11-1-2021

Evaluating and Understanding the Reason for an Increase in Nonconformances in the Laboratory

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Evaluating and Understanding the Reason for an Increase in Nonconformances in the Laboratory

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ABSTRACT

This is a study of nonconformances experienced by a laboratory of a pharmaceutical manufacturing facility in East Africa. There has been an increase in nonconformances from 216 nonconformances in 2017 to 229 in 2018 and by September 2019, 306 nonconformances were already logged. Increasing nonconformances result in delayed release of tested materials and many resources are wasted (e.g. chemicals, man hours and equipment). Analysts become frustrated, which may result in inexhaustive investigations. Understanding the reason for the increase in nonconformances will enable the facility to derive effective solutions to the identified causes, hence reducing the number of nonconformances and improving the productivity and morale of employees. This quantitative, nonexperimental, longitudinal survey study was intended to evaluate and understand the reason for increasing nonconformances. Trends of the nonconformances, previous investigations, procedure for investigation and the training given to analysts have been reviewed. Laboratory incidences were the most recurring nonconformances; and these were mainly caused by analyst errors. Corrective and Preventive Actions (CAPAs) were derived by cross functional teams whenever root causes were identified. Procedure for investigation of nonconformances refers to investigative tools. Identification of root causes to nonconformances recently became mandatory. Analysts have limited advanced industrial training on investigation of nonconformances. Another study should be carried out to understand the cause of analyst errors. The study can be rolled out to other departments at the manufacturing facility to create similar improvements. Analysts should enroll into advanced courses of industrial pharmacy to gain advanced industrial skills which they can apply in investigations to find root causes to nonconformances.

KEYWORD: Regulatory compliance, current Good Manufacturing Practices, Define Measure Analyse Improve and Control (DMAIC), Failure investigations, Laboratory nonconformances, Quality culture, Lean manufacturing

Current Good Manufacturing Practices (CGMPs) refers to the regulations that guide the design, monitoring, and maintenance of manufacturing facilities and processes. They are accepted industry practices outlining the minimum standards for manufacturing practices for production of drugs and biologics intended for human and animal use (FDA, 2018; NDA, 2020; WHO, 2008). The pharmaceutical regulatory agencies, such as the National Drug Authority of Uganda (NDA), World Health Organisation (WHO), and Food and Drug Authority (FDA), enforce the regulations to ensure that manufacturing facilities of pharmaceutical products, medical devices, food and beverages, and dietary supplements are in good condition, the equipment is well maintained and calibrated, and the employees are well trained and qualified to handle the manufacturing equipment and processes. Laboratory nonconformances can come from three categories. The first category is an out of specification (OOS) test result; a test result that falls outside the specification or acceptance

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criteria established in drug applications, drug master files and official compendia or approved company specification. Conformance to specification means that the drug substance and drug product, when tested according to the listed analytical procedures, will meet the acceptance criteria. Specifications are critical quality standards that are proposed and justified by the manufacturer and approved by regulatory authorities as conditions of approval (Ravi Kiran et al., 2017). The second category of nonconformances is an out of trend (OOT) test result, a test result that does not follow the expected trend in comparison with either results obtained among the batch or results of other batches or atypical observation identified which is not obvious as per expectations. The third category of nonconformances ais a laboratory incidence, an occurrence, other than OOS/OOT during the performance of a test procedure or identified during review such as instrument malfunction, analyst errors, system suitability failure, laboratory obvious errors, variations of results among replicate determinations or any kind of other error.

The problem of nonconformances in the quality control laboratory was known as early as the 1920s but it was not understood until the 1990s that lack of statistical and metrological thinking was the main aspect of the problem (Ravi Kiran et al., 2017). Regulatory agencies assess the facilities that manufacture, package, test and distribute drug products for adherence to the CGMPs and this assessment is a measure of their regulatory compliance (Markovitz, 2011). Critical among the key principles of CGMP is quality control which includes all measures taken, including the setting of specifications, sampling, testing and analytical clearance, to ensure that raw materials, intermediates, packaging materials and finished pharmaceutical products conform with established specifications or identity, strength, purity and other characteristics (WHO, 2018).

All regulators are always interested in understanding a facility`s approach to investigation of nonconformances with the aim of identifying how exhaustive the investigations are in identifying root causes to observed nonconformances. Regulations require identification of product defects and the cause of the defects and implementation of the corrective actions as part of a quality management system. Title 21 of the U.S. Code of Federal Regulations (2019), requires manufacturers to use appropriate methodology to detect recurring quality problems and identify actions needed to correct and prevent recurrence of nonconformances. However, the regulations do not state how to do this; they do not identify good or bad corrective and preventive action programs, systems or steps. The responsibility of conducting effective investigations and identifying appropriate CAPAs is left to the pharmaceutical industries (Haleem et al., 2015). There is a general lack of documented guidance that can be used daily to ensure compliance (Pathak, 2007). Haleem et al. (2015), concluded that in general, CAPA experts recommend that root cause investigations follow a four-step process:

1. Identify the problem.
2. Evaluate its magnitude, which includes assessing risk.
3. Investigate and assign responsibility.
4. Analyse and document the root cause of the problem.

Ravi Kiran et al. (2017), documented a detailed investigation of a nonconformance that was observed while testing a finished product in the laboratory. The investigation follows the recommended four step process in order to reach to the root cause of the problem. Recommendation has been given to the pharmaceutical industry to go beyond good and adopt best practices, as is exercised in other sectors, such as the nuclear and aerospace operations. Highlighting of errors to facilitate improvement is among the best practices that were emphasized (Chalk, 2012).

Failure investigations are carried out with the principle aim of determining the root cause of a nonconformance. McElroy (2017) noted that effective investigation of laboratory nonconformances to identify root causes is a mandatory requirement of CGMP. The investigation should ask whether procedures were followed and whether there was appropriate control to prevent distribution of the defective product. The magnitude of the investigation should correlate with the

significance and risk of the nonconformance. Human error is often incorrectly concluded as the root cause of the manufacturing defect with retraining as the corrective action resulting in recurrence of the nonconformance because human error is not the true root cause. Human error is an insufficient root cause because it does not identify the real problem causing the defect. Beginning to understand why the human erred will help us understand the true cause of the problem. Possible causes of human errors include: confusing procedure, internal (personal) distractions, external distractions, unawareness of existence of the procedure, procedural updates, intentional misuse or willful misconduct, inadequate electronic clearance on automated systems, inadequate paper based systems, inadequate software-based systems, employee apathy and, finally, the employee may actually be unable to perform certain steps (McElroy, 2017). Although these observations and recommendations provided were based on a manufacturing set up, they are also applicable in a quality control laboratory.

The general expectation in a GMP compliant facility is that a proper evaluation in terms of defining, measuring and analysing the problem eases control and results in sustainable improvement. Poorly investigated nonconformances can result in drug application refusal (do Carmo et al., 2017).

Little research has been done specifically about nonconformances in the laboratory (Haleem et al., 2015). Numerous articles exist on nonconformances in the pharmaceutical industry and the importance of identifying their root causes is their underlying observation (Berardinelli, 2012; Chowdary & George, 2012; Pathak, 2007; Yu & Kopcha, 2017). The six-sigma principle of Define, Measure, Analyse, Improve and Control (DMAIC) is a structured problem-solving method that involves a sequence of interlinked phases that are aimed at permanently solving problems. It involves defining a problem, measuring the magnitude of the problem, analysing the problem to understand it better, improving the situation in which the problem occurred and controlling the situation so that the problem does not recur and ensuring that improvement interventions are maintained (Berardinelli, 2012; Yu & Kopcha, 2017). This principle is generally agreed upon as an acceptable guidance for problem solving that is aimed at continuous improvement as illustrated in Figure 1 which shows the relationship among the key concepts that demonstrate continuous improvement, a prerequisite for regulatory compliance.

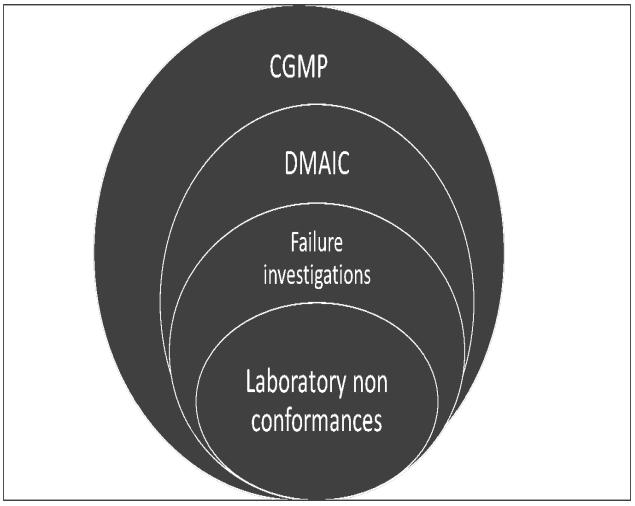

Figure 1. *Graphic sketch of the key concepts*

This figure illustrates the relationships among key concepts that are pre-requisites for regulatory compliance

The available literature on nonconformances can be broadly grouped into four categories. The first category of studies highlights quality expectations in the industry in general with focus on quality culture (Friedli et al., 2018; Harrison & Schniepp, 2015; Lolas & Uydess, 2013). In reference to Patel et al. (2015), quality (culture) behavior can be defined as follows:

Behaviors observed at the site or organization that are associated with a strong quality culture in areas such as clear communication and transparency, commitment and engagement, technical excellence, and standardization of requirements.

Quality (system) maturity is defined as follows:

objective characteristics of a quality system that can be observed or verified upon inspection or internal audit that have a positive relationship with quality culture behaviors, including formal programs in preventive maintenance, environmental health and safety, risk management, human error prevention, and

training or continuous improvement. The Economist Intelligence Unit in 2005, recommended that pharmaceutical industries should assess whether root cause analysis is aimed at identifying the underlying causes of human errors so that human error prevention and continuous improvement can be realised through application of lean manufacturing principles aimed at waste reduction. A robust quality culture that supports continuous improvement has been identified to be key in impacting operational performance of any organization (Friedli et al., 2018). A quality culture that supports continuous retraining of personnel in areas applicable to their job descriptions was a key strategy in ensuring regulatory compliance (Jagun, 2018). An analyst who is highly trained in a required field will understand the reason behind each step in a procedure and will be more willing to follow that procedure. Furthermore, such highly trained analysts will base their deep understanding of the analytical techniques to proactively identify gaps in the procedures and hence be able to improve on them in areas where they are deficient. The leadership of pharmaceutical companies have to be strategic and adopt improvement strategies to achieve regulatory compliance (Jagun, 2018). Decisions based on data have been shown to have greater impact and found to be more sustainable (Torbeck, 2011). The culture of measurement and data should be integrated into the daily operations of a pharmaceutical facility for its own benefit and that of its patients. This study has generated data that can be used to understand the causes of the increasing nonconformances in the laboratory and the data generated will be able to support management decisions in improving the performance of the laboratory. Analysis of this data has revealed that analyst errors are the leading cause of the nonconformances in the laboratory therefore creating the need to further understand the underlying causes of analyst errors. Deficiencies in documentation have been identified as a common area in inspections done by regulatory authorities (Geyer et al., 2018). Such deficiencies which could include poorly written procedures, could result in analyst errors. Investigations that are not exhaustive enough will conclude the cause as analyst error, without identifying the underlying cause of the poorly written unclear procedure.

The second category of studies highlights the importance of conducting exhaustive investigations to identifying the underlying root causes. Chowdary and George (2012), concluded that the application of principles that are aimed at elimination of waste improves the competitiveness of a facility (p.70). This results in increased profitability allowing the facility to invest in more value adding activities including development of new products. Politis and Rekkas (2011) argued that due to the growing scarcity of resources, pharmaceutical facilities need to adopt lean manufacturing principles in order to remain competitive. Nonconformances are wasteful; the resources such as chemicals, time and analyst man hours that are spent on investigating nonconformances could be better utilised in other value adding testing activities that would result in prompt release of materials for production.

An investigation will only be useful if it is able to identify the true root cause of the problem so that when the CAPA is derived, similar nonconformances do not recur. Anyakora et al. (2017) maintained that quality improvement interventions are cost beneficial to local manufacturing companies (p.8). Understanding the cause of increasing nonconformances is cost beneficial to the facility because it will result in deriving effective solutions to those causes which will eventually eliminate recurrence of the nonconformance. Achieving excellence is a basic requirement of GMPs. Several principles contribute to regulatory excellence of a pharmaceutical industry such as intentionality, attitude, continuous improvement, discipline, integrity, sustainability and urgency (Henson, 2011b). These principles can be applied to the investigation of nonconformances in the laboratory to realise benefits of excellence such as reduced waste, expenditures, enhanced credibility and improved employee morale. which results in things getting done. This study was aimed at employing these principles of excellence in order to realise similar benefits in the laboratory of the manufacturing facility.

The third category of literature regarding nonconformances, highlights challenges that

pharmaceutical facilities face as they work to attain compliance. In a phenomenological study that involved interviews of top executives of pharmaceutical industries, Pathak (2007) demonstrated that “noncompliances can be connected to lack of time to do the job, inadequate training, accountability of personnel, or poor decision making process - or a combination of the above” (p.14). This was a general study that involved top management and excluded employees who execute the daily operations of the industry. This study of nonconformances was able to cover that gap by assessing similar challenges at an operational level, the laboratory. A lack of vigilance in some facilities that has been coupled with poorly defined procedures and low capability to perform exhaustive investigations results in such facilities concluding with any possible cause, such as human error as the cause for nonconformances. These erroneous conclusions typically lead to recurrences (Haigney, 2018). Appropriate vigilance is reflected by the laboratory`s ability to adopt best practices that ensure a reduction in defects thus improving efficiency. Key among these practices is the six-sigma principle of DMAIC (Rayser, 2019). Conducting a study to understand causes of increasing nonconformances is also part of vigilance in the facility. As part of this vigilance, the cause of analyst errors in the laboratory should also be studied. Henson (2011a) reviewed an FDA warning letter and highlighted that personnel qualification can affect regulatory compliance. Inability of training procedures in pharmaceutical facilities to effectively assess the level of understanding that has been attained by the participants and instead focus on training techniques that demonstrate to regulators that training actually occurred can also result in nonconformances (London & Gray, 2017). Rooney et al. (2002) analysed causes of human errors in the healthcare service and defined performance shaping factors (PSF) as “anything that affects a worker`s performance of a task within a system” (p.30). They categorized them as internal PSF, external PSF and stressors and gave several examples of each category. The findings and recommendations of this study are applicable to a laboratory in a pharmaceutical facility as similar systems exist with similar factors, possibly, that could cause analysts to err. If these factors are not identified and eliminated, analysts will continue making similar errors and the number of nonconformances will continue to increase. Pluta (2012) concluded that “operations and compliance must support each other. Investigations need to be conducted thoroughly; questions, reporting problems, and other highlighting of problem situations must be encouraged and rewarded” (p.5).

The fourth category of literature addressing nonconformances focusses on the consequences of noncompliance to regulatory guidelines. Poorly investigated nonconformances can result in drug application refusal (do Carmo et al., 2017). Regulators have a responsibility of ensuring that the drugs that are sold to the patients of their country meet the standard requirements of safety, identity, strength, purity and quality. If a facility cannot exhaustively investigate its own failures, regulators will have concerns about the quality of its medicines and may deny its drug applications. If a facility demonstrates its ability to effectively investigate its nonconformances, regulators will have confidence and respond positively to drug applications. This creates a need to evaluate the cause for the increase in nonconformances in the laboratory. Having exhaustive investigations will ensure successful drug applications by this facility. The regulators will have confidence in their quality management systems.

Most studies on continuous improvement in the pharmaceutical industry have been done in the manufacturing section with no concern to the laboratory. There are many improvement opportunities that can be done in a laboratory and reduction of incidence of nonconformances is key among them. A similar approach that has been used by other studies in manufacturing areas can be applied in the laboratory. There is very little literature on how investigation of nonconformances in a pharmaceutical laboratory should be conducted to avoid recurrences. The pharmaceutical facility must come up with compliant ways of exhaustively investigating nonconformances which should include understanding the causes of analyst errors. Although several articles have been

written on reduction of human error, very few address how this can be achieved in a laboratory. By using investigative tools such as 5-Why analysis, the underlying cause of the human error can be identified hence effective and lasting solutions can be derived. Some of the recommendations that have been proposed in studies about challenges of noncompliance have not been implemented in the laboratory of this manufacturing facility. After identifying analyst errors as the leading cause of nonconformances, a robust quality culture requires that the reason behind the analyst errors be further investigated.

This study originates from a quality culture that desires to understand the cause of increasing nonconformances so that corrective and preventive measures are put in place that will result in improvements in the efficiency of testing and continue to maintain regulatory compliance. Figure 2 illustrates the origin of the study from available literature by showing how the current study is related to the four main categories of literature that were earlier described.

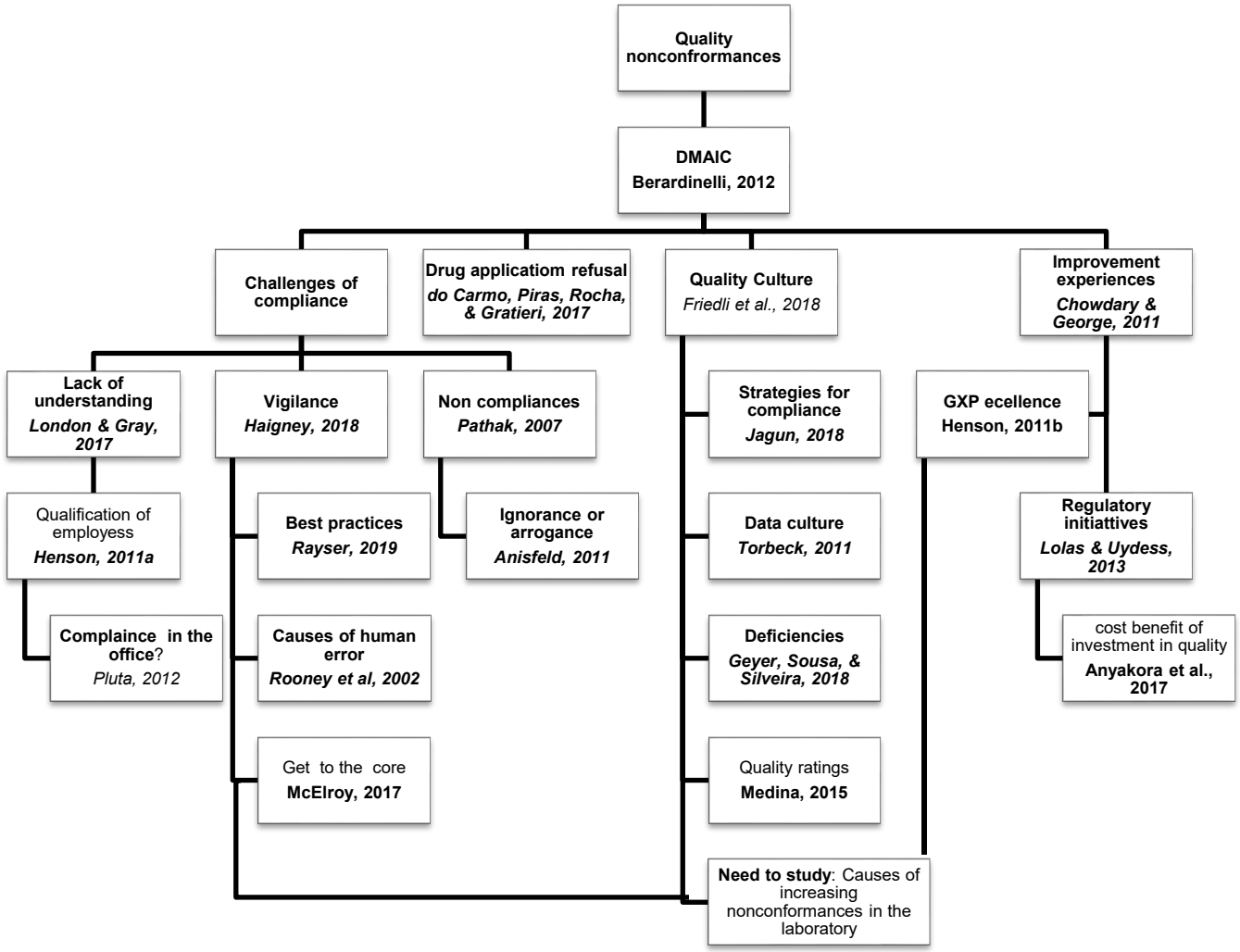

Figure 2. *Literature map. This figure illustrates the origin of the study from the available literature*

Quantitative research methods can be used to examine relationships between and among different variables (Creswell & Creswell, 2018). A survey design provides a quantitative description of trends by studying a sample of that population. The quantitative survey approach enabled the collection of descriptive data associated with nonconformances in the laboratory. The survey design was economical and had rapid turnaround time in data collection which was aligned with the short period of time available to conduct the study. An experimental design was not adopted because it would be costly to perform such a study within a commercial set up. A longitudinal survey was adopted to study the cause of increasing nonconformances over the period when the laboratory consistently recorded increasing

number of nonconformances. A qualitative research would not allow an interpretation of the patterns in the trends of nonconformances that were being observed in the laboratory over the review period. Hence a quantitative, nonexperimental longitudinal survey study design was suitably adopted to evaluate and understand the reason for an increase in nonconformances in the laboratory of this facility,

Studying the causes of increasing nonconformances in the laboratory is important for several reasons. First, very few specific studies are available about nonconformances in the laboratory indicating the need to add to the literature that is available so s to cover this gap. Secondly, this study identified the causes of recurring nonconformances in the laboratory, if these are eliminated, it will help improve the productivity of the laboratory; effective corrective and preventive solutions will be derived to the key causes of nonconformances that have been identified by the study. The morale of the analysts will improve as their tests will result in less nonconformances. Less resources will be wasted on investigations hence reducing the cost of scrap. (Qeshmy et al., 2019) performed a detailed analysis of the root causes of human errors in an automotive company and studied ways in which such errors can be mitigated. A similar study should be done in a pharmaceutical facility to prove the feasibility of such applications and make use of the previous research in the non-pharmaceutical industry (Haleem et al., 2015).

Thirdly, based on the results and recommendations of the study, management will be able to proactively allocate resources in preventing occurrence of nonconformances in the laboratory. Finally, other facilities both in the pharmaceutical sector and in other sectors, can also perform similar studies in order to reduce the incidence of nonconformances hence lowering waste and increasing their productivity and competitiveness.

2. METHODS

This quantitative, nonexperimental longitudinal survey study was intended to evaluate and understand the reason for an increase in nonconformances in the laboratory of the facility. All other departments at the facility were out of scope.

During the survey, nonconformances logged in the laboratory from 2017, 2018 until September 2019 were reviewed to establish the number logged for each category of nonconformances i.e. laboratory incidences, OOTs and OOSs. This enabled understanding of categories with the greatest contributor to nonconformances. Trends were analysed to identify the most common recurring nonconformances in the laboratory. Recurring nonconformances give an indication of either inexhaustive investigations, ineffective solutions or poor implementation of solutions and hence these would require more review to ensure that their investigations are improved upon and detailed root cause analysis is done to avoid recurrence. Root causes associated with the nonconformances were reviewed to identify the most common cause of the nonconformances and the solutions that were proposed. Having a repetitive cause indicates another underlying cause that was not identified and hence still exists. This persistent unidentified underlying cause continues to lead to nonconformances in the laboratory until it is identified and corrected. The procedure for investigation of nonconformances was assessed to establish its comprehensiveness e.g., use of tools like fishbone diagram, 5-why analysis, Failure Mode Effect and criticality Analysis (FMEA) and for compliance to regulatory guidelines. The extent of the guidance given in an investigation procedure is an indication of how exhaustive an investigation will be. Qualifications and trainings of analysts including those who investigate nonconformances were analysed to assess their understanding of the requirements of the procedure for investigations as well as regulatory expectations of handling of nonconformances.

3. RESULTS AND DISCUSSION

The nonconformances were categorised as laboratory incidences, Out of Specifications (OOS) and Out of Trends (OOT). Whoever observed a nonconformance in the laboratory was required to report it immediately to the section head or the quality assurance personnel in the laboratory. Basing on the magnitude of

the nonconformance, a cross functional team composed of a member from the quality assurance department of the facility, the analyst who was involved in the nonconformance, the section head of the analyst as well as the manager of the quality control laboratory would meet and then derive a strategy for carrying out the investigation guided by the investigation procedure.

Table 1

Category and number of nonconformances logged in the quality control laboratory over the review period.

Year	Type of Nonconformance		
	Laboratory Incidence	Out of trend	Out of Specification
2017	143	16	55
2018	175	14	40
2019	264	14	28
Total	582	44	123
Mean	194	15	41

Laboratory incidences were the most recurring nonconformances and these were mainly caused by analyst errors. As shown in Table 1 above and Figure 3 below, from the 749 nonconformances that were logged in the period evaluated, 77.70% were laboratory incidences, 16.42% were OOSs and 5.87% were OOTs. The causes of the nonconformances were categorized as analyst errors, instrument errors, procedural errors and others. An analyst error was defined as any human action or lack of action that leads to exceeding the tolerances of the condition defined for the normative work of the analytical/ measurement system with which the human interacts. It may be categorised as incorrect preparatory work like weighing error, dilution error, transcription error and pipetting error. An instrument error is an error associated with malfunctioning of the instrument, equipment or software e.g. failure of lamp ignition of a High-Performance Liquid Chromatography [HPLC] machine and malfunctioning of the detector. A procedural error is an error which may arise due to unavailability/inadequacy of written instruction(s) or failure to implement a method in case of validation. Other error is any other incidence occurring because of reasons other than analyst error, instrument error or procedural error.

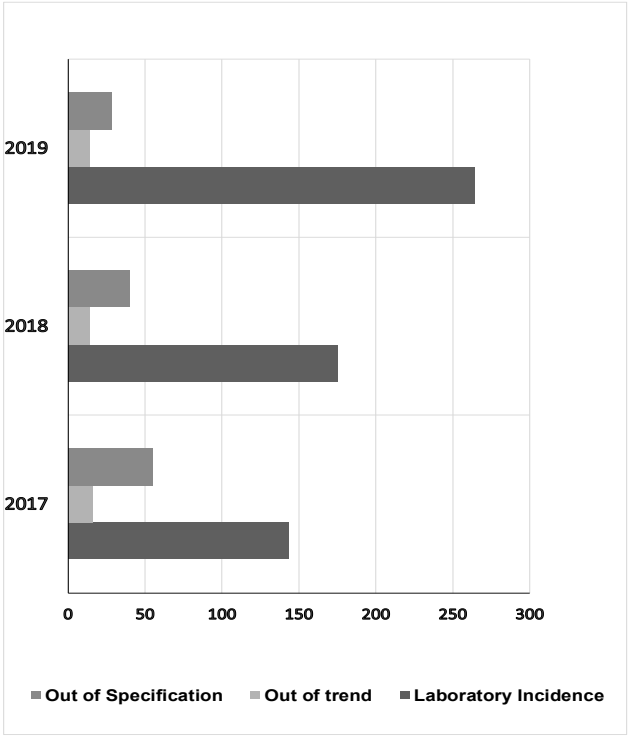

Figure 3. *Category and number of nonconformances logged. This figure categorises and quantifies the nonconformances in the quality control laboratory over the review period.*

From Figure 3 above, the main nonconformance throughout the review period is laboratory incidences. As shown in Table 2, the majority of nonconformances were caused by analyst errors. Other causes included instrument error, procedural errors and others which included any cause that did not fall in the standardized classification as per the procedure.

Table 2

Causes of nonconformances in the quality control laboratory over the review period.

	Cause of nonconformance				
Year	Analyst error	Instrument error	Procedural error	Others	Cause not identified
2017	57	36	1	44	21
2018	96	57	5	29	19
2019	133	58	8	42	24
Total per cause	286	151	14	115	64
Mean	**95**	**50**	**5**	**38**	**21**

The cause could not be identified in some of the investigations.

The procedure for investigation of nonconformances gives reference to investigative tools like fishbone/Ishikawa diagram and the 5-Why analysis. It had been recently revised to add a mandatory requirement to identify root causes to nonconformances, or at least identify a probable cause.

The leading two causes of nonconformances are analyst errors (45.4%) and instrument errors (24.0%) (see Figure 4). Procedural errors were the least likely cause of nonconformances (2.2%). The cause of some nonconformances was not identified for some cases (10.2%). Congestion was the main cause for the category of others. The laboratory was small and congested hence the analysts had little working space.

Corrective and Preventive Actions (CAPAs) were derived by cross functional teams that composed of a member from the quality assurance department of the facility, the analyst who was involved in the nonconformance, the section head of the analyst who observed the nonconformance as well as the manager of the quality control laboratory. Based on the root causes that were identified during the investigation, corrective and preventive actions were derived.

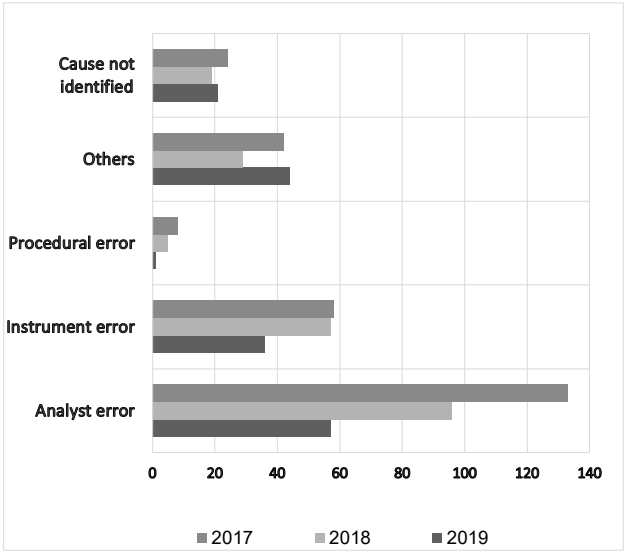

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Figure 4*. Causes of nonconformances in the quality control laboratory. This figure demonstrates causes of the nonconformances over the review period.*

The analysts, including those responsible for conducting investigations have been thoroughly trained on the new procedure. However, they have no external training outside the company on investigation of nonconformances. A review of qualifications and trainings of analysts revealed that most analysts have bachelor's degrees in science fields, the entry level qualification requirement for an analyst in this facility and none had any advanced industrial training to enhance their investigation skills. From the study conducted, the main reason for

the increase in nonconformances in the laboratory is analyst errors hence the cause(s) for the analyst errors need to be identified and addressed in order to reduce the number of nonconformances and improve the productivity of the laboratory. Since this project has been successful in identifying the main cause of nonconformances in the laboratory, it can be rolled out to other departments at the facility.

4. CONCLUSION

The main reason for the increase in nonconformances in the laboratory is the increase in analyst errors. In line with the concept of quality culture that requires detailed root cause analysis, causes of the analyst errors are currently being analysed and congestion within the laboratory has been identified as a principal cause. A congested area is likely to have external factors that will cause distraction to the analysts as they carry out the analysis. Laboratory expansion to create more space is currently underway. Procedural errors are the least cause of nonconformances. In a few cases, the cause of the nonconformance could not be identified. The identified CAPAs were based on the root causes identified during the investigation. The investigation procedure has recently been revised to make it mandatory for investigations to identify root causes of nonconformances.

5. RECOMMENDATIONS FOR NEXT STEPS.

Investigations of nonconformances should always find the causes of human errors. When this is done, effective and long lasting CAPAs will be derived that will sustainably lower the incidence of nonconformances in the laboratory. The procedure for investigation should have a mandatory requirement to identify root cause of analyst errors. The qualifications of personnel have been proven to be a key factor associated with compliance. Investigators and analysts should be enrolled in advanced industrial courses which teach lean manufacturing and equip students with trending investigation skills and tools as well as knowledge on how these can be applied in the industry. Management should continue using these results to proactively allocate resources in preventing occurrence of nonconformances in the laboratory by training its personnel throughout the facility and adding advanced qualifications as part of the recruitment criteria. The study can be rolled out to other departments to evaluate and understand the reason for the incidence of nonconformances in their respective areas. The causes of human errors in the facility should be identified to derive sustainable solutions to them. Other pharmaceutical facilities can perform similar studies that are rooted in a quality culture that desires to understand the cause of increasing nonconformances so that corrective and preventive measures are put in place that will result in improvements in the efficiency of testing and continue to maintain regulatory compliance. This study is applicable to any area where nonconformances are observed and these can manifest as defective products in such areas.

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ACKNOWLEDGEMENTS

I would like to thank all of the BIRS guest faculty from global industry and regulatory organizations for generously sharing their professional expertise and providing donated, in-kind time towards building the professional skills and technical capabilities of the students within the BIRS program. I would also like to thank my fellow peers in the BIRS MS student cohort for providing guidance and constructive feedback during the classroom group work and interactive sessions; Abigail Ekeigwe and Mercy Okezue, Purdue ABE BIRS PhD candidates, for their mentorship and input throughout the project; Professor Fran Eckenrode for providing content expertise throughout the review process on this paper; and Lauren Terruso, operations manager for BIRS Center, for all of her efforts on editing multiple iterations of the technical paper draft in preparation for publication. The international component of the Purdue BIRS program was initiated through educational support provided by the Merck Foundation and most recently through a capacity building effort funded by the Bill and Melinda Gates foundation, grant # 41000460.