International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2019): 7.583

Quality Assurance and Quality Control in Forensic Fingerprint Laboratories in Bahrain and Dubai: Comparative Study

Muna Sultan Ahmed[1], Bassam Alhamad[2], Saad Suleiman[3]

Abstract: ***The current study aims to compare the adoption of quality assurance and quality control standards in the forensic fingerprints laboratories (FFPL) in Bahrain and Dubai. Particularly, the study aims to: 1) identify the differences in the adoption of QA/QC (ISO/IEC 17025) in FFPL between Bahrain and Dubai; 2) to identify the advantages of adopting a specialized accreditation scheme such as ISO 17025 and ILAC; and 3) to identify the extent to which the accreditation by ISO 17025 and ILAC in forensic labs in Bahrain improve the QA practices. The researcher adopted the descriptive research method. A mixed-method approach was utilized by the researcher, where both quantitative and qualitative research instrument, i.e. a questionnaire and an in-depth interview, were employed to collect the data from the sample of the study which consisted of (68) employees from forensic fingerprint laboratories in Bahrain and UAE-Dubai (quantitative sample) and (2) interviewees representing highly authorized personnel in the two countries (qualitative sample). The data were analyzed using the Statistical Package for Social Sciences (SPSS) version 25. The findings of the study demonstrated that there are statistically significant differences in quality management responsibility between FFPL in Bahrain and FFPL in Dubai, for the benefit of FFPL in Dubai. It indicated that although the forensic fingerprints both laboratories in Bahrain and Dubai have gained ISO 9001, however Dubai's forensic fingerprints laboratories demonstrated a better performance in accordance with the quality assurance and quality control standards.***

Keywords: Forensic science, Fingerprint, Quality Assurance, Quality Control, ISO17025, Bahrain, Dubai

1. Introduction

Quality assurance and quality control systems in forensic laboratories are considered highly essential in improving the workflow of this critical field, (Hazard et al., 2018). These quality systems promote trust in the validity of the material evidence presented in court of law (Milosevic et al., 2008). The application of these quality assurance and quality control systems in forensic laboratory qualifies the lab in terms of commonality of the procedures in lab, defining of required working instruments, its calibration and verification, defining of qualified working profile for using those instruments, defining of the obligatory working procedures, etc., (Milosevic et al., 2008). The quality paradigm consists of the implementation of standardization, certification, accreditation, and evaluation processes that eventually aim to improve the data exchange between laboratories and enables maintaining a comprehensive data-basing due to standardized methods that are capable of ensuring reliable and valid results (Hazard et al., 2018).

An overview of the quality assurance setting at the FFPLs in Bahrain (B-FFPL) and Dubai (D_FFPL) shows that both FFPLs have an impartiality policy; however it is not documented as a separate policy in Bahrain, whereas it is considered part of the quality assurance program in D-FFPL. The impartiality is ensured at both places through training programs, administration reviews and proficiency testing. Regarding structural requirements, both are part of police department. Both FFPLs have clear job descriptions in accordance to ISO9001; however B-FFPL has no specialized accreditation or certification for their laboratories, whereas D-FFPL has ISO17025 as the main base quality requirement for the laboratories and ILAC G19 specifically for Forensic Labs. Both FFPLs have personnel, facilities, equipment systems and support services available, necessary to manage and perform Its laboratory activities. In reference to resources requirements, both have competency and proficiency tests, however D-FFPL perform additional random case selections as part of their ISO-17025 requirements. Regarding the personnel awareness, B-FFPL satisfied ISO 9001 requirements and they aimed to word achieving ISO17025 standards. D-FFPL claimed their full knowledge of the requirements through continuous training and awareness programs. Both FFPLs hire qualified personnel or experts in their departments. Equipment are well tested, operated, calibrated and maintained by both FFPLs in accordance to ISO9001 requirements. As part of additional requirements by ISO17025, D-FFPL undergoes additional inter-laboratory comparisons with Abu-Dhabi, Sharja, and Ras- Alkhaimah. Both have a defined list of external providers that is well maintained. Technical records are stored and retained in such a way that they are readily retrievable. Both FFPLs have defined / documented procedures for ensuring the validity of results and follow an integrated procedure in reporting. Regarding complaints handling and non-conformities, both FFPLs have a defined and a documented system as per ISO9001 standards. Both FFPLs have a system to control their data both in automatic and manual systems, as well as safety and backup systems to maintain its data in terms of accuracy and security.

1.1 Problem Statement

The evolution of quality requirements in laboratories has started in the early 1980's and developed into an industry of quality systems and assessment bodies to ensure every result produced by a forensic science laboratory is not only accurate, but is also assured (Venter, 2010). Hence, the forensic laboratories' managers and personnel must fully comprehend the scope of quality systems through investigating all of the international recommendations related to the concepts of quality assurance and quality control. The prominent and most reliable way to achieve this

target is through conducting comparative studies and investigations, which will eventually lead to benchmarking the laboratories with the best quality assurance and control practices within the same industry. Therefore, there is a concern in developing FFPLs, and whether ISO 9001:2015 or ISO17025 requirements will enhance the management system of the FFPLs. A comparison between two managements systems namely B-FFPL and D-FFPL, have ISO9001 standards, however D-FFPL has additional requirements as per ISO17025 standards. The current study aims to answer the following questions:

- What are the differences in the adoption of QA/QC (ISO/IEC 17025) in FFPL between Bahrain and Dubai?

Advantages of adopting a specialized accreditation scheme such as ISO 17025 and ILAC will be reflected in this research study. The study targets achieving the following objectives:

- To identify the differences in the adoption of QA/QC (ISO/IEC 17025) in FFPL between Bahrain and Dubai.
- To identify the advantages of adopting a specialized accreditation scheme such as ISO 17025 and ILAC.
- To identify the extent to which the accreditation by ISO 17025 and ILAC in forensic labs will improve the QA practices in Bahrain.

This study will contribute to the literature of QA practices in FFPLs, and very limited research cover application of FFPLs in Bahrain. The study will highlight recommendations to improve the QA and QC procedures for FFPL in Bahrain.

2. Literature Review

Forensic science is laying a solid ground in the region of effective crime prevention, especially in the regions where more sophisticated use of available technology is prevailing (Malkoc and Neuteboom, 2007). Saferstein (1988,1993) has defined forensic science as the application of science to criminal and civil laws that are enforced by police agencies in a criminal justice system. QA and QC are interrelated to each other significantly as they depend on each other, where QC is the element that is responsible for the evaluation of the process and the QA is the feedback in order to ensure that the policies in place are going to be utilized appropriately (Usmani, 2019). Stimac (2003) has stated that the importance of an analyst and his or her laboratory to give accurate and objective information should be the inherent and unremitting scientific responsibility. Both necessities are extensively defined as quality assurance guidelines in the operation manuals of most forensic laboratories and are demonstrable requirements within all casework documentation. Inappropriate deviation from accuracy and objectivity carries ethical and legal consequences." Earwaker et al. (2015) have cited that within UK policing, it is routinely the responsibility of fingerprint laboratory practitioners to chemically develop areas of latent fingerprint ridge detail on evidential items, and to determine which areas of ridge detail are of sufficient quality to be submitted to fingerprint experts for search or comparison against persons of interest. Due to a unique role and responsibilities of FSL, the establishment, implementation and documentation of procedures for the purpose of reducing and minimizing errors is crucial (Lappas and Lappas, 2016). According to Wilson-Wilde et al. (2010), in order to prepare or to ensure the reliability, consistent performance and safety of service, products, systems, standards, procedures and specifications are designed and established. Moreover, Levy et al. (1999) stated in their study that QA in Forensic Science maintains consistent results of forensic tests; hence it affects significantly accomplishment of successful decisions or conclusions from criminal investigations. Jamieson (2016) conducted a study that laboratory accreditation augments quality assurance programs in forensic science laboratories, encouraging good practices of forensic science, reliable procedures and techniques, and responsible expert opinions. Moreover, Mohr (2005) indicated that a new standard might decrease doubt in the courtroom and develop the scientific examination provided by ISO 17025. Li and Adeli (2009), Libeer (2001), and Zampa et. al. (2018) pointed out that the proficiency test is an exterior quality control that defines inter-laboratory usage and comparison to observe the laboratory performance. In addition, Elliott et al., (2018) and Cooper et. al. (2010) mentioned that laboratory outcomes are displayed "to challenge in the adversarial justice system", so QA supposes unparalleled functions in the FS disciplines and QA programs aimed to discover, avoid errors and to recruit suitable corrective actions. In addition, Elliott et al. (2018) stated that the laboratory should undergo risk assessment and assure a suitable procedure to eliminate or reduce such risk to the personal and environmental region. Cooper. et al. (2010) mentioned that the routine equipment maintenance is a significant part of any QA program which should be documented and practiced, hence ensuring progression and improvement. The standards of quality are nowadays being made reachable by applying to qualified individuals and organizations for assessment, consultation, and improvement (Koski et. al., 2018). Pádár et. al. (2015) studied the accreditation of forensic laboratories as a part of the 'European Forensic Science 2020' in countries of the Visegrad Group to measure the equivalence of professional examination of forensic and the evidence collection, processing, methods used and delivery of forensic information.

Hutchins and Olbercht (2009) stated that accreditation increases the connectivity between national and international agencies through standardized programs, software, and technologies, for example AFIS which is the 'Automatic Fingerprint Identification System' is used to store and compare finger and palm prints with unknown impressions to identify the print source. In the fingerprint department in Bahrain, this system is used to feed the national database for comparison purposes in Bahrain only. Consequently, this system provides a standard manner of workflow and allows harmonization toward cooperation and accreditation with other parties applying the same technology. Page et al. (2019) mentioned that by depending on different types of Forensic Science (FS) evidence in compound investigations of criminal cases, the procedures for guaranteeing the quality of analysis is challenging. Developments towards managing quality system and assuring the robust usage of scientific essentials and how accurate results are clarified

and reported, assure validity of the results and are included in the "criminal justice system". Budowle et al. (2009) stated that the Forensic Science Labs (FSL) quality system will be improved if the accreditation is activated, however, it's not only required by FSL alone but it is required by FS starting from the scene of the crime up until reaching the court. Wilde et al. (2010) mentioned that this standard is not planned for applications of forensic science though many Forensic Labs get accredited against ISO 17025, because it provides requirements for laboratories to standardize conducting tests, with highlighting the importance on policy and documentation. Soria (2018) discussed the importance of standardization and harmonization with international cases, where they ensure unified procedures and standards used that make the understanding of results and exchange of results easy and useful. One of the factors that affect the forensic science laboratories is the difference in scientific methods used in the laboratory (Andersen, 2014). Ricci et al. (2013) stated that each laboratory should build its "own analytical system, reliable and reproducible, through its own validation". The researchers believe that the spread of the implemented methods by per standards of ISO 17025 is a need for any future cooperation or data sharing of common protocols. Cooney (2010) asserted that consistency can only have been obtained with standardized programs for training in the field of fingerprint; however, these programs should be designed to fit their needs. This will lead to harmonization and standardization of universal nature. Hofmeister et al. (2017) pointed out that the support of the system of information or data management assures the high-quality level of data through continual monitoring and QA and QC measures. As stated by Vlachos (2012) and Vlachos et al. (2009), it should be stressed that ISO 17025 guarantees consistency in quality at any desired level. The keys are to constantly attain advanced quality flexibility and innovation in its management. Wilde (2018) highlighted that the product recent image is built on global, national, or regional level.

3. Methodology

To achieve the objectives of the study, the researcher designed questionnaire and interview that cover the ISO 17025 clauses and other related quality matters obtained from literature. This study will adopt a mixed method research design as fusing numerous methods into a solitary assessment frequently results in a more grounded and more comprehensible assessment than regular assessment approaches depending on just a single method. The questionnaire was employed in order to investigate the nature of applying ISO 17025 in FFPL. On the other hand, the interview was conducted to highlight the current practices according the certification or accreditation of ISO 9001, ISO 17025 accreditation, and others ISO standards that are already achieved.

It is worth mentioning that the questionnaire and interview that cover the ISO 17025 clauses and literature were adopted and adapted from the general guidelines and structure for ISO 17025 found in the literature. Such adoption and adaptation were carried out to align with the research objectives. The interviews carried out in Bahrain and Dubai covered the discussion of current practice in accordance to the granted certification or accreditation. Currently, B-FFPL carries the certification of ISO 9001, while Dubai achieved the certification and accreditation of ISO 9001, ISO 17025, ILAC-G19 and other general ISO certificates such as: ISO 14001 and ISO 18001.

Based on ISO 17025 clauses, quality indicators were identified and grouped into nine groups called factors as shown in Table 1.

Table 1: Factors Used in the Questionnaire Design obtained from Literature Studies

No	Factors Used in the Questionnaire Design	No of Indicators	Previous studies
1	Management Responsibilities	7	Levy et al. (1999), Jamieson (2019), Mohr (2005), GGS for ISO 17025
2	Resources Management	16	Giannelli (2003), GGS for ISO 17025
3	Product Realization	5	Asten (2014), Watson and Jones (2013),
4	Measurement Analysis	8	Lappas and Lappas (2016), Mohr (2005), GGS for ISO 17025
5	Timeliness	3	Sciacovelli and Plebani (2017), Al-Moathen, (2011)
6	Work	6	Burnett (2006), AL-Moathen, (2011)
7	Cost	3	Cooper et al. (2010), AL-Moathen, (2011)
8	Awareness	5	Hazard et al. (2018), AL-Moathen, (2011)
9	Quality Procedures	6	Hazard et al. (2018), Milosevic et al. (2008), Wakefield (2006), Lappas and Lappas (2016), GGS for ISO 17025

The questionnaire includes, in addition to these factors and their indicators per each factor, as well as demographic data. The demographic data includes the following: the respondent age; gender; highest level of education completed; years of working experience in the field of forensic science; place of work.

Because of the study limited population, the quantitative sample is taken equal to the total population, which consisted of (68) employees from forensic fingerprint laboratories in Bahrain and UAE-Dubai. The questionnaire was employed in order to investigate the nature of applying ISO 17025 in FFPL. Meanwhile, the qualitative sample was conducted with the Head of Fingerprint Department at the General Directorate of Criminal Detection and Forensic Science at the Ministry of Interior, Kingdom of Bahrain and the Director of Training Research and Development Department in Dubai Table 2 shows the distribution of the sample used in the study.

Table 2: The Distribution of the Sample of the Current Study

Research Instrument	Bahrain Sample		UAE-Dubai Sample	
Questionnaire	Male	28	Male	32
	Female	6	Female	2
Total	34		34	

Interview	One Interviewee: The Head of fingerprint department at The general directorate of criminal detection and forensic science in Bahrain.	One Interviewee: The Director of Training Research and Development Department in Dubai.

4. Results and Analysis

This section reports the results derived from the analysis of the data generated from the two research instruments that were employed in the current study, i.e. the questionnaire collected from (68) respondents working in FFPL in BH and Dubai, and the in-depth interview. It is worth mentioning that the data collected from the questionnaire were analyzed using the Statistical Package for Social Sciences (SPSS). To verify the validity of the study tool, the researcher calculated the Spearman's Coefficient of Correlation between the questionnaire and its factors. The calculated Spearman's coefficient of correlation for the indicators of the questionnaire is a statistically significant relation (p=0.01) between each of the factors and its indicators. Table 3, 4, 5 & 6 demonstrate the distribution of the population's age, gender, professional background and work experience.

Table 3: Participant's Age

Age	Bahrain		Dubai	
	Frequency	Percent	Frequency	Percent
21 – 25	4	11.8%	4	11.8%
26 – 30	14	41.2%	4	11.8%
31 – 35	5	14.7%	6	17.6%
36 – 40	3	8.8%	6	17.6%
41 – 45	7	20.6%	5	14.7%
more than 45	1	2.9%	9	26.5%
Total	34	100%	34	100%

Table 4: Participant's Gender

Gender	Bahrain		Dubai	
	Frequency	Percent	Frequency	Percent
Male	28	82.4%	32	94.1%
Female	6	17.6%	2	5.9%
Total	34	100%	34	100%

Table 5: Participant's Professional Background

Qualification	Bahrain		Dubai	
	Frequency	Percent	Frequency	Percent
High school	18	52.9%	19	55.9%
Diploma's degree	1	2.9%	0	0.0%
Bachelor's degree	13	38.2%	13	38.2%
Master's degree	2	5.9%	2	5.9%
Total	34	100%	34	100%

Table 6: Participant's work experience

Experience	Bahrain		Dubai	
	Frequency	Percent	Frequency	Percent
0 – 4	16	47.1%	2	5.9%
5 – 9	8	23.5%	6	17.6%
10 – 14	3	8.8%	7	20.6%
15 – 19	4	11.8%	5	14.7%
20 – 24	3	8.8%	4	11.8%
25 or above	0	0.0%	10	29.4%
Total	34	100%	34	100%

The t-test results show that there are statistically significant differences in all indicators for factors between FFPL in Bahrain and FFPL in Dubai, for the benefit of FFPL in Dubai. The results obtained shows that the range of factor's weights for B-FFPL are lower than the ranges obtained for D-FFPL, as shown in Table 7.The standard deviations are also lower for D-FFPL. The most influential indicators for every factor are shown in Table 8.

Table 7: Range of Weight for the Different Factors

No.	Factors	Range of factors' weights for Bahrain	**Mean**	**SD**	Range of factors' weights for Dubai	**Mean**	**SD**
1	Management Responsibility	65.3- 87.6%	3.941	0.697	93.5- 98.2%	4.811	0.445
2	Resources management	67.6- 87.1%	3.888	0.651	95.3- 98.8%	4.842	0.330
3	Product Realizations	77.1- 84.7%	4.065	0.640	94.7- 97.1%	4.800	0.465
4	Measurement Analysis	70.0- 84.7%	3.688	0.998	95.9- 97.1%	4.835	0.434
5	Timelines	69.4- 84.7%	3.873	0.998	94.7- 96.5%	4.775	0.511
6	Quality of work	70.6- 84.7%	3.951	0.724	86.5- 97.6%	4.760	0.417
7	Cost	70.0- 77.1%	3.676	0.878	93.5- 94.7%	4.706	0.567
8	Awareness	70.0- 77.1%	3.071	1.052	93.5- 94.7%	4.606	0.736
9	Quality Procedures	70.6- 84.7%	3.564	0.882	86.5- 97.6%	4.887	0.343

Table 8: Most Influential Indicators per Factor

		Most influential Indicators	
No.	Factors	Bahrain	Dubai
1	Management Responsibility	• Commitment of Laboratory to providing internal and external customers with quality services • Operation of quality management system by organization managers to meet ISO 9001 requirements	
2	Resources management	• Competency of analysts by experience • Effectiveness of laboratory resources in meeting customer requirements	• Suitability of the laboratory environment for the laboratory work activities • Equipment are calibrated / tested by qualified people
3	Product Realizations	• Customer requirements of products are satisfied • Labeling of equipment to indicate next operational qualification and calibration check date	• Maintenance of laboratory test equipment • Labeling of equipment to indicate next operational qualification and calibration check date
4	Measurement Analysis	• Evaluation of customer requirements • Availability of sample container requirement list	• Availability of Sample container requirement list • Availability of internal auditing to show whether the quality management system is effectively implemented and maintained
5	Timelines	• Testing on time all products by laboratory	• Working hours in laboratory satisfy testing of all finished

		Most influential Indicators	
No.	Factors	Bahrain	Dubai
		• Working hours in laboratory satisfy testing of all finished products	products • Enough analysts to perform the needed analysis
6	Quality of work	• Using the new technology in doing the various type of tests • Equipment logbooks maintained and available	• Using the new technology in doing the various type of tests • Implementing of Quality assurance and quality control program
7	Cost	• Availability of standardized calibration operating • Minimizing of cost through continuous maintenance of equipment	• Availability of standardized calibration operating • Removal of defective equipment from the lab and labeled as defective or out of services
8	Awareness	• ISO 17025 is essential for forensic labs • ISO 17025 is about (accreditation, certification, or lab safety)	• ISO 17025 standards has been issued for laboratories • I heard about ISO 17025
9	Quality Procedures	• There are documented procedures of sample receiving, chain of custody, sample analysis, review of data, and reporting in place • There are documented manual for each test procedure in place	• There are documented manual for each test procedure in place • There are quality control procedures in place

Referring to Table 8 as per the factor “management responsibility”, the first noted difference was observed for resources management, where the two main indicators for B-FFPL were competency of analysts and the tendency to meet customer requirements, however D-FFPL most influential indicators were more towards the standards and requirements, covering the suitability and quality provision of laboratory procedures and equipment. This emphasis is reflected by ISO17025 that concentrates on detailed and standardized procedures for equipment. Similar trend is noted for Product Realization and Measurement Analysis, where B-FFPL concentrates on customer requirements, however D-FPL concentrates on the detailed and standardized procedures such as maintenance of laboratory test equipment, labeling of equipment to indicate next operational qualification and calibration check date, availability of Sample container requirement list, and availability of internal auditing to show whether the quality management system is effectively implemented and maintained. Moreover, the results of the analysis of the questionnaire on this regard are confirmed by the interview results that competency and quality is standardized in Dubai. They have competent staff following a continual education plan, training system, documented plans, virtual court, and a process of random case selection to review them every period of time. As stated, this is part of the ISO 17025 standards to concentrate on the competency standardization. However, in Bahrain they provide training courses, but do not have that continual education and training plans. As mentioned in literature review, Giannelli (2003) stated that the management or government can invest by gaining accreditation for laboratories which will provide standard protocols and procedures, competent examiners with standard training plans.

The most influential indicator of quality related to “Timeliness” among FFPL in Bahrain is reflected by the indicator "Testing on time all products by laboratory" with a mean of (4.235) and a standard deviation of (0.890) and the most influential indicator of the “Quality of Work” factor among FFPL in Dubai is the indicator "Using the new technology in doing the various type of tests" with a mean of (4.884) and a standard deviation of (0.478).From literature review Sciacovelli and Plebani (2017) stated that laboratories should be aware about Quality Indictors (QI) or Key Performance Indicators (KPIs) which monitors process starting and ending times, for example, since 2014, Bahraini fingerprint department applied the key performance indicators (KPI) to measure its processes against defined specifications, at a set certain period of time. As a result, improvements in the productivity reached 98% in 2017, and also improvement in decreasing the time needed to finish the tests needed and producing the final report. The same practice was reflected in D-FFPL, where the interviewee stated the KPIs and mentioned that this is part of the requirements of ISO17025.

Regarding timeliness, both FFPLs have required working hours, however the most influential indicator in B-FFPL is testing all samples on time, however D-FFPL that the needed analysis must be maintained. The error as per ILAC G19 standards is not bearable. Similarly, as per the “Quality of Work” and “Cost”, D-FFPL emphasizes on removal of defective equipment as a priority on maintenance of equipment, in specific, when results are not repeatable or accurate. The most influential indicator of the quality related to “Cost” among FFPL in Dubai is the indicator "Availability of standardized calibration operating" with a mean of (4.735) and a standard deviation of (0.567) and the highest influential indicator of the quality assurance and control related to “Awareness” among FFPL in Bahrain is the indicator "ISO 17025 is essential for forensic labs" with a mean of (3.559) and a standard deviation of (1.186).

To investigate the differences between these means, one-way ANOVA was applied. The result for means and standard deviations of the responses in accordance to age is shown in Table 9.

Table 9: Means and Standard Deviations of the Responses of the Questionnaire Sample According to Age

Factors	Statistics	21–30 (n=26)	31–40 (n=20)	41 or more (n=22)
Management Responsibility	Mean	4.236	4.486	4.442
	Std. Deviation	0.692	0.697	0.798
Resources management	Mean	4.180	4.450	4.506
	Std. Deviation	0.706	0.679	0.703
Product Realizations	Mean	4.331	4.460	4.527
	Std. Deviation	0.697	0.639	0.669
Measurement Analysis	Mean	4.058	4.275	4.489
	Std. Deviation	0.999	1.065	0.778
Timelines	Mean	4.038	4.500	4.500
	Std. Deviation	0.958	0.713	0.958
Quality of work	Mean	4.135	4.450	4.530
	Std. Deviation	0.792	0.665	0.616
Cost	Mean	3.987	4.233	4.394
	Std. Deviation	0.877	1.004	0.808
Awareness	Mean	3.392	4.030	4.191
	Std. Deviation	1.288	1.242	0.847

The results of one-way ANOVA demonstrate that there are no statistically significant differences between QA and QC in forensic fingerprint laboratories in Bahrain and Dubai ascribed to age for all factors except awareness factor. To determine the source of differences in the level of awareness ascribed to age, Scheffe test was used, as shown in Table 10. The results of Scheffe test on the level of the awareness in FFPLs in Bahrain and Dubai demonstrated that the estimates of the samples who are "31 or more years" are significantly higher than estimates of “21-30 years old".

Table 10: Statistical Analysis of the Differences of the Questionnaire Sample According to Age

Factors	Source	Sum of Squares	df	Mean Square	F	Sig.
Management Responsibility	Between Groups	0.843	2	0.421	0.792	0.457
	Within Groups	34.582	65	0.532		
	Total	35.425	67			
Resources management	Between Groups	1.467	2	0.733	1.509	0.229
	Within Groups	31.600	65	0.486		
	Total	33.067	67			
Product Realizations	Between Groups	0.482	2	0.241	0.534	0.589
	Within Groups	29.327	65	0.451		
	Total	29.809	67			
Measurement Analysis	Between Groups	2.219	2	1.109	1.218	0.303
	Within Groups	59.211	65	0.911		
	Total	61.429	67			
Timelines	Between Groups	3.421	2	1.710	2.142	0.126
	Within Groups	51.906	65	0.799		
	Total	55.327	67			
Quality of work	Between Groups	2.119	2	1.060	2.150	0.125
	Within Groups	32.042	65	0.493		
	Total	34.161	67			
Cost	Between Groups	2.022	2	1.011	1.263	0.290
	Within Groups	52.048	65	0.801		
	Total	54.070	67			
Awareness	Between Groups	8.642	2	4.321	3.271	0.044
	Within Groups	85.859	65	1.321		
	Total	94.501	67			

The results show that there are statistically significant differences in the level of QA and QC compliance to requirements in FFPLs in Bahrain and Dubai ascribed to experience in the following factors: measurement analysis improvement, quality of work, cost, and awareness. To determine the source of differences in the level of these factors ascribed to experience, Scheffe test was also applied. The results of Scheffe test demonstrate that the estimates of the samples who have "10 years of experience or above" with regard to the level of the measurement analysis improvement, quality of work, cost, and awareness in forensic fingerprint laboratories in Bahrain and Dubai according are significantly higher than estimates of those who have "0-9 years’ experience".

5. Conclusions

The current study aimed to compare the adoption of QA and QC standards in FFPLs in Bahrain and Dubai. Particularly, the study aims to: 1) identify the differences in the adoption of QA/QC (ISO/IEC 17025) in FFPL between Bahrain and Dubai. The conclusions show advantages of adopting a specialized accreditation scheme such as ISO 17025 and ILAC; hence it is recommended to FFPL in Bahrain to work

on gaining the certification by ISO 17025 in order to improve the QA practices.

The findings of the study demonstrated that there are statistically significant differences in all factors and the indicators in favor to D-FFPL. The results indicated that although both the FFPLs in Bahrain and Dubai have gained ISO 9001, however D-FFPL demonstrated a better performance in accordance with the QA and QC standards.

In conclusion, the big difference in favor of Dubai towards the implementation of the quality assurance and quality control practices are related to the accreditation by ISO 17025 and ILAC, which concentrates on the technical aspects of quality in laboratories. Such technical aspects of quality in laboratories that appeared from the survey results were management of labs, utilities, detective equipment, labeling, ways of disposal which resulted in the better and improved lab testing environment. The international reputation of restricted policies and procedures due to ISO 17025 accreditation is a value that was clear in the replies of Dubai FFPL.

The variance of quality was higher in B-FFPLs, because of the implementation of the general management procedures related to all units including the labs as stated in ISO9001, however Dubai had specific lab policies and procedures in impartiality and confidentiality which is a key factor in FFPLs. Dubai had detailed methods of testing under prescribed environmental results, which are not mandatory based on ISO 9001 standards. FFPLs in Dubai have explicit quality policy for labs as part of the ISO 17025 requirements, and not implicitly hidden under the general quality policy as in ISO 9001.

Other factors could also be considered for further enhancements. The study showed that there are statistically significant differences in the QA and QC in FFPLs in Bahrain and Dubai ascribed to the age variable and experience. However, there are no statistically significant differences in the QA and QC in FFPLs in Bahrain and Dubai ascribed to the variables of gender and qualification.

The study has further concluded that the product service reliability is achieved if procedures are abided according to standards. Specifically, and more importantly, forensic sciences are of higher sensitivity and of greater impact that implies higher confidence levels in results, hence strict abidance of standards is essential. Being quality assured builds the trust in forensic labs. The study reflected higher consistency and competency in the implementation of QA and QC procedures for the forensic labs in Dubai than in Bahrain.

References

[1] AL-Moathen, W., 2011. "Evaluation of Quality Assurance Products Laboratory in Bahrain Petroleum Company In The Kingdom Of Bahrain." AMA International University.

[2] Andersen, J. E. (2014). On the development of quality assurance. *TrAC Trends in Analytical Chemistry*, *60*, 16-24. Doi: 10.1016/j.trac.2014.04.016

[3] Asten, V., A., C. (2014). On the added value of forensic science and grand innovation challenges for the forensic community. *Science & Justice*, *54* (2), 170-179. Doi: 10.1016/j.scijus.2013.09.003

[4] Budowle, B., Bottrell, M. C., Bunch, S. G., Fram, R., Harrison, D., Meagher, S., and Stacey, R. B. (2009). A Perspective on Errors, Bias, and Interpretation in the Forensic Sciences and Direction for Continuing Advancement. *Journal of Forensic Sciences*, *54*. doi:10.1111/j.1556-4029.2009. 01081.x

[5] Burnett, D. (2006). ISO 15189:2003 – Quality management, evaluation and continual improvement. *Clinical Chemistry and Laboratory Medicine (CCLM)*, *44* (6). doi:10.1515/cclm.2006.126

[6] Cooney, L. E. (2010). Latent Print Training to Competency: Is it Time for a Universal Training Program? *Journal of Forensic Identification*, *60* (2), 223- 245.

[7] Cooper TG, Noonan E, von Eckardstein S, Auger J, Baker HW, Behre HM, Haugen TB, Kruger T, Wang C, Mbizvo MT, Vogel-song KM. (2010). "World Health Organization reference values for human semen characteristics". *Human Reproduction Update*, Volume 16, Issue 3, May-June 2010, Pages 231–245, https://doi.org/10.1093/humupd/dmp048

[8] Earwaker, HC, Bleay, S and Charlton, D. (2015). "*Fingerprinting: the UK landscape: processes, stakeholders, and interactions"*. Forensic Science Knowledge Transfer Network.

[9] Elliott, S. P., Stephen, D. W., and Paterson, S. (2018). The United Kingdom and Ireland association of forensic toxicologists' forensic toxicology laboratory guidelines (2018). *Science & Justice*, *58* (5), 335-345. Doi: 10.1016/j.scijus.2018.05.004

[10] Gayath, P. (2017). "*Lab Manual on Blood Analysis and Medical Diagnostics*". S. Chand Publishing, 2017. ISBN: 8121939674, 9788121939676.

[11] Giannelli, P. C. (2003). Crime Labs Need Improvement. *Issues in science and technology*, 55-58.

[12] Hazard, D., Stauffer, E., and Margot. P. (2018). "*Forensic Science and the Paradigm of Quality*". Encyclopedia of Criminology and Criminal Justice. DOI: https://doi.org/10.1007/978-1-4614-5690-2_141

[13] Hofmeister, U., Martin, S. S., Villalobos, C., Padilla, J., & Finegan, O. (2017). The ICRC AM/PM Database: Challenges in forensic data management in the humanitarian sphere. *Forensic Science International*, *279*, 1-7. Doi: 10.1016/j.forsciint.2017.07.022

[14] Hutchins, T., and Olbercht, A. (2009). "*AACSB International Accreditation and The Earnings of College Graduates*". American journal of business education: Vol. 2. No. 1 (2009).

[15] Jamieson, A. (2016). "*Accreditation: laboratory*". The Forensic Institute, Glasgow, UK: 15 March 2016. https://doi.org/10.1002/9780470061589.fsa440.pub2. Retrieved from: https://onlinelibrary.wiley.com/doi/abs/10.1002/9780470061589.fsa440.pub2

[16] Koski, G., Kennedy, L., Tobin, M. F., & Whalen, M. (2018). Accreditation of Clinical Research Sites — Moving Forward. *New England Journal of Medicine*, *379* (5), 405-407. doi:10.1056/nejmp1806934

[17] Lappas, N., T and Lappas, C., M. (2016). *"Quality Assurance and Quality Control*". Semantic Scholar: 2016. DOI:10.1016/b978-0-12-799967-8.00011-6

[18] Levy, S., Bergman, P., and Frank, A. (1999). Quality assurance in forensic science. *Accreditation and Quality Assurance*, *4* (6), 253-255. doi:10.1007/s007690050361

[19] Li, H., and Adeli, K. (2009). Laboratory quality regulations and accreditation standards in Canada. *Clinical Biochemistry*, *42* (4-5), 249-255. Doi: 10.1016/j.clinbiochem.2008.09.006

[20] Libeer, J. (2001). Role of external quality assurance schemes in assessing and improving quality in medical laboratories. *Clinica Chimica Acta*, *309* (2), 173-177. doi:10.1016/s0009-8981 (01)00518-6

[21] Malkoc, E., and Neuteboom, W. (2007). The current status of forensic science laboratory accreditation in Europe. *Forensic Science International*, *167* (2-3), 121-126. doi: 10.1016/j.forsciint.2006.06.064

[22] Mattei, C., Alshawaf, A., D'Abaco, G., Nayagam, B., and Dottori, M. (2018). "Generation of neural organoids from human embryonic stem cells using the rotary cell culture system: effects of microgravity on neural progenitor cell fate". *Stem Cells Dev*. 27, 848–857. doi: 10.1089/scd.2018.0012

[23] Milosevic, M; Bjelovuk, I; and Kesic, T. (2008). "*Quality management system in forensic laboratories*". Criminal Justice and Police Academy, Belgrade. UDC: 005.6:343.982/.983. Retrieved from:http://jakov.kpu.edu.rs/bitstream/handle/123456789/274/272.pdf?sequence=1

[24] Mohr, K. (2005). ISO 17025 and the effect on forensic facility design. *Forensic Magazine*, *USA*. Retrieved from: https://www.forensicmag.com/article/2005/12/iso-17025-and-effect-forensic-facility-design

[25] Page, H., Horsman, G., Sarna, A., and Foster, J. (2019). A review of quality procedures in the UK forensic sciences: What can the field of digital forensics learn? *Science & Justice*, *59* (1), 83-92. doi: 10.1016/j.scijus.2018.09.006

[26] Pádár, Z., Nogel, M., and Kovács, G. (2015). Accreditation of forensic laboratories as a part of the "European Forensic Science 2020" concept in countries of the Visegrad Group. *Forensic Science International: Genetics Supplement Series*, *5*, e412-e413. Doi: 10.1016/j.fsigss.2015.09.163

[27] Prajogo, D. I., and Hong, S. W. (2008). "*The effect of TQM on performance in R&D environments: A perspective form South Korean firm*". Technovations 28 (2008) 855–863. Retrieved from:http://isiarticles.com/bundles/Article/pre/pdf/4303.pdf

[28] Ricci, U., De Sanzo, C., Carboni, I., Iozzi, S., Nutini, A., and Torricelli, F. (2013). Accreditation of a forensic genetics laboratory in Italy. *Forensic Science International: Genetics Supplement Series*, *4* (1), e294-e295. Doi: 10.1016/j.fsigss.2013.10.150

[29] Saferstein, R. Ed., (1988). "*Forensic Science Handbook*". vol. II (Prentice Hall, Englewood Cliffs, NJ).

[30] Saferstein, R. Ed., (1993). "*Forensic Science Handbook*". vol. III (Regents/Prentice Hall,Englewood Cliffs, NJ).

[31] Sciacovelli, L., Aita, A., and Plebani, M. (2017). Extra-analytical quality indicators and laboratory performances. *Clinical Biochemistry*, *50* (10-11), 632-637. doi: 10.1016/j.clinbiochem.2017.03.020

[32] Stimac, J.T., (2003). "*Forensic Science, or Business? The Use of Production Standards*". Journal of Forensic Identification, 53:5, 2003.

[33] Tashakkori, A., and Teddlie, C. (2003). "*Handbook of Mixed Methods in Social and Behavioral Research*". Thousand Oaks, CA: Sage Publications.

[34] Usmani, F. (2019). "*Quality assurance vs. quality control*". PM study circle: October 21, 2019. Retrieved from:https://pmstudycircle.com/2012/01/quality-assurance-vs-quality-control/

[35] Vlachos, P.A., Tsamakos, A.P., Vrechopoulos, A.P., Avradimis, P.K. (2009). "**Corporate social responsibility: Attributions, loyalty, and the mediating role of trust".** *Journal of the Academy of Marketing Science, 37 (2) (2009), pp. 170-180.*

[36] Vlachos, P.A. (2012). "Corporate social performance and consumer- retailer emotional attachment". The moderating role of individual traits. *European Journal of Marketing, 46 (11/12), 1559-1580.*

[37] Wakefield, M. (2006) Quality Assurance and Quality Control Procedures for Fingerprint Detection. *Journal of Forensic Identification*, 56 (5), pp809

[38] Watson, D., L. and Jones, A. (2013). "Digital Forensics Processing and Procedures": Meeting the Requirements of ISO 17020, ISO 17025, ISO 27001 and Best Practice Requirements". 1st Edition. Syngress Press.

[39] Wilson Wilde, L., Norman, J., Robertson, J., Sarre, S., and Georges, A. (2010). "*Current issues in species identification for forensic science and the validity of using the cytochrome oxidase I (COI) gene*". Forensic Sci Med Pathol 6:233–241

[40] Zampa, F., Fish, J., Hilgert, M., Lövby, T., Svensson, M., Vaughan, J., and Mattei, A. (2018). The 2016 ENFSI Fingerprint Working Group testing programme. *Forensic Science International*, *292*, 148-162. Doi: 10.1016/j.forsciint.2018.09.026