects and/or to the society

You will not receive any payment for your participation in this research study as compensation. In addition, the result of the study will be beneficial for the detection and managing of laboratory equipment maintenance challenges. Hence, you are indirectly benefiting other patients and the society in this respect.

Participation and Withdrawal from the Study

The participation is voluntary and you have the right not to participate in this study. You may withdraw at any time and place without consequences of any kind. You may also reject to give any information. You can ask any questions regarding to this study.

Contact information

If you have any questions about this study you can contact the principal investigators for further information.

Name: Daniel Melkamu, Phone: +251911 574371 E-mail: danimelkamu@gmail.com

Annex 2. Informed consent form

Questionnaire ID …..……

I had been informed that the objective of this study is to assess laboratory equipment maintenance practice and associated challenges in selected public hospitals present at Addis Ababa, Ethiopia. The results of this study present a framework for laboratory equipment maintenance practice and associated challenge with the purpose of enhancing and improving our understanding of the practice and challenges in Ethiopia and to be used as an input for the future development of strategies or guidelines. I had been also informed about the confidentiality of this study.

The principal investigator requested me to participate in the study that would require my willingness to provide the required data, and filling questionnaire. Therefore, with full understanding of the importance of the study, I agreed voluntarily to provide the requested data. I_____ hereby give my consent for providing the requested information. Signature:_____Date_____

Annex 3. Research Questioner

Research questioner on assessment of Laboratory equipment maintenance practice and associated Challenges in selected public Hospitals present at Addis Ababa, Ethiopia.

MONTH OF SURVEY: _____YEAR: _____

No	A. Socio-Demographic	Response
1	Name of health facility	
2	Department	
3	Sex	□ Male □ Female
4	Age	_____(In year)
5	Educational Status	□ Diploma □ First Degree □ Second Degree □ Others specify
6	Employment Status	□ Laboratory professional □ Biomedical engineer □ Other Specify
7	Length of Years in Services	_____(year)
8	What is your responsibility in the department?	□ Laboratory manager □ Laboratory Quality officer □ Laboratory technologist /technicians □ Biomedical engineers
	B. Laboratory facilities	
9	Are there trained biomedical engineers in your facility?	□ Yes □ No
10	Are there preventive maintenance procedure takes place in your department for all equipment? If yes go to the next questions	□ Yes □ No If no why? _____
11	How often does your department carry-out preventive maintenance? (more than one answer is possible)	□ Daily □ Weakly □ Monthly □ Other specify_____
12	Are there corrective maintenance procedure takes place in your department for all	□ Yes □ No

	equipment? If yes go to the next questions	If no why?_____
13	How often does your department Carry-out preventive maintenance? (more than one answer is possible)	□ Weakly □ Monthly □ Every six months □ After replacing spare parts □ Other specify_____
14	Are there preventive maintenance log sheet for all equipment available in your department?	□ Yes □ No If no why_____
15	Are there equipment service contact information is available in your department for equipment failure?	□ Yes □ No If no why_____
16	Are there equipment information sheet that includes Instrument name, Instrument model, Instrument serial No, Last service date, Next service date, Last calibration date, Next calibration date and Location of Equipment?	□ Yes □ No If no why_____
17	Are there equipment operator manuals available in your department?	□ Yes □ No If no why_____
18	What are the major equipment maintenance challenges for the equipment? (more than one answer is possible)	□ Lack of spare parts □ Lack of reagents □ Lack of trained biomedical engineers. □ Lack of service contract □ Other Specify _____
19	What are the major laboratory equipment failures in your facility?	□ Age of the machine □ Electrical(improper current supply) □ Carelessness of the workers □ Work load
20	Are there backup laboratory procedure/ backup equipment for equipment failure?	□ Yes □ No If no why_____
21	Have you attended training or workshop on the use and maintenance on any of this equipment?	□ Yes □ No If yes, state the number of training:

		_____ and when _____ If no why?_____
22	Does the laboratory have any in- service training on laboratory equipment maintenance? If yes go to the next questions	□ Yes □ No If no why?_____
23	How often does the department organize the training?	□ Occasionally □ Regularly
24	What is the replacement policy for the equipment?	□ When the equipment are obsolete □ When the hospital gets fund □ When the existing ones are damaged or non- functioning due to lack of spare part/lack of trained engineer □ Retirement based on expiration of manufacturer's recommended date □ Other Specify _____
25	Does the laboratory have service agreement for the equipment?	□ Yes □ No If no why_____

Open-ended interview questions for laboratory professional and biomedical engineers

1. What do you think about the current status of laboratory equipment maintenance practice in your facility?

2. What are the major challenges you have faced during maintaining laboratory equipment?

3. What is the better option to improve laboratory equipment maintenance practice?

Observational checklist

Name of the Hospital_____

Activity	Yes	No	Remark
Is equipment installed and placed as specified in the operator's manuals and uniquely labeled or marked?			
Is current equipment inventory data available on all equipment in the laboratory? Including Name of equipment, Manufacturer's contact details, Condition received (new, used,), Serial number, Date of purchase, Date when put "out of service", Date of entry into service			
Is relevant equipment service information readily available in the laboratory?			
• Service contract information			
• Contact details for service provider			
• Decontamination records			
• Performance and maintenance records			
• Last date of service			
• Next date of service			
Are the equipment manufacturer's operator manuals readily available to testing staff?			
Are Spare parts available to perform minor repairs as per manufacturer's instructions?			
Is routine preventive maintenance performed on all equipment and recorded on log sheet?			
Is equipment routinely serviced according to schedule by qualified and competent personnel, and is this information documented in appropriate logs?			
Is non-functioning equipment appropriately labeled and removed from the laboratory and storage areas?			
Are there back-up procedures for equipment failure			
Daily startup performed			
Daily control performed			

List the equipment available in the Department

No	Type of Laboratory Equipment	Quantity in Use	Quantity Out of use	If out of use, what are the major challenges for maintaining the equipment? 1. Lack of spare parts, 2. Lack of reagent 3. Lack of trained Service engineer, 4. Lack of service contract.
1.				
2.				
3.				
4.				
5.				
6.				
7.				
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9.				
10.				
11.				
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17.				
18.				

Declaration

I, the undersigned, declare that this M.Sc. thesis is my original work, has not been presented for a degree in this or any other university and that all sources of materials used for the thesis have been duly acknowledged.

M.Sc. candidate: Daniel Melkamu (B.Sc.)

Signature: _____

Date of submission: _____

This thesis has been submitted with our approval as advisors.

Advisor Fatuma Hassen (MPH, PhD candidate)

Signature: _____

Date: _____

Place: Addis Ababa, Ethiopia.

Advisor: Alemayehu Nigatu (BSc,MSc MPH)

Signature:_____

Date: _____

Place: Addis Ababa, Ethiopia.