INVESTIGATING QUALITY CONTROL OF UNIBEN TABLE WATER PRODUCTION.

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD BACHELOR OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

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CERTIFICATION

The undersigned persons certify that this research project work titled “Investigating Quality Control of Uniben Table Water Production.” was carried out by **Timothy Okechukwu Israel** with matriculation number **ENG1805693** of the Department of Production, Faculty of Engineering, University of Benin, Benin City is approved and considered adequate in the scope and content for the partial fulfillment of the requirement for the award of Bachelor of Engineering (B.Eng) Degree in Production.

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DEDICATION

This work is dedicated to God Almighty for His strength, guidance and support through my academic years in the prestigious university of Benin; My Pastor, Pastor Grace Otakpobuno for her influence so far in my life and to my beloved brother, Timothy Samuel for supporting me in every area of my life, also to Mr. and Mrs. Timothy for their love, guidance and unending prayers and finally my supervisor Engr. G. F. Aibangbee who acted as a father figure in ensuring I do well in this research work.

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A big shout to my wonder studying partners "THE PROJECT FAMILY" I am short of words to describe how grateful I am, you guys means so much to me, for everything we went through together, thank you guys!!!

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Abstract

This study delves into the quality control practices of Uniben table water factory, with a focus on ensuring the production of safe and high-quality bottled water. The research aims to comprehensively assess the current quality control measures, identify areas for improvement, and propose recommendations to enhance the overall quality management system.

The study adopts a mixed-methods approach, integrating qualitative interviews combining interviews with consumers of the factory's produce and qualitative analysis of water quality parameters using the R-Charts, Run Test and Process Capability. Through this approach, the research seeks to provide a holistic understanding of the quality control practices in the Uniben table water factory.

In conclusion, the analysis of result clearly showed that only one sample (bottle water) in the month of April achieved process capability and is fit for production. The month of May till July 2023 did not have samples that achieved process capability. The study concludes with recommendations for implementing a comprehensive quality control framework to enhance the quality and safety of table water production.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Water is a substance composed of the chemical elements called hydrogen and oxygen and they exist in gaseous state (vapour), liquid state, and solid state (ice). It is arguably the most abundant and also essentials of compounds you can find around the globe. Water is colourless in nature, tasteless and odourless. Its significant capability lies in its capacity to dissolve a wide range of other substances. In fact, water's remarkable ability to act as a solvent is indispensable for the functioning of living organisms. The origin of life itself is believed to have occurred in solutions within the Earth's oceans, and the very processes that sustain living beings, such as blood circulation and digestion, depend on water-based solutions.

Beyond our planet, water is also found on other celestial bodies, both within our solar system and beyond. This essential molecule is not limited to Earth alone.

While water might seem colorless in small amounts, it actually possesses a faint blue color due to its slight absorption of light at longer, red wavelengths. This subtle characteristic contributes to the unique properties of water that make it so vital for life and its various processes.

All living organisms require water for their survival, and as humans, we experience improved well-being by regularly consuming water. Surprisingly, approximately 60 percent of your body weight is composed of water, as stated by the U.S. Geological Survey, (2019). Water is utilized throughout your body's cells, organs, and tissues to manage temperature and support various bodily processes. Given that your body loses water through activities like breathing, sweating, and digestion, it becomes crucial to rehydrate by consuming liquids and ingesting water-rich foods. The specific quantity of water necessary varies based on a range of factors, according to the Mayo Clinic, (2022): The climate you live in, how physically active you are, and whether you are experiencing an illness or have any other health problems all affect recommended intake.

Statistical Quality Control (SQC) is a method used to monitor and control the quality of a product or service by using statistical techniques and methods. It is a systematic approach to ensuring that the products manufactured meet the specified quality standards and requirements. SQC helps organizations to identify and control the sources of variability in the production process, which can lead to defects or nonconformance.

SQC involves collecting data, analyzing the data using statistical tools, and making decisions based on the results of the analysis. The data collected can come from a variety of sources, including production processes, inspection results, and customer feedback. The statistical techniques used in SQC can range from simple statistical measures, such as mean and standard deviation, to more complex statistical models, such as control charts and Design of Experiments (DOE).

1.2 Statement of the Problem

In the production process of table water, quality control has to be conducted on the product. Quality control has a great impact in the quality of a product, whether it ends up defective in nature or not. In order for any company to attain its goal of maximizing profits, it's essential that its products possess superior quality. This ensures customer satisfaction and enables effective competition within the market against other products. To achieve products of high quality and minimize defects, specific measures like employing methods of statistical quality control in the production process become necessary for any organization.

This research work focuses on implementing statistical quality control techniques in the production of bottled water. The aim is to guarantee that the product's quality remains consistent with established standards. This is particularly relevant given the significance of bottled drinking water in today's context.

1.3 Aim and Objective of the Study

1.31 Aim

The aim of this study is to investigate the quality control of table water production.

1.32 Objectives

To carry out this study, the following objectives will be pursued:

I. To carry out extensive literature review of the subject matter.

II. To collect data from the water factory

III. To carry out analysis of data collected

IV. Result and Conclusion.

1.4 Significance of the study

This research is significant in the sense that it will greatly assist the production and operating unit in having the essential guidelines that will ensure that quality table water is produced on a regular basis. The importance of this study aimed at detecting if there are any need for improvement on customer's satisfaction and increased profit with respect to the production of Uniben table water. This study should serve as vital information needed for manufacturers in their quest to meet customer's satisfaction.

This work ensures that the standard specifications should be adhered to by the manufacturer to the end that the company's reputation is improved upon and profit is maximized.

1.5 Scope of the Study

This study investigates the boundaries within the Uniben Table Water, the enterprise is situated in 8HMX+9CW University of Ekehuan Campus, Ogogugbo, Benin City 300102, Edo, Nigeria.

CHAPTER TWO

LITERATURE REVIEW

2.1 The Value of Water to the Society

Water of good drinking quality is of basic importance to human physiology, and man's continued existence depends very much on its availability Onweluzo, (2010). Good drinking water has remained a challenge, particularly in underdeveloped and developing countries Isikwue, (2014). According to statistics from the Federal Ministry of Health, only about 30% of Nigerians have access to portable water while the United Nations estimated that about 1.2 billion people all over the world lack access to potable water Onweluzo, (2010); Oyeku, (2001) and Ajewole, (2005). The presences of pesticides and insecticides in water have impacted on health and have also become an issue Isikwue, (2014) and Kegley, (1998). There is need to define and ascertain the quality of water due to the increasing demand of this resource. Water quality is high and can be said to be potable if its physical, chemical and microbiological qualities conform to specified standards by regulatory authorities WHO, (2008). Water quality guidelines form the basis for judgment of acceptability of public water supplies and the most preferred is the World Health Organization (WHO) regulations and NIS Regulations by Standard organization of Nigeria used in Nigeria. Unavailability and scarcity in the supply of drinking water has given rise to the involvement of private companies in the production of packaged drinking water Dada, (2009). Sachet water which is commonly accepted to be safe due to its affordability to the local populace and instant means of quenching public thirst. Bottled water is also widely consumed by the middle class and high-class individuals due to its tasteless form, absence of odour, colour and the presumption that it is mostly free from germs Ibrahim, (2015) and Chiarenzelli, (2008). However, the hygiene of the environment, source of the water, treatment processes and conditions under which majority of brands of bottled water are produced and stored are faced with a number of risk and uncertainties Ekwujuru, (2011). Many Researchers have carried out a number of studies on the quality assessment of bottled drinking water in different cities in Nigerian and other parts of the world. Most of these studies reported that approximately 50% drinking water available to the populace seems to be unfit for consumption. In the assessment of the quality of bottled and sachet water sold in Bauchi metropolis Ibrahim, (2015), results showed that 73.30% and 25.00% of sachet and bottled water considered in the study were not fit for human consumption at the time of the studies. The study of the quality of packaged drinking water brands marketed in Ibadan metropolis and Ile-Ife city in South Western Nigeria Oyedeji, (2009), showed that most of the sachet water brands fell below WHO drinking water standards and therefore is of doubtful quality. The quality assessment of packaged water in Uyo Metropolis South Southern Nigeria Odiongenyi, (2015) revealed that the conductivities of some of the samples were above the WHO standard for drinking water. In the study of the physicochemical characteristics of bottled water in Bolgatanga Municipality of Ghana Oyelude, (2012), it was reported that two percent of the bottled water samples had pH levels below the minimum level of 6.5 recommended by WHO. The concentration of ions in selected bottled water brands sold in Malaysia, Aris, (2013), showed that the quality of the supplied bottled water samples was in accordance with standards set by WHO.

Access to good quality water is a challenge to developing and developed countries. This problem is orchestrated by the wanton pollution of the limited water resources around by the actions and inactions of humans. According to Boakye and Bentil (2010), rainfall would decrease on the average by 2.8% by 2020, 10.9% by 2050 and 18.6% by 2080 in all agro-ecological zones, except for the rainforest zone, where rainfall may increase. Over one billion people do not have access to safe sources of drinking water Gadgil (1998). This phenomenon is leading to the demise of about four hundred (400) children below the age five years on an hourly basis. This is largely due to the bacteriological contamination of potable water sources. Most public sector water production plants are unable to meet the demands of their clients. A number of reasons could be assigned for this gap. These include:

1. High cost of treatment of water;

2. High cost of maintenance of plants and equipment;
3. Water losses during distribution;
4. Increasing population and water demand;
5. Non-payment of water bills and others.

In 2000, the United Nations Declaration was adopted by about 180 member states. This led to the promulgation of the Millennium Development Goals (MDG). The MDG Goal Seven seeks to ensure environmental sustainability. According the United Nations Mid-term Assessment Report UNICEF and WHO, (2004), 80% of the world's population use an improved drinking water source in 2004, up from 71% in 1990. Although these numbers indicate the world is on track to meet the goal, there will be challenges as populations increase. The introduction of the sachet water into the market was to provide an alternative source of good quality water for consumption. The sachet water was supposed to be safe, hygienic, affordable and an instant source of water for consumers. With the flooding of the market with sachet water and vendors embarking on the best methods to sell their wares, it is incumbent that the quality of water being offered for sale is ascertained. As one seeks to satisfy a natural requirement of the human body (drinking water when thirsty), the person needs to be able to make an informed choice on the type of water to be assimilated.

2.2 The Concept of Table Water

Table water is purified water from a natural source in which impurities are reduced to over 99 percent. Mineral and spring water have significantly higher levels of minerals and salts of non-biological nature and are usually extracted from a natural underground water source by not undergoing the stringent process of impurities from the table through which the table water passes.

In our today society, table water is the go-to water source as it does not contain pollutants. With so much environmental pollution, it is becoming increasingly difficult to make sure that the water in our bottle is clean and safe enough.

Table water can be sourced from a variety of natural springs, but its hallmark characteristic is its consistent cleanliness. Before it is carefully packaged into bottles, it goes through an exceptionally stringent purification process. This process is designed to eliminate any impurities or contaminants, ensuring that the water meets high standards of quality and safety. Thus, the water that reaches your table has undergone a thorough purification journey to guarantee its purity and suitability for consumption. The criteria for achieving purification standards in table water are set at the highest level, and it is due to this exacting process that choosing table water for daily consumption proves more advantageous than opting for spring water, mineral water, or tap water. Every possible impurity that might exist within the water is meticulously eradicated.

The Nigerian government's lack of focus or insufficient investment in water infrastructure development has led to the emergence of an unreliable and unsafe public water supply, as discussed by Dada (2009). The consequences of this inadequacy are far-reaching, impacting the accessibility and quality of water for the population. In response to the challenges posed by the inconsistent public water supply, private individuals have stepped in to address the growing demand for clean water. This has manifested in the proliferation of packaged drinking water, commonly known as "pure water," as highlighted by Dada's research in (2009). The involvement of private entities in this sector reflects a dynamic response to the deficiencies in the public water system, emphasizing the need for alternative solutions to ensure the availability of safe drinking water for the Nigerian population. Sachet water has become a helpful solution to the challenge of ensuring safe drinking water at home, especially with global goals like the Millennium Development Goals (MDGs) in mind Ndinwa et al., (2012). Sachet water is a convenient and safe way for people to quickly satisfy their thirst. This trend is now widespread in Nigeria, Ghana, and other nearby West African countries Cheabu et al, (2014). People in Nigeria often drink sachet water directly, especially during hot and dry seasons. Additionally, many city dwellers around the world prefer bottled water because it tastes good, has no odor, and is believed to be mostly free of germs. Bottled water becomes particularly important during natural disasters like earthquakes or floods, and also during societal crises such as terrorist attacks or war. In these situations, regular water supplies can be disrupted for a long time, making bottled water a reliable alternative Guler, (2007); Guler et al, (2009). The cleanliness of the places where most packaged water is made and stored is uncertain. To make sure consumers know about the quality, it's important to regularly check and assess the packaged drinking water. This way, people can be confident about what they're drinking Ndinwa et al., (2012); Alhassan et al, (2012); Cheabu et al, (2014). Various National and International organizations have set specific standards to ensure the safety of drinking water. These standards outline limits for physical, chemical, and microbiological properties. Exceeding these limits can be dangerous and potentially harmful to consumers. Several studies have assessed the quality of sachet and bottled drinking water in different Nigerian towns and cities, as well as in various parts of the world. Across these studies, it has been consistently found that about 50% of the available drinking water is not suitable for consumption. It is reasonable to assume that a similar situation may be observed in other Nigerian cities or towns Musa et al., (2014). There is a lack of detailed information on the quality of drinking water in Bauchi in recent times. One attempt to assess the quality of drinking water in Bauchi was made by Isikwue et al, (2014). However, their study only analyzed five sachet water samples, and they focused solely on sachet water without reporting on how well the physical characteristics met relevant standards. Important aspects of water quality, such as metal compositions, were not explored.

2.3 The Notion of Quality

Quality is a relative term, generally used with reference to the end use of the product Jayakumar et al, (2016). This is corroborated, according to Summers, (2018), by the American society for quality, which defines quality as a subjective term for which each person has his or her own definition.

2.4 Quality Control

Quality control has been characterized as an assurance of benchmarks and estimation and control to guarantee that the products kept principles that are honed and kept up. It compromises the distinguishing proof and expulsion of identifiable varieties from the arrangement of values. Significance of Quality control:

I. Products of uniform quality and unwavering quality help to expand deals turnover.

II. Quality control lessens protests from clients and creates mark dependability.

III. A methodical program of value control Create mindfulness of cognizance about quality among the workers.

IV. A sound arrangement of value change enhances the altruism of the undertaking.

V. Control over quality to completed products includes survey of the nature of crude materials, work, apparatus and different information sources.

2.5 Quality Improvement

Quality improvement is characterized as the process of diminishing fluctuations in both processes and products Montgomery, (2009). This implies a concerted effort to enhance consistency and reliability in the production and delivery of goods or services. The primary aim is to achieve a higher level of uniformity and predictability, thereby enhancing overall customer satisfaction.

The concept of quality was conceptualized as being multifaceted, encompassing a variety of dimensions. These dimensions can be classified into two categories: objective and subjective. Objective dimensions are those that can be quantified and measured using concrete criteria, such as product specifications or performance metrics. On the other hand, subjective dimensions are more centered on the perceptions and opinions of individuals, reflecting their personal preferences and experiences. Jayakumar et al, (2016).

The term "Dimensions of Quality" refers to the distinct attributes or features that constitute a product or service. These attributes collectively contribute to the perceived value and utility of the offering in the eyes of the customer. As elucidated by Jayakumar et al, (2016), customers employ these dimensions as evaluative criteria when making judgments about a product or service. These dimensions might include characteristics like durability, functionality, aesthetics, reliability, responsiveness, and many others, depending on the nature of the product or service.

In essence, the concept of quality extends far beyond mere functionality or technical specifications. It encapsulates a holistic perspective that considers both objective measurements and subjective perceptions, all of which collectively shape the overall perception and satisfaction of customers.

2.6 Statistical Quality Control

Statistical Quality Control (SQC) is a methodology used to monitor and control the quality of products or services. SQC uses statistical tools and techniques to measure and analyze the data gathered during manufacturing or service delivery to ensure that the products or services meet or exceed customer expectations.

Statistical Quality Control aims to identify and eliminate defects or variations in production processes, improving product or service quality and reducing waste. By analyzing data, SQC can help identify patterns and trends that can be used to make data-driven decisions that improve overall quality and productivity. SQC is widely used across many industries, including manufacturing, healthcare, and service industries

What are the Different Types of Statistical Quality Control?

There are several types of Statistical Quality Control techniques; here are some examples and relatable scenarios for each of them:

2.6.1 Acceptance Sampling

This technique involves taking a sample of products from a batch or lot and inspecting them to determine if they meet the quality standards. For example, a food manufacturer can randomly select a few packets of its products and inspect them for freshness, texture, and taste.

2.7 Techniques for quality control (Tools)

Quality Control tools serves as a method for gathering and analyzing data, pinpointing the underlying causes of issues, and assessing outcomes. They are employed to recognize, analyze, and address problems across various domains. The Quality Control tools have been categorized into the following 7 categories:

- Cause and Effect Diagram
- Pareto Diagrams
- Check Sheets
- Control Charts
- Flowchart
- Histograms
- Scatter Diagrams

1. Histogram

A histogram serves as a tool to summarize, analyze, and visually represent data, offering a graphical depiction of the level of variability within a data-set. Histograms sort observations or data points, which are measurable data, into categories and describe the frequency of the data found in each category.

2. Pareto Chart

A Pareto chart combines bars and a line graph, showcasing values in descending order through bars and representing the cumulative total with a line. This chart highlights the frequency and cumulative impact of defects, aiding in prioritizing issues for the most significant overall improvement.

- Each bar usually represents a type of defect or problem. The height of the bar represents any important unit of measure — often the frequency of occurrence or cost.
- The bars are presented in descending order (from tallest to shortest). Therefore, you can see which defects are more frequent at a glance.
- The line represents the cumulative percentage of defects.

3. Check Sheets

Check sheets serve as a statistical quality control tool that facilitates the systematic and organized collection of data from a process. Additionally, the data gathered with check sheets can be utilized as input for other quality tools like Pareto diagrams.

Also, data collected using check sheets can be used as input data for other quality tools such as Pareto diagrams. There are four main types of check sheets used for data collection (custom check sheets can also be designed to fit specific needs):

- Defective Item Check Sheet
- Defective Location Check Sheet
- Defective Cause Check Sheet
- Checkup Confirmation Check Sheet

4. Scatter Diagrams

A scatter diagram is a graphical method, not reliant on mathematics, but used to identify potential relationships or correlations between two numeric variables placed on the horizontal and vertical axes of a graph. This visual approach is rapid, straightforward to communicate, and generally easy to understand.

5. Flow Chart

A flowchart is a diagram illustrating a workflow or process, and it can be described as a graphical representation of an algorithm, a systematic, step-by-step method for task resolution. The flowchart depicts the steps as various boxes, connected in order by arrows.

6. Cause and Effect Diagram

A cause and effect diagram explores the reasons behind an occurrence by categorizing potential causes. It's effective for illustrating relationships among contributing factors and is commonly known as a fishbone diagram or Ishikawa diagram—one of the Seven Basic Tools of Quality. The term "fishbone" comes from the diagram's appearance, resembling a fish's skeleton with the head on the right and branching bones on the left.

7 Control Charts

Control Charts are determined by Dr. Walter Andrew Shewhart, (1924), the father of Statistical Quality Control. The Control Chart is a device which is utilized for investigation of process and control. It demonstrates the well-ordered way to deal with factual quality control and demonstrates the graphical portrayal of information. Control charts are a graphical representation of process data over time that helps to identify any changes or variations in the data. For example, a manufacturing plant can use control charts to monitor the weight of the products being produced, and detect any deviations in the weight from the established standards.

The control chart illustrates the desired quality attribute over time. It commonly includes a central line (CL) and two boundary lines: an upper boundary (UCL) and a lower boundary (LCL). These lines establish the expected average and inherent process variability. The central line is usually aligned with the arithmetic mean or anticipated value of the statistic being plotted, leading to roughly half of the subgroup values being distributed on either side.

The control limits are then usually set equal to the centerline plus and minus three theoretical standard deviation of the plotted values Benneyan, (1998).

Graphs for control charts are constructed on a rectangular coordinate system where the vertical axis (ordinate) corresponds to the statistical values $\overline{X}$ and $\overline{R}$, and the horizontal axis (abscissa) corresponds to identical values. Alternatively, the horizontal axis could also accommodate units of time, such as hours or dates, or even lot numbers.

Points on the chart, representing sample data points, averages, or ranges, can be marked with or without connecting lines, as outlined by Bhasin et al, (2016). Control charts find utility in two separate stages. During the initial phase, these charts are employed retrospectively on past data to ascertain the statistical stability of a process. Conversely, in the subsequent phase, they are utilized prospectively by analyzing sequential samples collected over time to identify deviations from a stable process, as highlighted by Smeti et al. (2007) and Montgomery, (2009).

2.8.1 Purpose of Control Chart

As specified by both Benneyan, (1998) and Krishnamoorthi et al. (2018), control charts play a multifaceted and indispensable role at various stages within the process improvement cycle, offering a comprehensive toolkit for enhancing quality and efficiency. These roles encompass:

I. **Testing and Establishing Statistical Control:** Control charts serves as an initial litmus test to determine whether a process is under statistical control or not. They help in identifying patterns of variability and deviations from the norm, indicating whether the process is stable and predictable.

II. **Monitoring Process Changes:** Once a process has been established as statistically controlled, control charts continuously monitor the process for any unexpected variations or shifts in quality. This proactive monitoring aids in early detection of anomalies, preventing potential defects or suboptimal outcomes.

III. **Identifying Improvement Opportunities:** Control charts act as a lens through which potential areas for process enhancement become visible. Any deviations or trends that fall outside the established control limits can signal opportunities for improvement, prompting further investigation and action.

IV. **Verification of Process Improvements:** When changes are implemented to improve a process, control charts provide a means to assess the effectiveness of these changes. They allow practitioners to validate whether the modifications have led to the desired reduction in variability and improved outcomes.

V. **Process Maintenance:** Control charts help maintain processes at their current level of performance. They ensure that a process remains stable and consistent, preventing degradation over time and helping organizations sustain their desired level of quality.

VI. **Process Control:** Control charts are used to keep processes within a specific target or nominal value. By setting control limits around the target value, organizations can ensure that variations remain within an acceptable range, minimizing the risk of producing defective products or services.

VII. **Troubleshooting Tool:** Control charts are invaluable in diagnosing the root causes of issues that arise in a process. Unusual patterns or trends on the chart can guide investigators toward specific areas that might need attention or improvement.

VIII. **Acceptance Tool:** In various industries, control charts are employed as a validation tool for assessing whether a product or service meets predetermined quality standards. They provide a visual representation of the quality level, aiding in decision-making about whether to accept or reject a batch of products.

In essence, control charts serve as a dynamic compass guiding process improvement initiatives. They facilitate the pursuit of consistency, reliability, and continuous enhancement, ultimately contributing to the overall success and competitiveness of an organization.

2.9 Merits of Previous Research

Statistical Quality Control (SQC) has found application across diverse industries to attain quality objectives. In the realm of healthcare, SQC strategies have been employed to curtail incidents of hospital-linked infections Limaye et al., (2008). In the domain of DNA microarray research, SQC techniques have been utilized to quantify individual gene expression Chimka et al, (2008). Similarly, in manufacturing operations, SQC approaches have been harnessed to mitigate fluctuations in processes Xiang et al, (2008), leading to enhanced consistency. Furthermore, the utility of SQC extends to managing buyer-supplier dynamics Morgan et al, (2007), overseeing adherence to geometric specifications in manufactured items Colosimo et al., (2008), identifying manufacturing defects Zantek et al., (2007), and optimizing auto body machining procedures Zhou et al., (2003).

SQC has a plethora of sophisticated applications, which have given it a strong foothold in the quality literature. However, there is a limited chronological account of SQC to date in the literature.

Dooler, (2000) examined the progression of the quality discipline through the lens of paradigm development, proposing the existence of three paradigms in quality: a pre-industrial era characterized by 'caveat emptor', an industrial era marked by quality control, and a post-industrial era represented by total quality management (TQM).

In a separate study, Smeti et al, (2007) employed statistical process control methodologies to enhance the quality of treated water in the Athens Water Supply and Sewage Company. Their focus was on measurements of turbidity, residual chlorine, and aluminum in the Polydendri tank during the year 2004, a period with potential fluctuations. Despite most chemical parameters of the Polydendri treated water adhering to the specifications of the 98/83/EEC Directive (with an exception in turbidity), the researchers underscored the role of statistical process control techniques in elevating water quality. By utilizing control charts designed to detect unique sources of variability, these methods facilitate timely detection and prompt corrective actions to prevent the accumulation of problems.

Ierenn et al, (2020), also applied a statistical quality control methodology to monitor the stability of processes within a Table Water Manufacturing Company. They employed various quality control tools including p-charts, u-charts, X-bar and R charts, along with a process capability chart. These tools were utilized to analyze field data collected over a span of 30 working days from the company's sachet water production and marketing processes. The goal was to determine whether these processes were operating within acceptable control limits and to assess the marketing process's ability to meet predefined specifications for the product.

In a similar vein, Ihunwo et al, (2016) conducted a study that delved into the management of the production process within a water bottling plant with the aim of enhancing quality. The research centered around a water bottling company chosen as a case study. The core objectives of their investigation revolved around implementing statistical process control (SPC) to effectively oversee the production process, elevate the overall quality, and streamline the production operations to minimize wastage.

In the study conducted by Chero, (2019), Statistical Process Control was employed as a tool to enhance process management. The focus was on applying statistical control charts within the chemical and food industrial processes. By doing so, the study shed light on the benefits of utilizing these control charts in maintaining effective control over various processes. The statistical control charts, through their visual representation of process data, facilitated the identification of variations and deviations from the norm, enabling timely corrective actions and improved process stability.

Opafola et al, (2019), conducted an investigation into the transportability of packaged sachet water on the premises of the Federal University of Agriculture, Abeokuta (FUNNAB) campus. To achieve this, a diverse selection of seven sachet water brands was procured through random sampling. The collected sachet water samples were subjected to comprehensive analysis to assess their physiochemical and bacteriological qualities. This assessment provided valuable insights into the overall quality of the packaged water available within the campus.

In a separate study, Yusuf et al, (2015), undertook a thorough physiochemical analysis of 21 distinct brands of sachet water that were being distributed within the Zaria metropolis. The main objective was to gauge the compliance of these brands with the stipulated threshold limits defined by both the World Health Organization (WHO) and the Nigerian Industrial Standard (NIS). This evaluation was carried out through the utilization of standardized analytical methods. By comparing the measured parameters of the sachet water samples against the established limits, the study aimed to determine whether these brands met the recommended quality standards set forth by international and national regulatory bodies.

2.10 Maintenance in the present

The emergence of sophisticated systems and autonomous production has resulted in heightened manufacturing costs due to unforeseen breakdowns. Approximately one-third of total maintenance expenses has been squandered because of poorly planned and, in certain instances, unnecessary maintenance operations Xia et al., (2012). Hence, it is imperative to establish a streamlined maintenance procedure that strategically constructs a framework for sustaining both equipment and systems, ensuring they operate under optimal conditions. With the passage of time and regular equipment usage, degradation is inevitable. Failing to undertake appropriate preservation measures will inevitably result in breakdowns, causing production downtime and harm to organizations. Preventive maintenance, when appropriately scheduled and carried out, demonstrates greater efficiency and benefits compared to corrective maintenance. This holds true not only in terms of the costs associated with the maintenance action but also in supporting the overall productivity of the business. Especially in the current economic downturn, marked by reduced company investments, the role of preventive maintenance becomes crucial in preserving existing equipment. This ensures prolonged operability and reliability, contributing to the sustained functionality of the equipment over an extended period. In this respect, increasing the downtime of equipment, the problems of quality, loss of production speed, safety hazards and environmental pollution become obvious results. These outcomes possess the capacity to negatively impact operating costs, profitability, customer satisfaction, and productivity, among other ramifications. To guarantee the optimal functioning of a production facility, aligning with prescribed production costs and anticipated profitability, the maintenance sector must make decisions regarding the necessary maintenance strategies to achieve the organization's objectives. Hence, it is crucial that the strategy and objectives of the service are not formulated in isolation but are instead derived from a comprehensive analysis of various factors. These factors include the company's production policies, along with other stipulations, requirements, and constraints outlined by private organizations, as discussed in the works of Muchiri et al. (2011) and Dilanthi, (2013). This approach ensures that the service aligns seamlessly with broader organizational policies and external considerations, contributing to a more holistic and effective operational framework.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

This research study was carried out using qualitative samples gotten from the quality manager and production manager of the water factor in view and also survey on this study was used as a means of getting insightful information for the furtherance of the research work.

The primary aim has always been to check for the quality control of the table water incorporated by the factory to see if they meet up the required standards. For an effective research, analytical activities should be carried out on the product or from the data obtained.

There are various techniques used in carrying out quality control, in this research study we will focus only on the control chart method and the reason for that is to check if the product produced are under statistical quality control. Analysis on the state of the water before production will be carried to see whether they meet the required specification for production.

3.2 Method of Data Collection

The method of data collection for this research work was of both primary and secondary nature. The primary nature involved the usage of an online survey, the importance of the survey data to get reviews from the final consumers on the quality of the product. This review stands as the foundational block to getting the required information needed to carry out the research work.

The secondary data collected was gotten directly from the water factory manager. Accurate data from the company in view is of great importance to this research work because it will help reduce errors during analysis and will greatly improve the result of the analysis. Data of both quantity and quality of water produced from proper recorded information were collected.

3.3 Method of Data Analysis

In carrying out quality control analysis, a control chart is used. There are various types of control charts that can be used in achieving the desired analytic result. They are thus listed below:

i. The P-chart control chart
ii. The Variable control charts
iii. The X-bar control chart
iv. The Range “R” control chart
v. The Standard Deviation “S” control chart
vi. The Attribute control chart

The control chart method used for analyzing data and samples in this research work is the P-chart control chart method.

3.4 The R-Chart Control Chart

A R-Chart also known as the Range Control Chart is a control chart used to monitor process dispersion; they are sensitive to changes in process dispersion. Although the underlying sampling distribution is not normal. The concepts for use of range charts are much the same as those for use of mean charts. Control limits for range charts are found using the average sample range in conjunction with these formulas:

$$UCL_R = D_4R \qquad \ldots 3.1$$

$$LCL_R = D_3R \qquad \ldots .3.2$$

Where values of D3 and D4 are obtain in the factor for range chart and R is the range of the central line.

If the process standard deviation is known, control limits for a range chart can be calculated using values from the factor range table.

$$LCL = \frac{3D3\sigma}{A2\sqrt{n}} \qquad \ldots 3.3$$

$$\text{UCL} = \frac{3D4\sigma}{A2\sqrt{n}} \qquad \ldots 3.4$$

Mean and range charts used together complement each other. Mean control charts and range control charts provide different perspectives on a process. As we have seen, mean charts are sensitive to shifts in the process mean, whereas range charts are sensitive to changes in process dispersion. Because of this difference in perspective, both types of charts might be used to monitor the same process. The logic of using both is readily apparent in the table. The mean chart picks up the shift in the process mean, but because the dispersion is not changing the range chart fails to indicate a problem. A change in process dispersion is less apt to be detected by the mean chart than by the range chart. Thus, use of both charts provides more complete information than either chart alone. Even so, a single chart may suffice in some cases. For example, a process may be more susceptible to changes in the process mean than to changes in dispersion, so it might be unnecessary to monitor dispersion. Because of the time and cost of constructing control charts, gathering the necessary data, and evaluating the results, only those aspects of a process that tend to cause problems should be monitored.

Once control charts have been set up, they can serve as a basis for deciding when to interrupt a process and search for assignable causes of variation. To determine initial control limits, the following procedure is observed:

- Obtain your samples and also compute the appropriate sample statistics for each sample (e.g mean)
- Establish preliminary control limit using the formulas
- Determine if any points fall outside the control limits
- If you find no out-of-control signals, assume that the process is in control. If not, investigate and correct assignable causes of variation. Then resume the process and collect another set of observations upon which control limits can be based
- Plot the data on the control chart and check for out-of-control signals

3.5 Run Tests

A run test is defined as a sequence of observations with a certain characteristic, followed by one or more observations with a different characteristic. This characteristic can be anything observable.

Control charts test for points that are too extreme to be considered random (e.g., points that are outside of the control limits. However, even if all points are within the control limits, the data may still not reflect a random process. In fact, any sort of pattern in the data would suggest a nonrandom process.

Analysts often supplement control charts with a run test, which checks for patterns in a sequence of observations. This enables an analyst to do a better job of detecting abnormalities in a process and provides insights into correcting a process that is out of control. A variety of run tests are available; when a process is stable or in statistical control, the output it generates will exhibit random variability over a period of time. The presence of patterns, such trends, cycles; or bias in the output indicates that assignable, or nonrandom, causes of variation exist. Hence, a process that produces output with such patterns is not in a state of statistical control. This is true even though all points on a control chart may be within the control limits. For this reason, it is usually prudent to subject control chart data to run tests to determine whether patterns can be detected.

The two major run tests used are:

- The number of runs up and down
- The number of runs above and below the median

To determine whether any patterns are present in control chart data, one must transform the data into both As and Bs and Us and Ds, and then count the number of runs in each case. These numbers must then be compared with the number of runs that would be expected in a completely random series. For both the median and the up/down run tests, the expected number of runs is a function of the number of observations in the series. The formulas are:

$$E_{(r)med} = \frac{N}{2} + 1 \qquad \ldots 3.5$$

$$E_{(r)u/d} = \frac{2N-1}{3} \qquad \ldots 3.6$$

Where:

N is the number of observations or data points

$E_{(r)}$ is the expected number of runs

The actual number of runs in any given set of observations will vary from the expected number, due to chance and any patterns that might be present. Chance variability is measured by the standard deviation of runs. The formulas are:

$$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} \qquad \ldots 3.7$$

$$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} \qquad \ldots 3.8$$

Distinguishing chance variability patterns requires use of the sampling distributions for median runs and up/down runs. When computing the standard deviations, z, by which an observed number of runs differs from expected number. The z value is then compared to the standard value of ± 2 (z for 95.5%). A test that exceeds the standard z value limits indicates the presence of patterns.

$$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs} \qquad \ldots 3.9$$

i.e

$$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} \qquad \ldots 3.10$$

$$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} \qquad 3.11$$

3.6 Process Capability

It is a technique used to determine if a process is capable of producing output that is within an acceptable range after the stability of the process has been established (no nonrandom variations). A process can be in control and still generate unacceptable output. Thus, we cannot automatically assume that a process that is in a control will provide desired output. Instead we must specifically check whether a process is capable of meeting specifications and not simply setup a control chart to monitor it. A process should both be in control and within specifications before production begins.

The check for the capability of a process C_p, the formula used is:

$$C_p = \frac{Specification\ Width}{6\sigma} = \frac{Upper\ Specification - \text{Lower Specification}}{6\sigma} \quad \ldots 3.12$$

For a process to be deemed capable, its capability index must be at least 1.00. the standard capability index value must be at least 1.33.

There are situations in which the target value is not centered between the specifications either intentionally or unavoidably. In such cases, a more appropriate measure of process capability is the capability index, C_{pk}, because it does not take the process mean into account. The formula is thus:

C_{pk} for Lower specification,

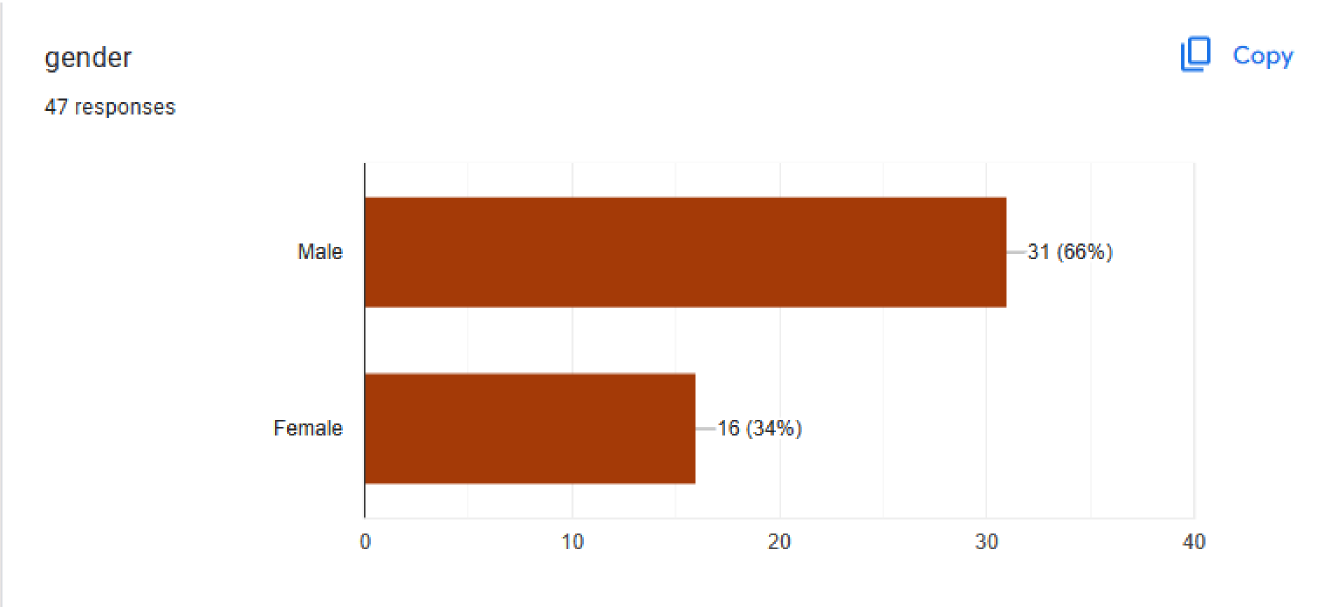
$$C_{pk} = \frac{Process\ Mean - \text{Lower Specification}}{3\sigma} \quad \ldots 3.13$$

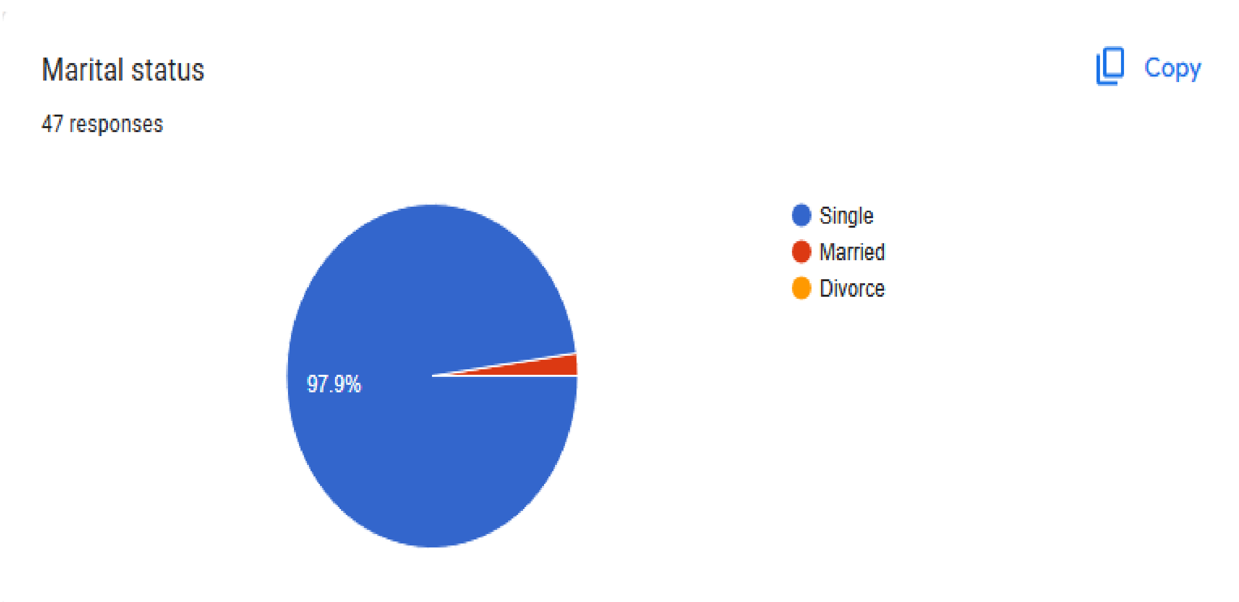
C_{pk} for Upper Specification.

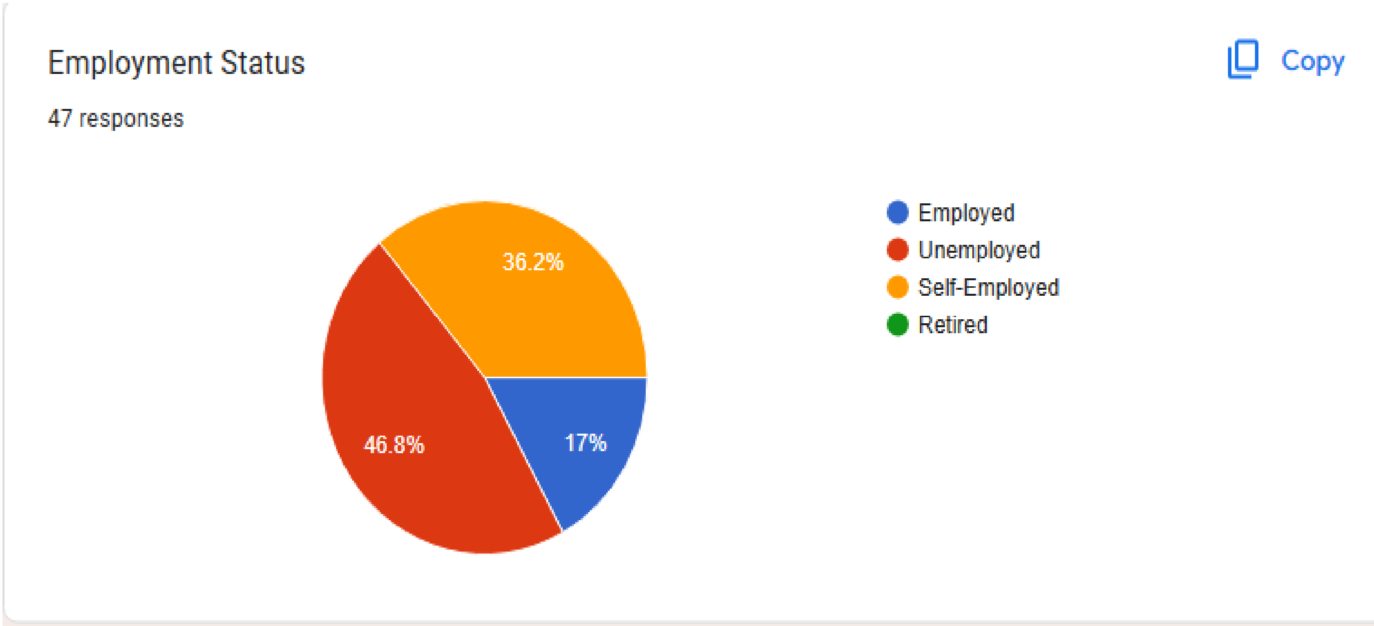
$$C_{pk} = \frac{Upper\ Specification - \text{Process Mean}}{3\sigma} \quad \ldots 3.14$$

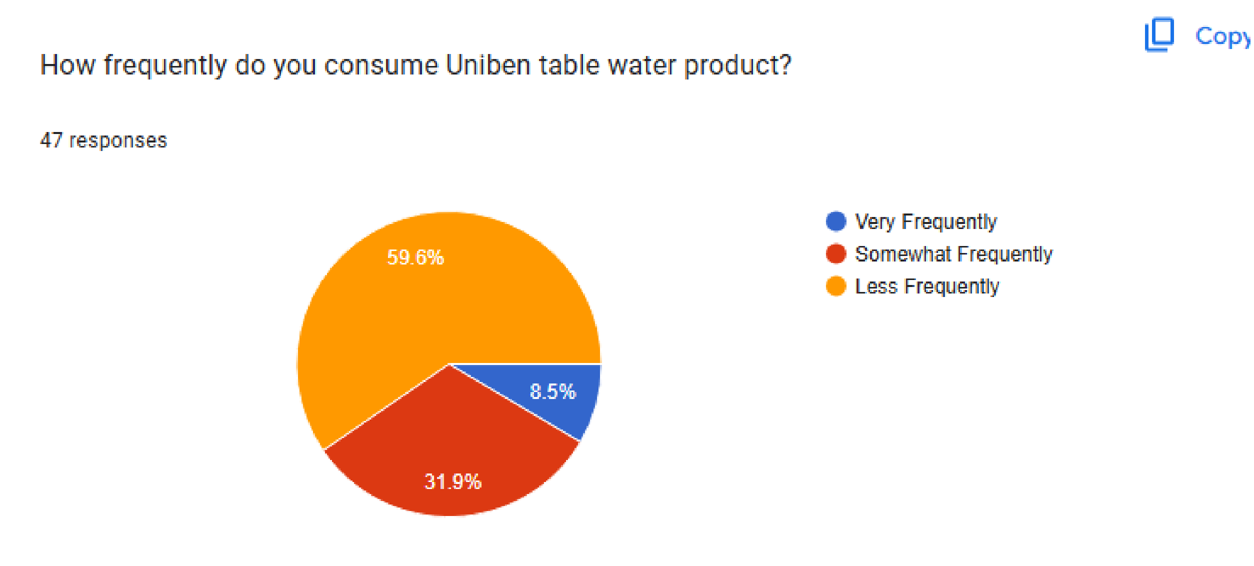
3.6 Data Obtained from Survey

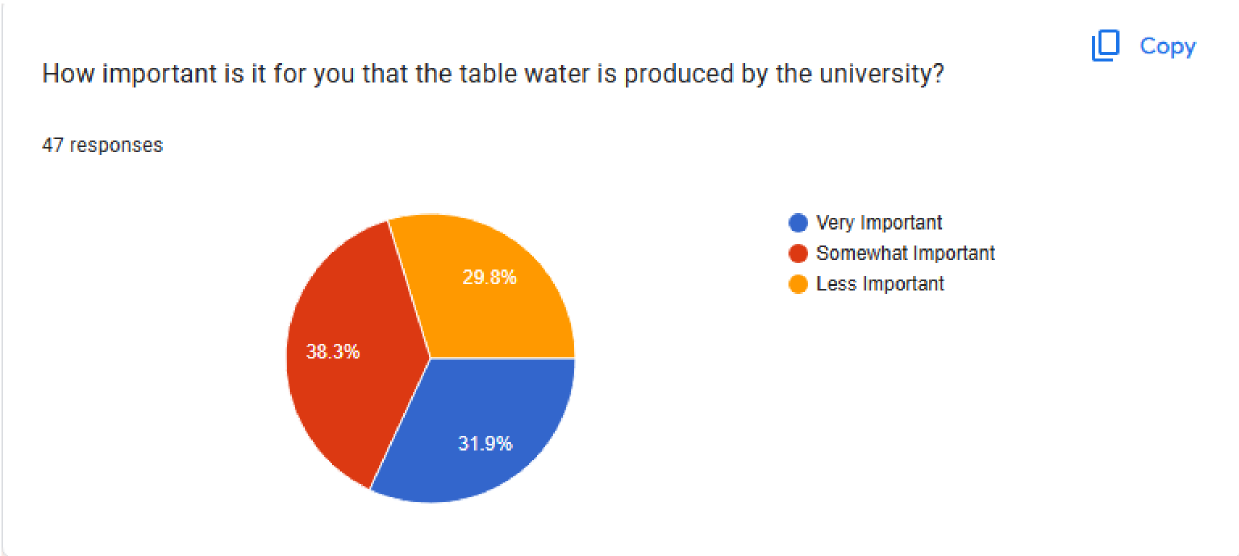
Below are the data gotten from online customer's reviews on the quality of the uniben table water:

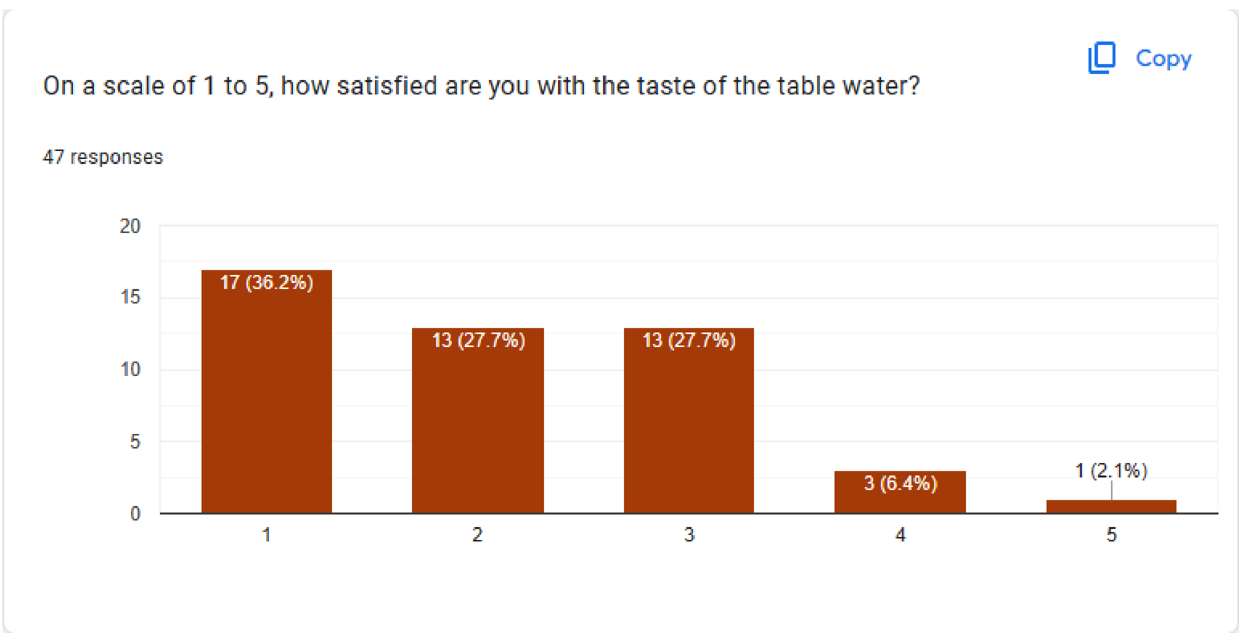


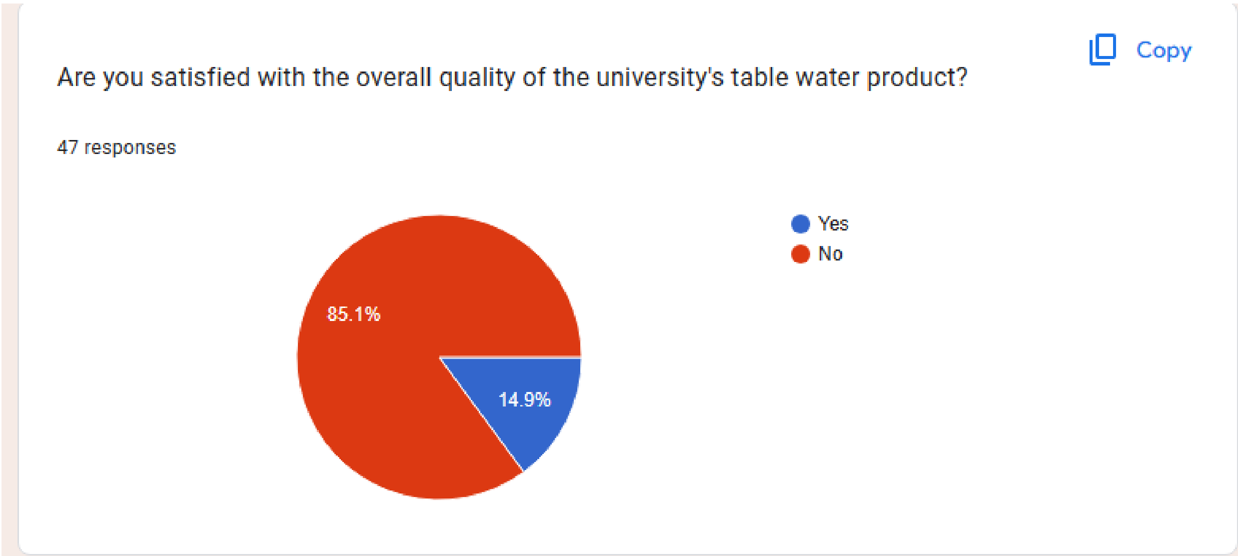


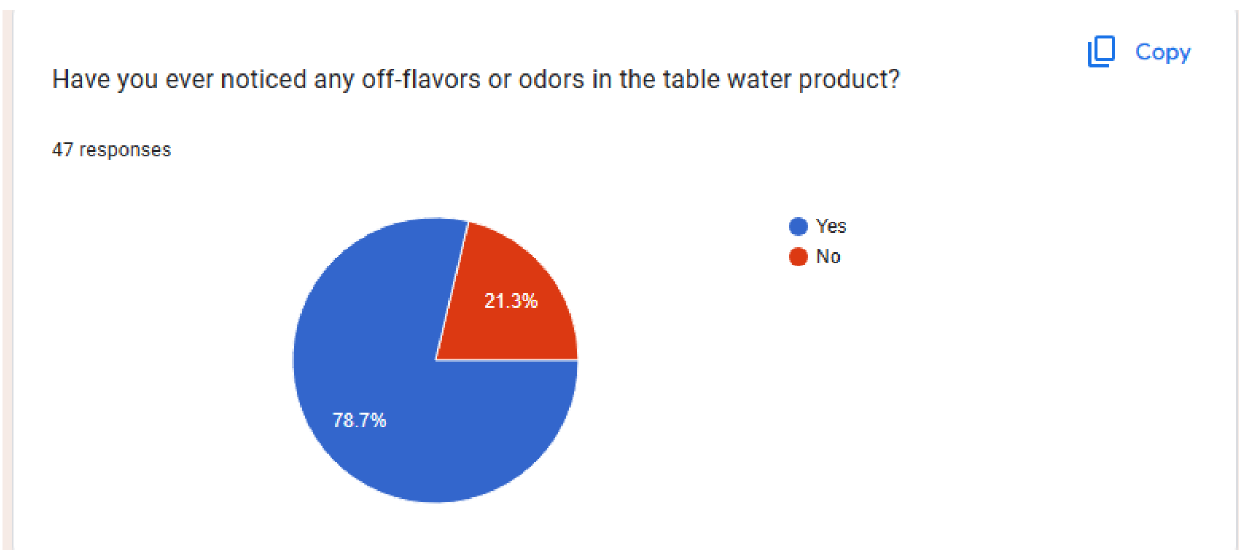

Employment Status
Copy
47 responses
36.2%
46.8%
17%
Employed
Unemployed
Self-Employed
Retired


Copy
How frequently do you consume Uniben table water product?
47 responses
59.6%
8.5%
31.9%
Very Frequently
Somewhat Frequently
Less Frequently


Copy
How important is it for you that the table water is produced by the university?
47 responses
29.8%
38.3%
31.9%
Very Important
Somewhat Important
Less Important


Copy
On a scale of 1 to 5, how satisfied are you with the taste of the table water?
47 responses
20
15
10
5
0
17 (36.2%)
13 (27.7%)
13 (27.7%)
3 (6.4%)
1 (2.1%)
1
2
3
4
5

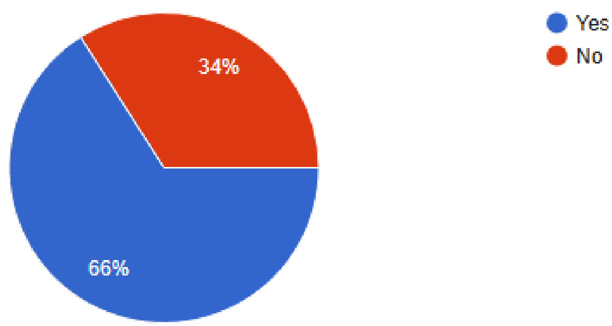

Copy
Are you satisfied with the overall quality of the university's table water product?
47 responses
Yes
No
85.1%
14.9%


Copy
Have you ever noticed any off-flavors or odors in the table water product?
47 responses
Yes
No
21.3%
78.7%

Copy

Do you find the labeling on the bottles clear and informative?

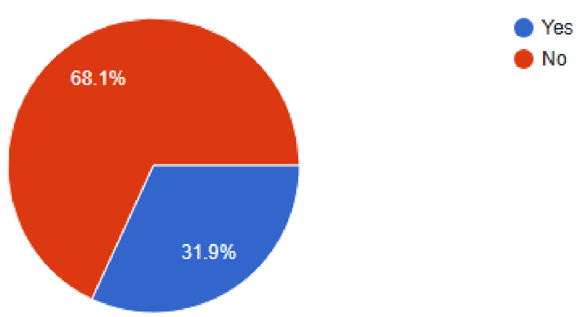
47 responses

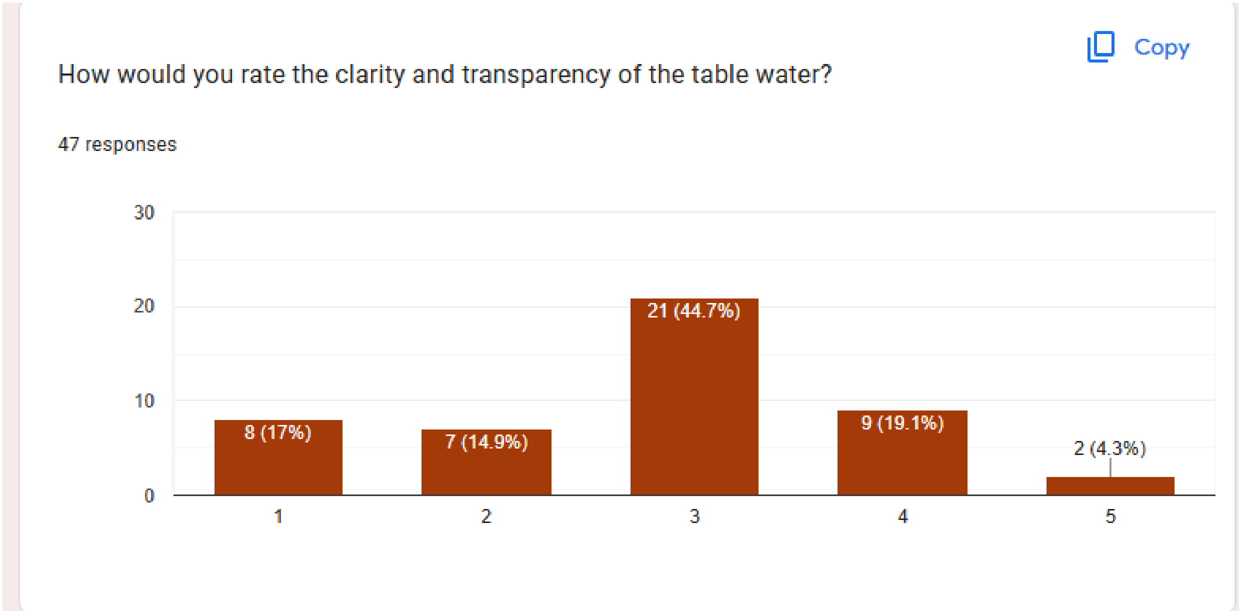


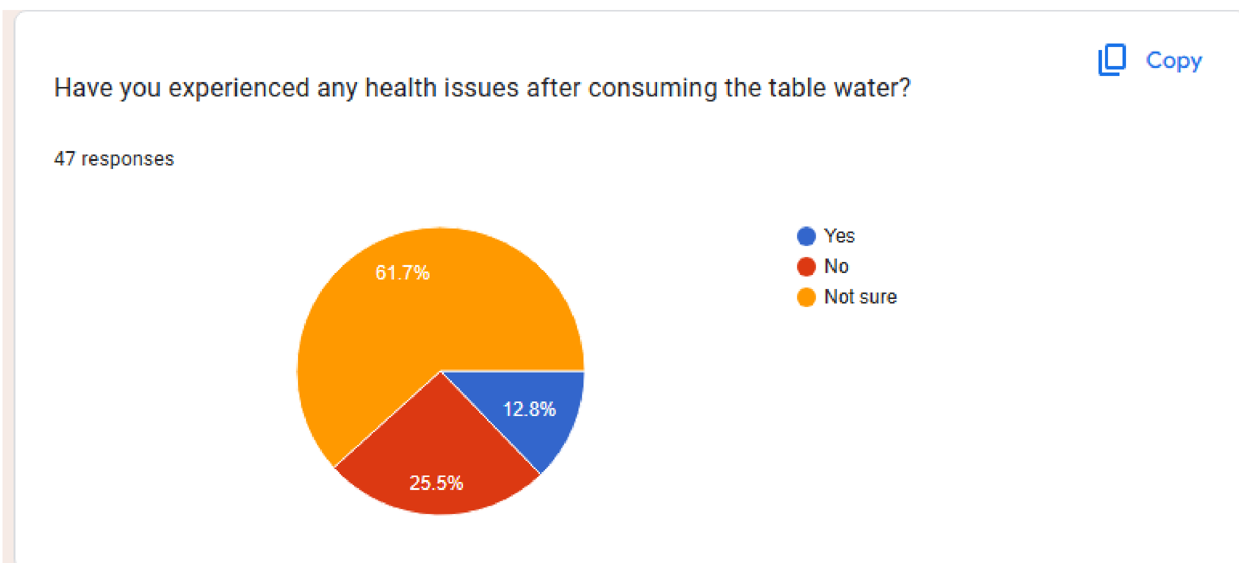
Copy

Have you experienced any issues with the packaging of the table water product (e.g., leaks, damaged bottles)?

47 responses




Copy
How would you rate the clarity and transparency of the table water?
47 responses
30
20
10
0
8 (17%)
7 (14.9%)
21 (44.7%)
9 (19.1%)
2 (4.3%)
1
2
3
4
5


Copy
Have you experienced any health issues after consuming the table water?
47 responses
61.7%
12.8%
25.5%
Yes
No
Not sure

Have you ever compared Uniben table water with other brands? If yes, how does it compare in terms of quality?

47 responses

No

Yes

Other brands are better in terms of quality

Almost the same

Yes. In terms of quality, other brands taste better than uniben water.

I find the quality that other brands offer better than that of the university.

Good

It's very substandard

Awesome quality

Have you ever compared Uniben table water with other brands? If yes, how does it compare in terms of quality?

47 responses

- Other brands like NOTRE DAME is way better than uniben table water, in terms of quality, availability, packaging etc. But the main issue with uniben table water is the bad/sour taste it has.
- The poor branding and packaging process as well as the less satisfaction it gives as a result of low hygiene and purification
- The water has taste unlike other products. If that can be improved then the water is good to go
- Less than most of them
- Uniben table water is of less quality not impressed at all
- Yes, other table water have great quality. Clean, odorless and tasteless compared to UNIBEN water.
- In synopsis... of All other brands I've dranked UNIBEN table water is the worse
- Bad

Have you ever compared Uniben table water with other brands? If yes, how does it compare in terms of quality?

47 responses

- With respect to quantity
- fairly ok...can definitely do better
- Uniben table water is terrible
- Yes, in terms of quality, other brands have better packaging and pay much more attention to purity and taste.
- It is compared low in quality to other brands
- Very poor
- Uniben table water is bad really bad.
- Uniben water is bad
- Not comparable, as the other brands produce better quality water

Have you ever compared Uniben table water with other brands? If yes, how does it compare in terms of quality?

47 responses

Less favourably

Very poor

Better than most

Not really

Other brands serves best

Other brands like NOTRE DAME is way better than uniben table water, in terms of quality, availability, packaging etc. But the main issue with uniben table water is the bad/sour taste it has.

The poor branding and packaging process as well as the less satisfaction it gives as a result of low hygiene and purification

The water has taste unlike other products. If that can be improved then the water is good to go

Have you ever compared Uniben table water with other brands? If yes, how does it compare in terms of quality?

47 responses

Yes.

Comparing to other standard brands, Uniben table water feels substandard

The taste and some times smell of uniben what is pronounced which shouldn't be

In terms of quality other brands provide better water quality than uniben's own. It's difficult to actually get the main problem now because I gotten too used to the taste of the water

It's fair

Yes. Taste, Branding and packaging

Other brands like Olivia are more access, make home deliveries and are cleaner

Poor

It doesn't compare

CHAPTER FOUR

ANALYSIS AND RESULTS

4.1 Analysis

This chapter contains the analysis of representation of data. Below are the parameters used to carry sample test before and during production.

Table 4.1 limit NIS standard used in the factory

PARAMETER, UNIT	LIMIT, N.I.S STANDARD
Temperature (C)	Ambient
Colour, T.C.U	3
Odour	Odourless
Taste	Tasteless
PH	6.5 – 8.5
Turbidity, NTU	5
Conductivity	1000
TDS (PPM)	500

For this research work, the following designations were used:

- Sample P used for sachet water
- Sample Q used for bottle water
- Sample R used for raw water

Table 4.2 PHYSICOCHEMICAL ANALYSIS RESULT FOR THE MONTH OF APRIL.

DATE		1/4/2023	1/4/2023	1/4/2023	1/4/2023	1/4/2023
SACHET TESTED	M	3	10	6	17	3
SAMPLE(TREATED WATER)	A	6	17	3	6	10
PH	M	7.2	7.4	7.2	7.3	7.4
	A	7.2	7.4	7.2	7-3	7.4
TDS (PPM)		132	122	127	130	122
CONDUCTIVITY(µs/cm)		264	244	254	260	244
COLOUR		Colourless	Colourless	Colourless	Colourless	Colourless
ODOUR		odourless	Odourless	Odourless	Odourless	Odourless
TASTE		Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
TURBIDITY		Clear	Clear	Clear	Clear	Clear
TEMP(ºC)		22.6	21.7	21.1	22.1	20.2
BOTTLE TESTED SAMPLE TREATED (TREATED WATER PH)		-	7.4	7.2	7.3	7.4
		-	7.4	7.2	7.3	7.4
TDS (PPM)		-	122	127	130	121
CONDUCTIVITY(µs/cm)		-	244	254	260	242
COLOUR		-	Colourless	Colourless	Colourless	Colourless
ODOUR		-	Odourless	Odourless	Odourless	Odourless
TASTE		-	Tasteless	Tasteless	Tasteless	Tasteless
TURBIDITY		-	Clear	Clear	Clear	Clear
TEMP(ºC)		-	21.7	21.2	22.1	21.2
RAW WATER PH		5.2	5.1	5.1	5.0	5.1
TDS (PPM)		120	100	127	123	126
CONDUCTIVITY(µs/cm)		240	200	255	246	252
COLOUR		Colourless	Colourless	Colourless	Colourless	Colourless
ODOUR		odourless	Odourless	Odourless	Odourless	Odourless
TASTE		Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
TURBIDITY		Clear	Clear	Clear	Clear	Clear
TEMP(ºC)		22.4	20.7	21.0	22.0	20.1

7/4/2023	17	10	7.5	7.5	120	240	Colourless	Odourless	Tasteless	Clear	21.2	7.5	7.5	120	240	Colourless	Odourless	Tasteless	Clear	22	5.1	130	260	Colourless	Odourless	Tasteless	Clear	21.2
8/4/2023	3	6	7.5	7.5	121	242	Colourless	Odourless	Tasteless	Clear	22.6	7.5	7.5	121	242	Colourless	Odourless	Tasteless	Clear	22.7	5	100	200	Colourless	Odourless	Tasteless	Clear	22.4
10/4/2023	10	3	7.4	7.4	121	242	Colourless	Odourless	Tasteless	Clear	21.5	7.4	7.4	120	240	Colourless	Odourless	Tasteless	Clear	21.6	5.2	120	240	Colourless	Odourless	Tasteless	Clear	22.4
11/4/2023	17	3	7.6	7.6	122	244	Colourless	Odourless	Tasteless	Clear	22.2	7.6	7.6	120	240	Colourless	Odourless	Tasteless	Clear	22.1	5.1	110	220	Colourless	Odourless	Tasteless	Clear	22.1
12/4/2023	10	6	7.4	7.4	121	242	Colourless	Odourless	Tasteless	Clear	21.2	7.4	7.4	120	240	Colourless	Odourless	Tasteless	Clear	22.4	5	100	200	Colourless	Odourless	Tasteless	Clear	20.1
13/4/2023	17	3	7.6	7.6	110	220	Colourless	Odourless	Tasteless	Clear	22.1	7.6	7.6	110	220	Colourless	Odourless	Tasteless	Clear	22.6	5.1	121	242	Colourless	Odourless	Tasteless	Clear	22
14/4/2023	10	6	7.4	7.4	128	256	Colourless	Odourless	Tasteless	Clear	22.2	7.4	7.4	123	246	Colourless	Odourless	Tasteless	Clear	22.4	5	100	200	Colourless	Odourless	Tasteless	Clear	22
15/4/2023	6	3	7.3	7.3	120	240	Colourless	Odourless	Tasteless	Clear	24.2	7.3	7.3	120	240	Colourless	Odourless	Tasteless	Clear	24.5	5.1	124	248	Colourless	Odourless	Tasteless	Clear	23.2
17/4/2023	17	10	7.4	7.4	133	266	Colourless	Odourless	Tasteless	Clear	21.4	7-4	7-4	132	264	Colourless	Odourless	Tasteless	Clear	21.6	5.2	126	252	Colourless	Odourless	Tasteless	Clear	21.2

18/4/2023	3	10	7.3	7.3	126	252	Colourless	Odourless	Tasteless	Clear	22	7.3	7.3	126	252	Colourless	Odourless	Tasteless	Clear	22.1	5.2	126	252	Colourless	Odourless	Tasteless	Clear	21.8
19/4/2023	17	6	7.3	7.4	123	246	Colourless	Odourless	Tasteless	Clear	22.6	7.3	7.3	123	246	Colourless	Odourless	Tasteless	Clear	22.7	5.1	126	256	Colourless	Odourless	Tasteless	Clear	22.1
20/4/2023	3	6	7.4	7.4	128	256	Colourless	Odourless	Tasteless	Clear	21.2	7.4	7.4	128	256	Colourless	Odourless	Tasteless	Clear	21.4	5.2	130	260	Colourless	Odourless	Tasteless	Clear	20.9
21/4/2023	10	6	7.3	7.3	130	260	Colourless	Odourless	Tasteless	Clear	22	7.3	7.3	132	264	Colourless	Odourless	Tasteless	Clear	22.4	5.1	124	248	Colourless	Odourless	Tasteless	Clear	21.9
22/4/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24/4/2023	10	17	7.4	7.4	135	270	Colourless	Odourless	Tasteless	Clear	21.2	7.4	7.4	135	270	Colourless	Odourless	Tasteless	Clear	21.6	5.0	130	260	Colourless	Odourless	Tasteless	Clear	21.2
25/4/2023	6	3	7.5	7.5	132	264	Colourless	Odourless	Tasteless	Clear	21.9	7.5	7.5	132	264	Colourless	Odourless	Tasteless	Clear	21.9	5.0	130	260	Colourless	Odourless	Tasteless	Clear	21.6
26/4/2023	3	6	7.5	7.5	127	254	Colourless	Odourless	Tasteless	Clear	20.8	7.5	7.5	130	260	Colourless	Odourless	Tasteless	Clear	20.9	5.0	135	270	Colourless	Odourless	Tasteless	Clear	20.6
27/4/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28/4/2023	3	17	7.3	7.3	132	264	Colourless	Odourless	Tasteless	Clear	21.2	7.4	7.4	132	264	Colourless	Odourless	Tasteless	Clear	21.6	5.0	130	260	Colourless	Odourless	Tasteless	Clear	21.2
29/4/2023	10	6	7.3	7.3	135	270	Colourless	Odourless	Tasteless	Clear	21.6	7-3	7-3	135	270	Colourless	Odourless	Tasteless	Clear	21.9	5.0	130	260	Colourless	Odourless	Tasteless	Clear	21.2

Table 4.3: A table containing the mean bar and standard deviation values of the samples.

Number of samples (N)	SAMPLE P			SAMPLE Q			SAMPLE R		
	PH	**$X - \bar{X}$**	**$(X - \bar{X})^2$**	**PH**	**$X - \bar{X}$**	**$(X - \bar{X})^2$**	**PH**	**$X - \bar{X}$**	**$(X - \bar{X})^2$**
1	7.2	-0.19	0.0361	7.4	0	0	5.2	0.117	0.0137
2	7.4	0.01	0.0001	7.2	-0.2	0.04	5.1	0.017	0.0003
3	7.2	-0.19	0.0361	7.3	-0.1	0.01	5.1	0.017	0.0003
4	7.3	-0.09	0.0081	7.4	0	0	5.0	-0.083	0.0069
5	7.4	0.01	0.0001	7.5	0.1	0.01	5.1	0.017	0.0003
6	7.5	0.11	0.0121	7.5	0.1	0.01	5.1	0.017	0.0003
7	7.5	0.11	0.0121	7.4	0	0	5.0	-0.083	0.0069
8	7.4	0.01	0.0001	7.6	0.2	0.04	5.2	0.117	0.0137
9	7.6	0.21	0.0441	7.4	0	0	5.1	0.017	0.0003
10	7.4	0.01	0.0001	7.6	0.2	0.04	5.0	-0.083	0.0069
11	7.6	0.21	0.0441	7.4	0	0	5.1	0.017	0.0003
12	7.4	0.01	0.0001	7.3	-0.1	0.04	5.0	-0.083	0.0069
13	7.3	-0.09	0.0081	7.4	0	0	5.1	0.017	0.0003
14	7.4	0.01	0.0001	7.3	-0.1	0.01	5.2	0.117	0.0137
15	7.3	-0.09	0.0081	7.3	-0.1	0.01	5.2	0.117	0.0137
16	7.3	-0.09	0.0081	7.4	0	0	5.1	0.017	0.0003
17	7.4	0.01	0.0001	7.3	-0.1	0.01	5.2	0.117	0.0137
18	7.3	-0.09	0.0081	7.4	0	0	5.1	0.017	0.0003
19	7.4	0.01	0.0001	7.5	0.1	0.01	5.0	-0.083	0.0069
20	7.5	0.11	0.0121	7.5	0,1	0.01	5.0	-0.083	0.0069
21	7.5	0.11	0.0121	7.4	0	0	5.0	-0.083	0.0069
22	7.3	-0.09	0.0081	7.3	-0.1	0.01	5.0	-0.083	0.0069
23	7.3	-0.09	0/0081				5.0	-0.083	0.0069
$\sum X$	169.9			162.8			116.9		

$$\overline{X} = \sum \frac{\sum X}{N} \; ; \qquad \ldots 4.1$$

$$\mathrm{P}\overline{X} = \frac{169.9}{23} = 7.39$$

$$\text{Standard deviation of } \mathrm{P}\overline{X} = \sqrt{\frac{\sum(X - \mathrm{P}\overline{X})}{N-1}} \qquad \ldots 4.2$$

$$\mathrm{P}\overline{X} = \sqrt{\frac{\mathbf{(0.0361*2)+(0.0081*7)+(0.0001*8)+(0{,}0121*4)}}{\mathbf{23-1}}} = 0.11$$

Median score = 7.4

Variance = 0.11^2 = 0.0121

$$\mathrm{Q}\overline{X} = \frac{162.8}{22} = 7.4$$

$$\text{Standard deviation of } \mathrm{Q}\overline{X} = \sqrt{\frac{\sum(X - \mathrm{Q}\overline{X})}{N-1}} \qquad \ldots 4.3$$

$$\mathrm{Q}\overline{X} = \sqrt{\frac{\mathbf{(0*9)+(0.04*3)+(0.01*10)}}{\mathbf{22-1}}} = 0.102$$

Median score = 7.4

Variance = 0.102^2 = 0.01

$$\mathrm{R}\overline{X} = \frac{116.9}{23} = 5.083$$

$$\text{Standard deviation of } \mathrm{R}\overline{X} = \sqrt{\frac{\sum(X - \mathrm{R}\overline{X})}{N-1}} \qquad \ldots 4.4$$

$$\mathrm{R}\overline{X} = \sqrt{\frac{\mathbf{(0.0137*5)+(0.0003*9)+(0.0069*9)}}{\mathbf{23-1}}} = 0.0058$$

Median score = 5.1

Variance = $0.0058^2 = 3.36 * 10^{-5}$

Using R – Chart

Range = highest – lowest

Rp = 7.6 – 7.2 = 0.4

Rq = 7.6 – 7.2 = 0.4

Rr = 5.2 – 5.0 = 0.2

$$\overline{R} = \sum \frac{\sum R}{N} \qquad \ldots 4.4$$

$\bar{R} = \frac{0.4+0.4+0.2}{3} = 0.33$

$D_4 = 2.57$

$D_3 = 0$

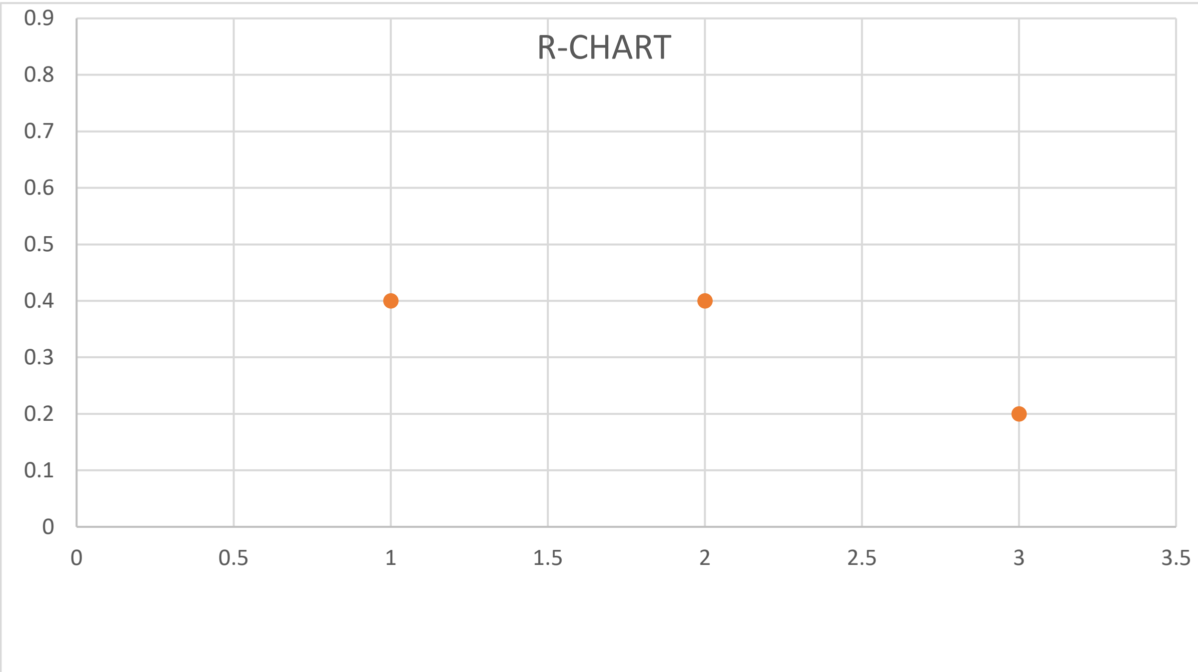
$UCL_R = D_4R$ …4.5

$UCL_R = 2.57 * 0.33 = 0.8481$

$LCL_R = D_3R$ …4.6

$LCL_R = 0 * 0.33 = 0$

Figure 4.1: R chart for the month of April



From the chart above, the process using the R-chart is in statistical control.

The next involves using the run test to check for presence of pattern and assignable cause of variations.

Table4.4: a table of the run chart for the month of April

No of samples	P	P(A/B)	P(U/D)	Q	Q(A/B)	Q(U/D)	R	R(A/B)	R(U/D)
1	7.2	B	-	7.4	-	-	5.2	A	-
2	7.4	-	U	7.2	B	D	5.1	-	D
3	7.2	B	D	7.3	B	U	5.1	-	-
4	7.3	B	U	7.4	-	U	5.0	B	D
5	7.4	-	D	7.5	A	U	5.1	-	U
6	7.5	A	U	7.5	A	-	5.1	-	-
7	7.5	A	-	7.4	-	D	5.0	B	D
8	7.4	-	D	7.6	A	U	5.2	A	U
9	7.6	A	U	7.4	-	D	5.1	-	D
10	7.4	-	D	7.6	A	U	5.0	B	D
11	7.6	A	U	7.4	-	D	5.1	-	U
12	7.4	-	D	7.3	B	D	5.0	B	D
13	7.3	B	D	7.4	-	U	5.1	-	U
14	7.4	-	U	7.3	B	D	5.2	A	U
15	7.3	B	D	7.3	B	-	5.2	A	-
16	7.3	B	-	7.4	-	U	5.1	-	D
17	7.4	-	U	7.3	B	D	5.2	A	U
18	7.3	B	D	7.4	-	U	5.1	-	D
19	7.4	-	U	7.5	A	U	5.0	B	D
20	7.5	A	U	7.5	A	-	5.0	B	-
21	7.5	A	-	7.4	-	D	5.0	B	-
22	7.3	B	D	7.3	B	D	5.0	B	-
23	7.3	B	-				5.0	B	-

For Sample P

P median score = 7.4

$P_{(A/B)}$ = 5 runs

$P_{(U/D)}$ = 16 runs

N = 23

For the expected number of runs for sample P

$E_{(r)med} = \frac{N}{2} + 1 = \frac{23}{2} + 1 = 12.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(23)-1}{3} = 15$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{23-1}{4}} = 2.345$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(23)-29}{90}} = 1.941$

For the Z test value under the sigma limit ± 2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma\mathrm{med}} = \frac{5 - 12.5}{2.345} = -3.198$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma\mathrm{u/d}} = \frac{16 - 15}{1.941} = 0.515$

From the above result, the Z_{med} does not reveal any pattern and its result is outside the specified range of ± 2 standard deviation. Although the $Z_{(u/d)}$ reveals pattern and is also within the range of ± 2 standard deviation, the process is not in control and there is non-random or assignable cause of variations.

For Sample Q

Q median score = 7.4

$Q_{(A/B)}$ = 8 runs

$Q_{(U/D)}$ = 13 runs

N = 22

For the expected number of runs for sample Q

$E_{(r)med} = \frac{N}{2} + 1 = \frac{22}{2} + 1 = 12$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(22)-1}{3} = 14.33$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{22-1}{4}} = 2.291$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(22)-29}{90}} = 1.894$

For the Z test value under the sigma limit ± 2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} = \frac{5 - 12.5}{2.345} = -1.746$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} = \frac{16 - 15}{1.941} = -0.702$

From the above result, the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern but their values is within the range of ± 2 standard deviation, therefore the process is in control and there is random or non-assignable cause of variations.

For Sample R

R median score = 5.1

$R_{(A/B)}$ = 6 runs

$R_{(U/D)}$ = 12 runs

N = 23

For the expected number of runs for sample P

$E_{(r)med} = \frac{N}{2} + 1 = \frac{23}{2} + 1 = 12.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(23)-1}{3} = 15$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{23-1}{4}} = 2.345$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(23)-29}{90}} = 1.941$

For the Z test value under the sigma limit ±2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma\mathrm{med}} = \frac{6 - 12.5}{2.345} = -2.7716$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma\mathrm{u/d}} = \frac{12 - 15}{1.941} = -1.5458$

From the above result, both the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern and their result is outside the specified range of ±2 standard deviation. Therefore, the process is not in control and there is non-random or assignable cause of variations.

Process Capability

This process can only be carried out when Z_{test} result is in process control. From our previous calculation, only Sample Q can pass through this test as it is in process control.

For Sample Q

Mean = $\frac{\sum \bar{Q}}{N}$ = $\frac{162.8}{22}$ = 7.4

Standard specification of PH value is 6.5 to 8.5

Where

Lower specification = 6.5

Upper specification = 8.5

σ = 0.0058

Using process capability index C_{pk},

C_{pk} for lower = $\frac{process\ mean - lower\ specification}{3\sigma}$ = = $\frac{7.4-6.5}{3(0.0058)}$ = 2.73

C_{pk} for upper = $\frac{upper\ specification - process\ mean}{3\sigma}$ = = $\frac{8.5-7.4}{3(0.0058)}$ = 3.33

A process is only capable when it is higher than or equal to the standard value of 1.33.

The both C_{pk} result meets this requirement and therefore the process is capable and production can now take place.

The C_{pk} value used is 2.73 as it is closer to 1.33

Table 4.5 PHYSICOCHEMICAL ANALYSIS RESULT FOR THE MONTH OF MAY.

DATE	SACHET TESTED	SAMPLE(TREATED WATER)	PH		TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)	BOTTLE TESTED SAMPLE TREATED (TREATED WATER PH)		TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)	RAW WATER PH	TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)
	M	**A**	**M**	**A**								**M**	**A**															
1/5/2023	6	10	7.5	7.5	133	264	Colourless	odourless	Tasteless	Clear	22.6	-	-	-	-	-	-	-	-	-	5.2	120	240	Colourless	odourless	Tasteless	Clear	20.4
2/5/2023	3	6	7.5	7.5	115	244	Colourless	Odourless	Tasteless	Clear	21.6	7.4	7.4	122	244	Colourless	Odourless	Tasteless	Clear	21.7	5.1	100	200	Colourless	Odourless	Tasteless	Clear	20.9
3/5/2023	10	17	7.3	7.3	132	254	Colourless	Odourless	Tasteless	Clear	20.9	7.2	7.2	127	254	Colourless	Odourless	Tasteless	Clear	21.2	5.1	127	255	Colourless	Odourless	Tasteless	Clear	20.6
4/5/2023	17	6	7.3	7-3	132	260	Colourless	Odourless	Tasteless	Clear	20.2	7.3	7.3	130	260	Colourless	Odourless	Tasteless	Clear	22.1	5.0	123	246	Colourless	Odourless	Tasteless	Clear	20.0
5/5/2023	10	6	7.3	7.3	132	244	Colourless	Odourless	Tasteless	Clear	19.3	7.4	7.4	121	242	Colourless	Odourless	Tasteless	Clear	21.2	5.1	126	252	Colourless	Odourless	Tasteless	Clear	19.1

6/5/2023	17	3	7.4	7.4	131	262	Colourless	Odourless	Tasteless	Clear	20.1	7.4	7.4	131	262	Colourless	Odourless	Tasteless	Clear	20.2	5.0	131	262	Colourless	Odourless	Tasteless	Clear	20.3
8/5/2023	10	6	7.5	7.5	125	250	Colourless	Odourless	Tasteless	Clear	19.6	7.5	7.5	125	250	Colourless	Odourless	Tasteless	Clear	19.7	5.0	130	260	Colourless	Odourless	Tasteless	Clear	19.4
9/5/2023	10	17	7.4	7.4	140	280	Colourless	Odourless	Tasteless	Clear	20.2	7.4	7.4	140	280	Colourless	Odourless	Tasteless	Clear	20.2	5.1	132	264	Colourless	Odourless	Tasteless	Clear	20.1
10/5/2023	17	3	7.4	7.4	154	308	Colourless	Odourless	Tasteless	Clear	20.1	7.4	7.4	154	208	Colourless	Odourless	Tasteless	Clear	20.1	5.0	150	300	Colourless	Odourless	Tasteless	Clear	20.0
11/5/2023	10	6	7.3	7.3	132	264	Colourless	Odourless	Tasteless	Clear	20.1	-	-	-	-	-	-	-	-	-	5.0	120	240	Colourless	Odourless	Tasteless	Clear	20.4
12/5/2023	17	3	7.3	7.3	123	246	Colourless	Odourless	Tasteless	Clear	20.6	-	-	-	-	-	-	-	-	-	5.0	120	242	Colourless	Odourless	Tasteless	Clear	22
13/5/2023	10	6	7.5	7.5	125	250	Colourless	Odourless	Tasteless	Clear	19.2	-	-	-	-	-	-	-	-	-	5.1	100	200	Colourless	Odourless	Tasteless	Clear	19.0
15/5/2023	6	10	7.6	7.6	138	276	Colourless	Odourless	Tasteless	Clear	18.7	-	-	-	-	-	-	-	-	-	5.0	120	240	Colourless	Odourless	Tasteless	Clear	18.7
16/5/2023	17	10	7.4	7.4	130	260	Colourless	Odourless	Tasteless	Clear	19.6	-	-	-	-	-	-	-	-	-	5.0	100	200	Colourless	Odourless	Tasteless	Clear	19.4

17/5/2023	3	10	7.5	7.5	134	268	Colourless	Odourless	Tasteless	Clear	19.2	-	-	-	-	-	-	-	-	-	5.1	125	250	Colourless	Odourless	Tasteless	Clear	20.0
18/5/2023	17	6	7.5	7.5	132	264	Colourless	Odourless	Tasteless	Clear	19.3	-	-	-	-	-	-	-	-	-	5.0	120	240	Colourless	Odourless	Tasteless	Clear	19.2
19/5/2023	3	10	7.3	7.3	129	258	Colourless	Odourless	Tasteless	Clear	18.8	7.3	7.3	129	258	Colourless	Odourless	Tasteless	Clear	18.8	5.1	125	250	Colourless	Odourless	Tasteless	Clear	18.6
20/5/2023	10	6	7.3	7.3	133	266	Colourless	Odourless	Tasteless	Clear	17.3	7.3	7.3	133	266	Colourless	Odourless	Tasteless	Clear	17.4	5.0	124	250	Colourless	Odourless	Tasteless	Clear	17.0
22/5/2023	17	3	7.4	7.4	130	260	Colourless	Odourless	Tasteless	Clear	18.3	-	-	-	-	Colourless	Odourless	Tasteless	Clear	-	5.0	120	240	Colourless	Odourless	Tasteless	Clear	18.1
23/5/2023	3	17	7.4	7.4	135	270	Colourless	Odourless	Tasteless	Clear	21.4	7.4	7.4	135	270	Colourless	Odourless	Tasteless	Clear	21.6	5.0	130	260	Colourless	Odourless	Tasteless	Clear	21.2
24/5/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25/05/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26/05/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27/05/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29/5/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30/5/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31/5/2023	17	6	7.3	7.3	125	250	Colourless	Odourless	Tasteless	Clear	18.9	7.3	7.3	130	260	Colourless	Odourless	Tasteless	Clear	18.9	5.1	1	-	Colourless	Odourless	Tasteless	Clear	18.2

Table 4.6: A table containing the mean bar and standard deviation values of the samples.

Number of samples (N)	**SAMPLE P**			**SAMPLE Q**			**SAMPLE R**		
	PH	**$X - \overline{X}$**	**$(X - \overline{X})^2$**	**PH**	**$X - \overline{X}$**	**$(X - \overline{X})^2$**	**PH**	**$X - \overline{X}$**	**$(X - \overline{X})^2$**
1	7.5	0.1	0.01	7.5	0.12	0.0144	5.2	0.16	0.0256
2	7.5	0.1	0.01	7.4	0.02	0.0004	5.1	0.06	0.0036
3	7.3	-0.1	0.01	7.3	-0.08	0.0064	5.0	-0.04	0.0016
4	7.3	-0.1	0.01	7.4	0.02	0.0004	5.1	0.06	0.0036
5	7.3	-0.1	0.01	7.5	0.12	0.0144	5.0	-0.04	0.0016
6	7.4	0	0	7.4	0.02	0.0004	5.0	-0.04	0.0016
7	7.5	0.1	0.01	7.4	0.02	0.0004	5.0	-0.04	0.0016
8	7.4	0	0	7.3	-0.08	0.0064	5.1	0.06	0.0036
9	7.4	0	0	7.3	-0.08	0.0064	5.0	-0.04	0.0016
10	7.3	-0.1	0.01	7.3	-0.08	0.0064	5.0	-0.04	0.0016
11	7.3	-0.1	0.01	7.3	-0.08	0.0064	5.0	-0.04	0.0016
12	7.3	-0.1	0.01				5.1	0.06	0.0036
13	7.6	0.2	0.04				5.0	-0.04	0.0016
14	7.4	0	0				5.0	-0.04	0.0016
15	7.5	0.1	0.01				5.1	0.06	0.0036
16	7.5	0.1	0.01				5.0	-0.04	0.0016
17	7.3	-0.1	0.01				5.1	0.06	0.0036
18	7.3	-0.1	0.01				5.0	-0.04	0.0016
19	7.4	0	0				5.0	-0.04	0.0016
20	7.4	0	0				5.0	-0.04	0.0016
21	7.3	-0.1	0.01				5.1	0.06	0.0036
$\sum X$	155.4			81.2			105.9		

$\overline{X} = \sum \frac{\sum X}{N}$;

$P\overline{X} = \frac{155.4}{21} = 7.4$

Standard deviation of $P\overline{X} = \sqrt{\frac{\sum (X - P\overline{X})}{N-1}}$

$P\overline{X} = \sqrt{\frac{(\mathbf{0.01*14})+(\mathbf{0*6})+(\mathbf{0.04*1})}{\mathbf{21-1}}} = 0.095$

Median score = 7.4

Variance = $0.095^2 = 0.00903$

$Q\overline{X} = \frac{81.2}{11} = 7.38$

Standard deviation of $Q\overline{X} = \sqrt{\frac{\sum (X - Q\overline{X})}{N-1}}$

$Q\overline{X} = \sqrt{\frac{(\mathbf{0*0144} * \mathbf{1})+(\mathbf{0.004*5})+(\mathbf{0.0064*4}) + (\mathbf{0.014})}{\mathbf{21-1}}} = 0.075$

Median score = 7.4

Variance = $0.075^2 = 0.00563$

$R\overline{X} = \frac{105.9}{21} = 5.04$

Standard deviation of $R\overline{X} = \sqrt{\frac{\sum (X - R\overline{X})}{N-1}}$

$R\overline{X} = \sqrt{\frac{(\mathbf{0.0256})+(\mathbf{0.0036*7})+(\mathbf{0.0016*13})}{\mathbf{21-1}}} = 0.06$

Median score = 5.0

Variance = $0.06^2 = 0.0036$

Using R – Chart

Range = highest – lowest

Rp = 7.6 – 7.3 = 0.3

Rq = 7.5 – 7.3 = 0.2

Rr = 5.2 – 5.0 = 0.2

$\overline{R} = \sum\frac{\sum R}{N}$

$\bar{R} = \frac{0.3+0.2+0.2}{3} = 0.233$

$D_4 = 2.57$

$D_3 = 0$

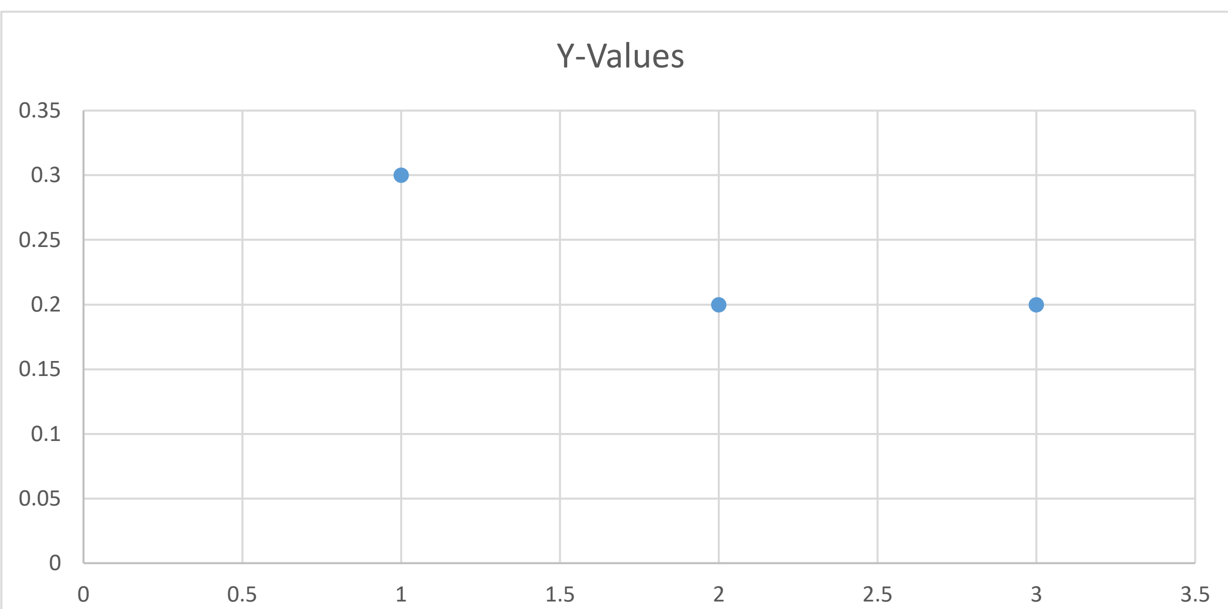
$UCL_R = D_4R$

$UCL_R = 2.57 * 0.233 = 0.6$

$LCL_R = D_3R$

$LCL_R = 0 * 0.233 = 0$

Figure4.2: R chart for the month of May.



From the chart above, the process using the R-chart is in statistical control.

The next involves using the run test to check for presence of pattern and assignable cause of variations.

Table 4.7: a table of the run chart for the month of May

No of samples	P	P(A/B)	P(U/D)	Q	Q(A/B)	Q(U/D)	R	R(A/B)	R(U/D)
1	7.5	A	-	7.5	A	-	5.2	A	-
2	7.5	A	U	7.4	=	-	5.1	A	U
3	7.3	B	D	7.3	B	D	5.0	-	D
4	7.3	B	-	7.4	-	U	5.1	A	U
5	7.3	B	-	7.5	A	U	5.0	-	D
6	7.4	-	U	7.4	-	D	5.0	-	-
7	7.5	A	U	7.4	-	-	5.0	-	-
8	7.4	-	D	7.3	B	D	5.1	A	U
9	7.4	-	-	7.3	B	-	50	-	D
10	7.3	B	D	7.3	-	U	5.0	-	-
11	7.3	B	-	7.3	B	D	5.0	-	-
12	7.5	A	U				5.1	A	U
13	7.6	A	U				5.0	-	D
14	7.4	-	D				5.0	-	-
15	7.5	A	U				5.1	A	U
16	7.5	A	-				5.0	-	D
17	7.3	B	D				5.1	A	U
18	7.3	B	-				5.0	-	D
19	7.4	-	U				5.0	-	-
20	7.4	-	-				5.0	-	-
21	7.3	B	D				5.1	A	U

For Sample P

P median score = 7.4

$P_{(A/B)}$ = 7 runs

$P_{(U/D)}$ = 10 runs

N = 21

For the expected number of runs for sample P

$E_{(r)med} = \frac{N}{2} + 1 = \frac{21}{2} + 1 = 11.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(21)-1}{3} = 13.67$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{21-1}{4}} = 2.236$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(21)-29}{90}} = 1.847$

For the Z test value under the sigma limit ± 2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma\mathrm{med}} = \frac{7 - 11.5}{2.236} = -2.0125$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma\mathrm{u/d}} = \frac{10 - 13.67}{1.847} = -1.987$

From the above result, both the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern, the Z_{med} result is outside the specified range of ± 2 standard deviation and the $Z_{(u/d)}$ result is within the range of ± 2 standard deviation, the process is not in control and there is non-random or assignable cause of variations.

For Sample Q

Q median score = 7.4

$Q_{(A/B)}$ = 4 runs

$Q_{(U/D)}$ = 4 runs

N = 11

For the expected number of runs for sample Q

$E_{(r)med} = \frac{N}{2} + 1 = \frac{11}{2} + 1 = 6.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(11)-1}{3} = 7$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{11-1}{4}} = 1.581$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(11)-29}{90}} = 1.278$

For the Z test value under the sigma limit ± 2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} = \frac{4-6.5}{1.581} = -1.581$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} = \frac{4-7}{1.278} = -2.347$

From the above result, the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern but only the Z_{med} result has its values within the range of ± 2 standard deviation, therefore the process is not in control and there is non-random or assignable cause of variations.

For Sample R

R median score = 5.1

$R_{(A/B)}$ = 1 runs

$R_{(U/D)}$ = 13 runs

N = 21

For the expected number of runs for sample P

$E_{(r)med} = \frac{N}{2} + 1 = \frac{21}{2} + 1 = 11.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(21)-1}{3} = 13.67$

For the standard deviation of the process:

$$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{21-1}{4}} = 2.236$$

$$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(21)-29}{90}} = 1.847$$

For the Z test value under the sigma limit ± 2:

$$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$$

$$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma\mathrm{med}} = \frac{1 - 11.5}{2.236} = -4.696$$

$$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma\mathrm{u/d}} = \frac{1 - 13.67}{1.847} = -0.363$$

From the above result, both the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern and the Z_{med} result is outside the specified range of ± 2 standard deviation. Therefore, the process is not in control and there is non-random or assignable cause of variations.

Table 4.8 PHYSICOCHEMICAL ANALYSIS RESULT FOR THE MONTH OF JUNE. 2023.

DATE	SACHET TESTED	SAMPLE(TREATED WATER)	PH		TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)	BOTTLE TESTED SAMPLE TREATED (TREATED WATER PH)		TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)	RAW WATER PH	TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)
	M	A	M	A								M	A															
1/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5/6/2023	3	17	7.4	7.4	120	240	Colourless	Odourless	Tasteless	Clear	16.0	-	-	-	-	-	-	-	-	-	5.1	125	250	Colourless	Odourless	Tasteless	Clear	16.0
6/6/2023	10	3	7.4	7.4	121	242	Colourless	Odourless	Tasteless	Clear	16.2	-	-	-	-	-	-	-	-	-	5.0	125	250	Colourless	Odourless	Tasteless	Clear	16.3
7/6/2023	17	3	7.4	7.4	120	240	Colourless	Odourless	Tasteless	Clear	17	-	-	-	-	-	-	-	-	-	5.1	131	262	Colourless	Odourless	Tasteless	Clear	17.0
8/6/2023	10	3	7.5	7.5	125	250	Colourless	Odourless	Tasteless	Clear	16.5	-	-	-	-	-	-	-	-	-	5.2	130	260	Colourless	Odourless	Tasteless	Clear	16.5

9/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
10/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
12/6/2023	3	10	7.5	7.5	134	268	Colourless	Odourless	Tasteless	Clear	19.2	-	-	-	-	-	-	-	-	-	5.1	125	250	Colourless	Odourless	Tasteless	Clear	20.0
13/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14/6/2023	17	6	7.5	7.5	132	264	Colourless	Odourless	Tasteless	Clear	19.3	-	-	-	-	-	-	-	-	-	5.0	120	240	Colourless	Odourless	Tasteless	Clear	19.2
15/6/2023	3	10	7.3	7.3	129	258	Colourless	Odourless	Tasteless	Clear	18.8	7.3	7.3	129	258	Colourless	Odourless	Tasteless	Clear	18.8	5.1	125	250	Colourless	Odourless	Tasteless	Clear	18.6
16/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17/6/2023	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19/6/2023	10	6	7.3	7.3	133	266	Colourless	Odourless	Tasteless	Clear	17.3	7.3	7.3	133	266	Colourless	Odourless	Tasteless	Clear	17.4	5.0	124	250	Colourless	Odourless	Tasteless	Clear	17.0
20/6/2023	17	3	7.4	7.4	130	260	Colourless	Odourless	Tasteless	Clear	18.3	-	-	-	-	Colourless	Odourless	Tasteless	Clear		5.0	120	240	Colourless	Odourless	Tasteless	Clear	18.1
21/6/2023	3	17	7.4	7.4	135	270	Colourless	Odourless	Tasteless	Clear	21.4	7.4	7.4	135	270	Colourless	Odourless	Tasteless	Clear	21.6	5.0	130	260	Colourless	Odourless	Tasteless	Clear	21.2
22/6/2023	17	6	7.3	7.3	125	250	Colourless	Odourless	Tasteless	Clear	18.9	7.3	7.3	130	260	Colourless	Odourless	Tasteless	Clear	18.9	5.1	1	-	Colourless	Odourless	Tasteless	Clear	18.2

23/6/2023	10	17	7.5	7.5	130	260	Colourless	Odourless	Tasteless	Clear	16.5	7.5	7.5	130	260	Colourless	Odourless	Tasteless	Clear	16.4	5.1	125	250	Colourless	Odourless	Tasteless	Clear	16.5
24/6/2023	10	3	7.5	7.5	135	270	Colourless	Odourless	Tasteless	Clear	17.1	-	-	-	-	-	-	-	-	-	5.1	132	264	Colourless	Odourless	Tasteless	Clear	17.0
26/6/2023	17	10	7.6	7.6	123	246	Colourless	Odourless	Tasteless	Clear	16.8	7.6	7.6	125	250	Colourless	Odourless	Tasteless	Clear	16.8	5.2	110	220	Colourless	Odourless	Tasteless	Clear	16.7
27/6/2023	10	3	7.4	7.4	131	262	Colourless	Odourless	Tasteless	Clear	-	-	-	-	-	Colourless	Odourless	Tasteless	Clear	-	5.2	123	246	Colourless	Odourless	Tasteless	Clear	16.7
28/6/2023	10	17	7.5	7.5	120	240	Colourless	Odourless	Tasteless	Clear	15.1	7.5	7.5	120	240	Colourless	Odourless	Tasteless	Clear	15.2	5.0	100	200	Colourless	Odourless	Tasteless	Clear	15.0
29/6/2023	3	17	7.5	7.5	125	250	Colourless	Odourless	Tasteless	Clear	16.0	7.5	7.5	125	250	Colourless	Odourless	Tasteless	Clear	16.0	5.2	120	240	Colourless	Odourless	Tasteless	Clear	15.2
30/6/2023	17	10	7.5	7.5	130	260	Colourless	Odourless	Tasteless	Clear	16.2	7.5	7.5	130	260	Colourless	Odourless	Tasteless	Clear	16.2	5.4	121	242	Colourless	Odourless	Tasteless	Clear	16.2

Table4.9: A table containing the mean bar and standard deviation values of the samples.

Number of samples (N)	SAMPLE P			SAMPLE Q			SAMPLE R		
	PH	**$X - \bar{X}$**	**$(X - \bar{X})^2$**	**PH**	**$X - \bar{X}$**	**$(X - \bar{X})^2$**	**PH**	**$X - \bar{X}$**	**$(X - \bar{X})^2$**
1	7.4	-0.06	0.0036	7.4	-0.07	0.0049	5.1	-0.04	0.0016
2	7.4	-0.06	0.0036	7.4	-0.07	0.0049	5.0	-0.14	0.0196
3	7.4	-0.06	0.0036	7.4	-0.07	0.0049	5.1	-0.04	0.0016
4	7.5	0.04	0.0016	7.5	0.03	0.0009	5.2	0.06	0.0036
5	7.5	0.04	0.0016	7.4	-0.07	0.0049	5.1	-0.04	0.0016
6	7.5	0.04	0.0016	7.5	0.03	0.0009	5.1	-0.04	0.0016
7	7.4	-0.06	0.0036	7.6	0.13	0.0169	5.1	-0.04	0.0016
8	7.3	-0.16	0.0256	7.5	0.03	0.0009	5.1	-0.04	0.0016
9	7.5	0.04	0.0016	7.5	0.03	0.0009	5.2	0.06	0.0036
10	7.4	-0.06	0.0036	7.5	0.03	0.0009	5.1	-0.04	0.0016
11	7.5	0.04	0.0016				5.2	0.06	0.0036
12	7.5	0.04	0.0016				5.1	-0.04	0.0016
13	7.6	0.14	0.0196				5.1	-0.04	0.0016
14	7.4	-0.06	0.0036				5.2	0.06	0.0036
15	7.5	0.04					5.2	0.06	0.0036
16	7.5	0.04					5.0	-0.14	0.0196
17	7.5	0.04					5.2	0.06	0.0036
18							5.4	0.26	0.0676
$\sum X$	126.8			74.7			92.5		

$\overline{X} = \sum \frac{\sum X}{N}$;

P$\overline{X}$ = $\frac{126.8}{17}$ = 7.46

Standard deviation of P$\overline{X}$ = $\sqrt{\frac{\sum(X - \text{P}\overline{X})}{N-1}}$

P$\overline{X}$ = $\sqrt{\frac{\mathbf{(0.0036*6)+(0.0016*9)+(0.0256)\ +(0.0196)}}{\mathbf{17-1}}}$ = 0.071

Median score = 7.4

Variance = 0.071^2 = 0.00504

Q$\overline{X}$ = $\frac{74.7}{10}$ = 7.47

Standard deviation of Q$\overline{X}$ = $\sqrt{\frac{\sum(X - \text{Q}\overline{X})}{N-1}}$

Q$\overline{X}$ = $\sqrt{\frac{\mathbf{(0*0049*4)+(0.0009*5)+(0.0169)}}{\mathbf{10-1}}}$ = 0.067

Median score = 7.4

Variance = 0.067^2 = 0.00449

R$\overline{X}$ = $\frac{92.5}{18}$ = 5.14

Standard deviation of R$\overline{X}$ = $\sqrt{\frac{\sum(X - \text{R}\overline{X})}{N-1}}$

R$\overline{X}$ = $\sqrt{\frac{\mathbf{(0.0016*9)+(0.0036*6)+(0.0016*9)+(0,0676)}}{\mathbf{18-1}}}$ = 0.092

Median score = 5.0

Variance = 0.092^2 = 0.00846

Using R – Chart

Range = highest – lowest

Rp = 7.6 – 7.3 = 0.3

Rq = 7.6 – 7.4 = 0.2

Rr = 5.4 – 5.0 = 0.4

$\overline{R} = \sum \frac{\sum R}{N}$

$\bar{R} = \frac{0.3+0.2+0.4}{3} = 0.3$

$D_4 = 2.57$

$D_3 = 0$

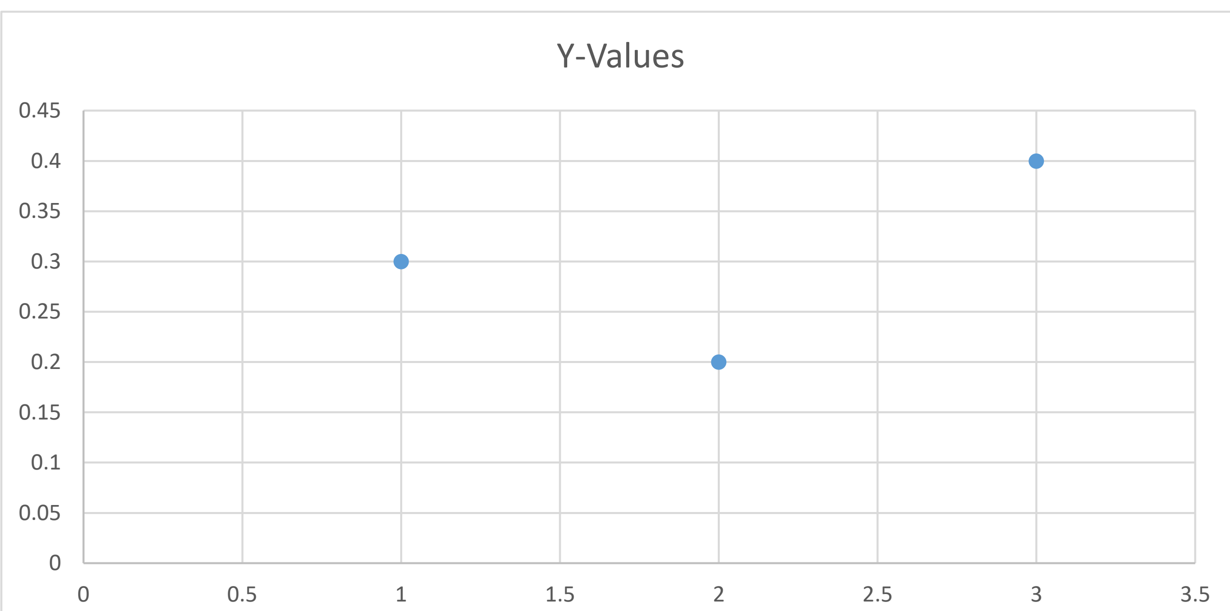
$UCL_R = D_4R$

$UCL_R = 2.57 * 0.3 = 0.6$

$LCL_R = D_3R$

$LCL_R = 0 * 0.3 = 0$

Figure 4.3: R chart for the month of June.



From the chart above, the process using the R-chart is in statistical control.

The next involves using the run test to check for presence of pattern and assignable cause of variations.

Table 4.10: a table of the run chart for the month of June

No of samples	P	P(A/B)	P(U/D)	Q	Q(A/B)	Q(U/D)	R	R(A/B)	R(U/D)
1	7.4	-	-	7.4	-	-	5.1	A	-
2	7.4	-	-	7.4	-	-	5.0	-	-
3	7.4	-	-	7.4	-	-	5.1	A	U
4	7.5	A	U	7.5	A	U	5.2	A	U
5	7.5	A	-	7.4	-	D	5.1	A	D
6	7.5	A	-	7.5	A	U	5.1	A	-
7	7.4	-	D	7.6	A	U	5.1	A	-
8	7.3	B	D	7.5	-	D	5.1	A	-
9	7.5	A	U	7.5	-	-	5.2	A	U
10	7.4	-	D	7.5	-	-	5.1	A	D
11	7.5	A	U				5.2	A	U
12	7.5	A	-				5.1	A	D
13	7.6	A	U				5.1	A	-
14	7.4	-	D				5.2	A	U
15	7.5	A	U				5.2	A	-
16	7.5	A	-				5.0	-	D
17	7.5	A	-				5.2	A	U
18							5.4	A	U

For Sample P

P median score = 7.4

$P_{(A/B)}$ = 3 runs

$P_{(U/D)}$ = 7 runs

N = 17

For the expected number of runs for sample P

$E_{(r)med} = \frac{N}{2} + 1 = \frac{17}{2} + 1 = 9.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(17)-1}{3} = 11$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{17-1}{4}} = 2$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(17)-29}{90}} = 1.643$

For the Z test value under the sigma limit ± 2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\mathrm{\sigma med}} = \frac{3-9.5}{2} = -3.25$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\mathrm{\sigma u/d}} = \frac{7-11}{1.643} = -2.43$

From the above result, both the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern, their results are outside the specified range of ± 2 standard deviation. Therefore, the process is not in control and there is non-random or assignable cause of variations.

For Sample Q

Q median score = 7.4

$Q_{(A/B)}$ = 1 runs

$Q_{(U/D)}$ = 4 runs

N = 10

For the expected number of runs for sample Q

$E_{(r)med} = \frac{N}{2} + 1 = \frac{10}{2} + 1 = 6$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(10)-1}{3} = 6.23$

For the standard deviation of the process:

$$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{10-1}{4}} = 1.5$$

$$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(10)-29}{90}} = 1.2065$$

For the Z test value under the sigma limit ± 2:

$$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$$

$$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} = \frac{1 - 6.33}{1.5} = -3.33$$

$$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} = \frac{4 - 6.33}{1.2065} = -1.9312$$

From the above result, the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern but only the $Z_{(u/d)}$ result has its values within the range of ± 2 standard deviation, therefore the process is not in control and there is non-random or assignable cause of variations.

For Sample R

R median score = 5.0

$R_{(A/B)}$ = 1 runs

$R_{(U/D)}$ = 9 runs

N = 18

For the expected number of runs for sample P

$$E_{(r)med} = \frac{N}{2} + 1 = \frac{18}{2} + 1 = 10$$

$$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(18)-1}{3} = 11.67$$

For the standard deviation of the process:

$$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{18-1}{4}} = 2.0616$$

$$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(18)-29}{90}} = 1.6964$$

For the Z test value under the sigma limit ± 2:

$$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$$

$$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} = \frac{1 - 10}{2.0616} = -4.3655$$

$$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} = \frac{9 - 11.67}{1.6964} = -1.5739$$

From the above result, both the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern and the Z_{med} result is outside the specified range of ± 2 standard deviation. Therefore, the process is not in control and there is non-random or assignable cause of variations.

Table 4.11 PHYSICOCHEMICAL ANALYSIS RESULT FOR THE MONTH OF JULY. 2023.

DATE	SACHET TESTED	SAMPLE(TREATED WATER)	PH		TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)	BOTTLE TESTED SAMPLE TREATED (TREATED WATER PH)		TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)	RAW WATER PH	TDS (PPM)	CONDUCTIVITY(µs/cm)	COLOUR	ODOUR	TASTE	TURBIDITY	TEMP(ºC)
	M	A	M	A								M	A															
1/7/2023	`3	6	7.4	7.4	131	262	Colourless	Odourless	Tasteless	Clear	15.1	-	-	-	-	-	-	-	-	-	5.1	120	240	Colourless	Odourless	Tasteless	Clear	15.0
3/7/2023	10	17	7.3	7.3	124	248	Colourless	Odourless	Tasteless	Clear	18.2	7.3	7.3	124	248	Colourless	Odourless	Tasteless	Clear	18.2	5.2	120	240	Colourless	Odourless	Tasteless	Clear	18.1
4/7/2023	6	3	7.4	7.4	132	264	Colourless	Odourless	Tasteless	Clear	17.1	-	-	-	-	-	-	-	-	-	5.1	130	260	Colourless	Odourless	Tasteless	Clear	17.0
5/7/2023	17	6	7.4	7.4	131	262	Colourless	Odourless	Tasteless	Clear	15.1	-	-	-	-	-	-	-	-	-	5.2	100	200	Colourless	Odourless	Tasteless	Clear	15.1
6/7/2023	17	10	7.5	7.5	120	240	Colourless	Odourless	Tasteless	Clear	14.2	-	-	-	-	-	-	-	-	-	5.2	130	240	Colourless	Odourless	Tasteless	Clear	14.2

7/7/2023	17	3	7.4	7.4	125	250	Colourless	Odourless	Tasteless	Clear	16.0	7.4	7.4	125	250	Colourless	Odourless	Tasteless	Clear	16.1	5.2	100	200	Colourless	Odourless	Tasteless	Clear	16
8/7/2023	3	6	7.5	7.5	121	242	Colourless	Odourless	Tasteless	Clear	17.0	-	-	-	-	-	-	-	-	-	5.2	100	200	Colourless	Odourless	Tasteless	Clear	17
10/7/2023	10	17	7.4	7.4	127	254	Colourless	Odourless	Tasteless	Clear	14.6	7.4	7.4	127	254	Colourless	Odourless	Tasteless	Clear	14.9	5.2	100	200	Colourless	Odourless	Tasteless	Clear	14.6
11/7/2023	17	3	7.3	7.3	125	300	Colourless	Odourless	Tasteless	Clear	14.2	7.3	7.3	125	250	Colourless	Odourless	Tasteless	Clear	14.2	5.1	110	220	Colourless	Odourless	Tasteless	Clear	14.1
12/7/2023	10	6	7.4	7.4	100	200	Colourless	Odourless	Tasteless	Clear	15.1	7.4	7.4	122	244	Colourless	Odourless	Tasteless	Clear	15.1	5.2	100	200	Colourless	Odourless	Tasteless	Clear	15.1
13/7/2023	17	10	7.3	7.3	120	240	Colourless	Odourless	Tasteless	Clear	15.1	7.6	7.3	120	240	Colourless	Odourless	Tasteless	Clear	15.1	5.2	110	220	Colourless	Odourless	Tasteless	Clear	15.1
14/7/2023	10	3	7.3	7.3	110	220	Colourless	Odourless	Tasteless	Clear	14.2	7.3	7.3	110	220	Colourless	Odourless	Tasteless	Clear	14.2	5.2	100	200	Colourless	Odourless	Tasteless	Clear	14.1
15/7/2023	10	3	7.4	7.4	120	240	Colourless	Odourless	Tasteless	Clear	14.1	7.3	7.4	120	240	Colourless	Odourless	Tasteless	Clear	14.1	5.2	120	240	Colourless	Odourless	Tasteless	Clear	14.1
17/7/2023	17	10	7.3	7.3	122	244	Colourless	Odourless	Tasteless	Clear	14.2	7.3	7.3	122	244	Colourless	Odourless	Tasteless	Clear	14.2	5.2	120	240	Colourless	Odourless	Tasteless	Clear	14.1

18/7/2023	17	3	7.3	7.3	100	200	Colourless	Odourless	Tasteless	Clear	14.2	7.3	7.3	122	244	Colourless	Odourless	Tasteless	Clear	14.2	5.3	120	240	Colourless	Odourless	Tasteless	Clear	14.0
19/7/2023	17	6	7.3	7.3	120	240	Colourless	Odourless	Tasteless	Clear	13.1	7.3	7.3	100	200	Colourless	Odourless	Tasteless	Clear	13.1	5.2	100	200	Colourless	Odourless	Tasteless	Clear	13.1
20/7/2023	3	6	7.3	7.3	110	220	Colourless	Odourless	Tasteless	Clear	13.1	7.3	7.3	120	240	Colourless	Odourless	Tasteless	Clear	13.1	5.2	110	220	Colourless	Odourless	Tasteless	Clear	13.1
21/7/2023	10	6	7.4	7.4	120	240	Colourless	Odourless	Tasteless	Clear	19.1	-	-	-	-	-	-	-	-	-	5.2	90	180	Colourless	Odourless	Tasteless	Clear	19.1
22/7/2023	17	3	7.3	7.3	100	200	Colourless	Odourless	Tasteless	Clear	18.0	-	-	-	-	-	-	-	-	-	5.1	100	200	Colourless	Odourless	Tasteless	Clear	18.0
24/7/2023	10	17	7.0	7.0	122	244	Colourless	Odourless	Tasteless	Clear	17.0	7.0	7.0	100	200	Colourless	Odourless	Tasteless	Clear	17.0	5.2	90	180	Colourless	Odourless	Tasteless	Clear	17.0
25/7/2023	6	3	7.4	7.4	110	220	Colourless	Odourless	Tasteless	Clear	17.0	-	-	-	-	-	-	-	-	-	5.1	120	240	Colourless	Odourless	Tasteless	Clear	17.0
26/7/2023	3	6	7.3	7.3	100	200	Colourless	Odourless	Tasteless	Clear	16.1	-	-	-	-	-	-	-	-	-	5.1	100	200	Colourless	Odourless	Tasteless	Clear	16.1
27/7/2023	10	17	7.4	7.4	120	240	Colourless	Odourless	Tasteless	Clear	16.0	-	-	-	-	-	-	-	-	-	5.2	90	180	Colourless	Odourless	Tasteless	Clear	16.0

Table 4.12: A table containing the mean bar and standard deviation values of the samples.

Number of samples (N)	SAMPLE P			SAMPLE Q			SAMPLE R		
	PH	**$X - \bar{X}$**	**$(X - \bar{X})^2$**	**PH**	**$X - \bar{X}$**	**$(X - \bar{X})^2$**	**PH**	**$X - \bar{X}$**	**$(X - \bar{X})^2$**
1	7.4	0.05	0.0025	7.3	-0.02	0.0004	5.1	-0.08	0.0064
2	7.3	-0.05	0.0025	7.4	0.08	0.0064	5.2	0.02	0.0004
3	7.4	0.05	0.0025	7.4	0.08	0.0064	5.2	0.02	0.0004
4	7.4	0.05	0.0025	7.3	-0.02	0.0004	5.2	0.02	0.0004
5	7.5	0.15	0.0225	7.4	0.08	0.0064	5.2	0.02	0.0004
6	7.4	0.05	0.0025	7.6	0.28	0.0784	5.2	0.02	0.0004
7	7.5	0.15	0.0225	7.3	-0.02	0.0004	5.2	0.02	0.0004
8	7.4	0.05	0.0025	7.3	-0.02	0.0004	5.2	0.02	0.0004
9	7.3	-0.05	0.0025	7.3	-0.02	0.0004	5.1	-0.08	0.0064
10	7.4	0.05	0.0025	7.3	-0.02	0.0004	5.2	0.02	0.0004
11	7.3	-0.05	0.0025	7.3	-0.02	0.0004	5.2	0.02	0.0004
12	7.3	-0.05	0.0025	7.3	-0.02	0.0004	5.2	0.02	0.0004
13	7.4	0.05	0.0025	7.0	-0.32	0.0004	5.2	0.02	0.0004
14	7.3	-0.05	0.0025				5.2	0.02	0.0004
15	7.3	-0.05	0.0025				5.3	0.12	0.0144
16	7.3	-0.05	0.0025				5.2	0.02	0.0004
17	7.3	-0.05	0.0025				5.2	0.02	0.0004
18	7.4	0.05	0.0025				5.2	0.02	0.0004
19	7.3	-0.05	0.0025				5.1	-0.08	0.0064
20	7.0	-0.35	0.1225				5.2	0.02	0.0004
21	7.4	0.05	0.0025				5.1	-0.08	0.0064
22	7.3	-0.05	0.0025				5.1	-0.08	0.0064
23	7.4	0.05	0.0025				5.2	0.02	0.0004
$\sum X$	169			95.2			119.2		

$\overline{X} = \sum \frac{\sum X}{N}$;

$P\overline{X} = \frac{169}{23} = 7.35$

Standard deviation of $P\overline{X} = \sqrt{\frac{\sum(X - P\overline{X})}{N-1}}$

$P\overline{X} = \sqrt{\frac{\mathbf{(0.0025*20)+(0.0225*2)+(0.01225*1)}}{\mathbf{23-1}}} = 0.0099$

Median score = 7.4

Variance = 0.0099^2 = 0.000098

$Q\overline{X} = \frac{95.2}{13} = 7.32$

Standard deviation of $Q\overline{X} = \sqrt{\frac{\sum(X - Q\overline{X})}{N-1}}$

$Q\overline{X} = \sqrt{\frac{\mathbf{(0*0004*8)+(0.0064*3)+(0.0784)+(0.1024)}}{\mathbf{13-1}}} = 0.13$

Median score = 7.3

Variance = 0.13^2 = 0.0169

$R\overline{X} = \frac{119.2}{23} = 5.18$

Standard deviation of $R\overline{X} = \sqrt{\frac{\sum(X - R\overline{X})}{N-1}}$

$R\overline{X} = \sqrt{\frac{\mathbf{(0.0004*17)+(0.0064*5)+(0.0144)}}{\mathbf{23-1}}} = 0.049$

Median score = 5.2

Variance = 0.049^2 = 0.0024

Using R – Chart

Range = highest – lowest

Rp = 7.5 – 7.0 = 0.5

Rq = 7.6 – 7.0 = 0.6

Rr = 5.3 – 5.1 = 0.2

$\overline{R} = \sum \frac{\sum R}{N}$

$\bar{R} = \frac{0.5+0.6+0.2}{3}$ = 0.433

D_4 = 2.57

D_3 = 0

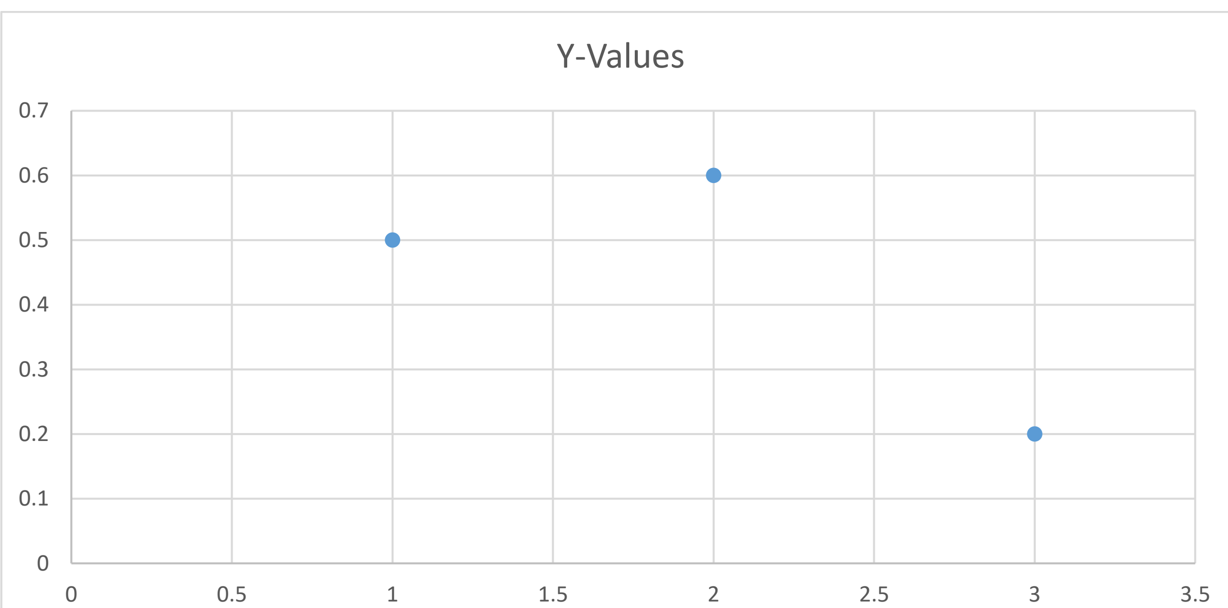
$UCL_R = D_4R$

UCL_R = 2.57 * 0.433 = 01.114

$LCL_R = D_3R$

LCL_R = 0 * 0.433 = 0

Figure 4.4: R chart for the month of July.



From the chart above, the process using the R-chart is in statistical control.

The next involves using the run test to check for presence of pattern and assignable cause of variations.

Table 4.13: a table of the run chart for the month of July

No of samples	P	P(A/B)	P(U/D)	Q	Q(A/B)	Q(U/D)	R	R(A/B)	R(U/D)
1	7.4	-	-	7.3	-	-	5.1	B	-
2	7.3	B	D	7.4	A	U	5.2	-	-
3	7.4	-	U	7.4	A-	-	5.2	-	-
4	7.4	-	-	7.3	-	D	5.2	-	-
5	7.5	A	U	7.4	A	U	5.2	-	-
6	7.4	-	D	7.6	A	U	5.2	-	-
7	7.5	A	U	7.3	-	D	5.2	-	-
8	7.4	-	D	7.3	-	-	5.2	-	-
9	7.3	B	D	7.3	-	-	5.1	B	D
10	7.4	-	U	7.3	-	-	5.2	-	U
11	7.3	B	D	7.3	-	-	5.2	-	-
12	7.3	B	-	7.3	B	D	5.2	-	-
13	7.4	-	U	7.0			5.2	-	-
14	7.3	B	D				5.2	-	-
15	7.3	B	-				5.3	A	U
16	7.3	B	-				5.2	-	D
17	7.3	B	-				5.2	-	-
18	7.4	-	U				5.2	-	-
19`	7.3	B	D				5.1	B	D
20	7.0	B	D				5.2	-	U
21	7.4	-	U				5.1	B	D
22	7.3	B	D				5.1	B	-
23	7.4	-	U				5.2	-	U

For Sample P

P median score = 7.4

$P_{(A/B)}$ = 3 runs

$P_{(U/D)}$ = 14 runs

N = 23

For the expected number of runs for sample P

$E_{(r)med} = \frac{N}{2} + 1 = \frac{23}{2} + 1 = 12.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(23)-1}{3} = 15$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{23-1}{4}} = 2.3452$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(23)-29}{90}} = 1.9408$

For the Z test value under the sigma limit ± 2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} = \frac{3 - 12.5}{2.3452} = -4.05$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} = \frac{14 - 15}{1.9408} = -0.5153$

From the above result, both the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern, and Z_{med} results is outside the specified range of ± 2 standard deviation. Therefore, the process is not in control and there is non-random or assignable cause of variations.

For Sample Q

Q median score = 7.3

$Q_{(A/B)}$ = 2 runs

$Q_{(U/D)}$ = 4 runs

N = 13

For the expected number of runs for sample Q

$E_{(r)med} = \frac{N}{2} + 1 = \frac{13}{2} + 1 = 7.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(13)-1}{3} = 8.33$

For the standard deviation of the process:

$\boldsymbol{\sigma}_{med} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{13-1}{4}} = 1.7321$

$\boldsymbol{\sigma}_{u/d} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(13)-29}{90}} = 1.4103$

For the Z test value under the sigma limit ± 2:

$Z_{test} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$

$Z_{med} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} = \frac{2 - 7.5}{1.7321} = -3.175$

$Z_{u/d} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} = \frac{4 - 8.33}{1.4103} = -3.0724$

From the above result, the Z_{med} and the $Z_{(u/d)}$ does not reveal any pattern and their results are not within the range of ± 2 standard deviation, therefore the process is not in control and there is non-random or assignable cause of variations.

For Sample R

R median score = 5.2

$R_{(A/B)}$ = 3 runs

$R_{(U/D)}$ = 6 runs

N = 23

For the expected number of runs for sample P

$E_{(r)med} = \frac{N}{2} + 1 = \frac{23}{2} + 1 = 12.5$

$E_{(r)u/d} = \frac{2N-1}{3} = \frac{2(23)-1}{3} = 15$

For the standard deviation of the process:

$$\boldsymbol{\sigma}_{\text{med}} = \sqrt{\frac{N-1}{4}} = \sqrt{\frac{23-1}{4}} = 2.3452$$

$$\boldsymbol{\sigma}_{\text{u/d}} = \sqrt{\frac{16(N)-29}{90}} = \sqrt{\frac{16(23)-29}{90}} = 1.9408$$

For the Z test value under the sigma limit ± 2:

$$Z_{\text{test}} = \frac{Observed\ number\ of\ runs - Expected\ number\ of\ runs}{Standard\ Deviation\ of\ number\ of\ runs}$$

$$Z_{\text{med}} = \frac{Sample(med) - \mathrm{E(r)med}}{\sigma \mathrm{med}} = \frac{1-10}{2.0616} = -4.05$$

$$Z_{\text{u/d}} = \frac{Sample(u/d) - \mathrm{E(r)(u/d)}}{\sigma \mathrm{u/d}} = \frac{9-11.67}{1.6964} = -4.6373$$

From the above result, both the Z_{med} and the $Z_{(\text{u/d})}$ does not reveal any pattern and their results are outside the specified range of ± 2 standard deviation. Therefore, the process is not in control and there is non-random or assignable cause of variations.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From our results in the analysis of result, from the three samples tested in the month of April, only one sample (sample Q) achieved process capability and thereby meets the required standard to start-up production of table water, while sample P and sample R failed to pass the run test process leading to presence of nonrandom or assignable causes of variations; so the process capability test was not applied.

Sample P, Q and R for the month of May, June and July all failed to pass the run test process and therefore the process capability test was not applied because of the presence of assignable or nonrandom causes of variations in the process.

The results evidently show that there is need for improvement on the quality aspect of the Uniben Table Water Factory.

5.2 Recommendation

When a process does not meet the specifications of a run test or fail to achieve process capability, it's important to diagnose the issue and make proper adjustments. Here are some recommendations:

- Review Test Specifications: Double-check the test specifications to ensure they are accurate and up to date. If there are any discrepancies or ambiguities clarify them with the relevant stakeholders.
- Identify Root Cause: Investigate why the process did not meet the specifications. This could be due to equipment malfunction, human error, environmental factors, or other reasons. Identify the root cause to prevent recurrence.
- Adjust Process Parameters: If the issue is related to the process itself, consider adjusting the parameters. This could include changing temperature, pressure, time, or other variables to bring the process within specifications.

- Calibration and Maintenance: Ensure that all equipment involved in the process is properly calibrated and maintained. Regular calibration and maintenance can help prevent issues that lead to processes not meeting specifications.
- Training and Education: If the issue is related to human error, provide additional training or education to the individuals involved in the process. This can help improve understanding and adherence to the specifications.
- Documentation and Record Keeping: Maintain detailed documentation and records of the process and any adjustments made. This can help track changes and identify patterns that may lead to process deviations.
- Continuous Improvement: Use this opportunity to implement continuous improvement practices. Encourage feedback from team members and stakeholders to identify areas for improvement in the process.
- Review and Approval Process: Implement a review and approval process for any changes made to the process. This can help ensure that adjustments are appropriate and do not lead to further issues.

By following these recommendations, you can address issues with processes that do not meet run test specifications and work towards improving the overall efficiency and effectiveness of your operations.

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