Applied Engineering
2018; 2(2): 60-71
http://www.sciencepublishinggroup.com/j/ae
doi: 10.11648/j.ae.20180202.15

Research Article

Improving Operational Procedures in Riyadh's (Saudi Arabia) Water Treatment Plants Using Quality Tools

Yasser Alshammari[1], Djamel Ghernaout[2, 3, *], Mohamed Aichouni[4], Mabrouk Touahmia[5]

[1]Mechanical Engineering Department, College of Engineering, University of Ha'il, Ha'il, Saudi Arabia
[2]Chemical Engineering Department, College of Engineering, University of Ha'il, Ha'il, Saudi Arabia
[3]Chemical Engineering Department, Faculty of Engineering, University of Blida, Blida, Algeria
[4]Industrial Engineering Department, College of Engineering, University of Ha'il, Ha'il, Saudi Arabia
[5]Archetectural Engineering Department, College of Engineering, University of Ha'il, Ha'il, Saudi Arabia

Email address:
djamel_andalus@hotmail.com (D. Ghernaout)
[*]Corresponding author

To cite this article:
Yasser Alshammari, Djamel Ghernaout, Mohamed Aichouni, Mabrouk Touahmia. Improving Operational Procedures in Riyadh's (Saudi Arabia) Water Treatment Plants Using Quality Tools. *Applied Engineering*. Vol. 2, No. 2, 2018, pp. 60-71. doi: 10.11648/j.ae.20180202.15

Received: December 10, 2018; **Accepted**: December 22 2018; **Published**: January 22, 2019

Abstract: In Saudi Arabia, as population growth increases, the need for safe drinking water is more and more increasing for both human use and industrial applications. These requires highly efficient processing plants that meet the growing needs of customers and their expectations of providing more service to all segments of the society at the lowest possible cost. On the other hand, these stations consume high amounts of energy in addition to the high maintenance and operating costs due to emergency breakdowns, which in turn result in lower production and the exit of some units from operation. This research aims to enhance the operational procedures of the stations and to study the possibility of reducing the high consumption of electric power and work to increase the performance of the plants by reducing the costs of maintenance and operation through the application of Quality Tools (QTs). This work focused on: (1) collecting data, equipment inventory, maintenance and operation costs and energy consumption rate of the equipment; (2) analyzing these data using the Seven QTs and the New QTs for Management and Planning; (3) finding solutions and presenting the results using the Minitab software; and, (4) the obtained results will be then generalized to the other stations in other Saudi Arabia regions.

Keywords: Water Treatment Plant (WTP), Quality Tools (QTs), Operational Procedures (OPs), NATIONAL Water Company (NWC), Minitab™, Cause and Effect Diagram (CED), Pareto Diagram (PD), Scatter Diagram (SD)

1. Introduction

All know the importance of water in human life and there is no existence of organisms except in the presence of water and its sources [1-4]. However, around the world there are many affected areas where many people are dying daily and at high rates because they do not have access to safe drinking water [5,6]. World desertification phenomenon is also evident; caused by a large water shortage and increased pollution due to various human actions, the excessive use of water, the dumping of wastes into water sources such as rivers.

Saudi Arabia has made great efforts in the provision of fresh drinking water. Indeed, the Government of Saudi Arabia paid great attention and harnessed all its resources to preserve water and ensuring that it is accessible to all. The water authorities' focus is on raising the quality of water in the Kingdom and reducing waste through constructing high-efficiency processing and desalination plants at the lowest possible cost.

As such, the National Water Company (NWC) was established as a wholly owned Saudi joint stock company to provide all services related to water and sanitation. The NWC, with its various components of stations, networks and wells, is a vital service sector that primarily touches the needs of customers, necessitating the maintenance of these facilities around the clock. Indeed, such facilities are often exposed to some unexpected breakdowns causing some station units to arrest their functioning as well as a decrease in water provision. In addition, operating these stations will result in high-energy consumption and high costs in the maintenance and operation process, which in turn increase the cost of expenses on the company and raise the cost of production, where the cost per cubic meter is about three Saudi Riyals (0.68 Euros).

The aim of this research is to improve the operational procedures (OPs) of the stations and to study the possibility of reducing the high consumption of electric power and work to increase the performance of the plants by reducing the costs of maintenance and operation through the application of Quality Tools (QTs). In other words, it is expected that this research would conduct to improving the OPs at stations, which in turn significantly reduce the high costs of maintenance and high-energy consumption.

2. Study Problematic

In Saudi Arabia, the energy sector is facing a major challenge because of rising consumption, which is higher than global rates in all sectors. Therefore, there must be a pause to review and discuss methods to stop the waste of energy [7] in the industrial and service sectors, led by the NWC. Because the current phase requires concerted effort to reduce costs and decrease spending, this vital and important issue needs to be highlighted in exploring possibilities for diminishing wasted power in water plants and reducing maintenance and operating costs. The high consumption of electricity in these stations and the high costs of maintenance and operation were noted. This will increase the cost of production per cubic meter. Therefore, the focus of this research will be on the collection of field data [8] and operational reports for 2017 in ten treatment plants and water production, as shown in Table 1.

Table 1. *Ten water treatment plants (WTPs) and pumping stations in Riyadh's region.*

Electrical consumption rate for 2017 for the ten WTPs and pumping stations in Riyadh's region (kW/m^3)	
Buwayb Station 1	4.96
Buwayb Station 2	3.85
Wasia Station	2.90
Salboukh Station 1	4.00
Salboukh Station 2	3.32
Manfouha Station	3.84
Malaz Station	3.55
Shemessy Station	3.11
Hunei Station	1.92
Hair Station	2.87

These data will be analyzed and manners will be discussed to improve the OPs in these stations. The first and final objective left is to reduce the energy consumption by energy equipment's, decrease maintenance and operation costs and raise the quality of treated water using QTs.

3. Study Limits

3.1. Objective Limits

This study focuses on the use of the Seven QTs and planning to improve the OPs in WTPs. These tools are scatter diagram (SD), control charts (CCs), flow charts (FCs), Pareto diagram (PD), brainstorming, cause-and-effect diagram (CED) and finally tree diagram (TD). These tools were selected from a set of seven core QTs as well as Seven New Quality Management and Planning Tools because they are used in production areas where numerical data [9-11] are available.

3.2. Spatial Limits

The limits of this study are the WTPs at the NWC in Riyadh. The main objective of this study is to use and apply QTs to improve the OPs in WTPs, and then to generalize the use of these tools to any service or production sector in reducing the high costs of electricity use and not only for the purpose of generalization of solutions.

3.3. Time Limits

The data of this study were collected through the monthly reports of WTPs in the NWC during the year 2017.

4. Previous Studies

This section reviews the most important researches related to the subject of the study.

Feudo et al. [12] performed an assessment of energy at the water pump plant using multivariate analysis, which aimed to identify and apply approved measurements to assess the energy consumed in the water treatment system. They showed that global water consumption would increase by 55% by 2050. Groundwater sources are decreasing significantly, offset by high-energy costs, estimated at 5% to 30% of the total operating costs in water and wastewater treatments [13-15]. In some developing countries such as India and Bangladesh, the ratio is up to 40% of total operating costs. Therefore, this dilemma must be addressed and the maintenance of high-quality service standards must be imposed.

Castellet and Molinos-Senante [16] assessed the efficiency of wastewater treatment plants [17, 18] in terms of analysis of technical, economic and environmental data [19, 20]. They stressed that the assessment of the effectiveness of water plants, especially wastewater, has become necessary to compare their performance. Indeed, through performance, best operational practices can be identified that can contribute to cost reduction. They also noted that, in addition to increasing operational costs, another element was the removal of contaminants from wastewater treatment [21-23] and the resulting costly costs to plants. The evaluation of the effectiveness of stations is more important because it identifies the stations that use their resources better without reducing the quality of treated water. Accordingly, companies can identify the best operating procedures that can be applied in WTPs to help reduce operating costs.

In a report on water and energy, the United Nations World Water Assessment Program [24] highlighted the close relationship between water and energy management, and that the links between freshwater and energy are essential for sustainability and for advancing development [24]. Water is crucial for producing, transporting and using energy; and without energy, drinking water cannot be pumped. This mutual link imposes the improvement of total benefiting from them and their protection through their ideally optimized using.

A report on the energy efficiency of water and sanitation facilities [25], published by the US Environmental Protection Agency [25], concluded that energy savings through energy efficiency improvements cost little to generate, transport, and distribute energy from power generation plants. It also offers multiple economic and environmental benefits. By saving energy, operating costs may be reduced and water departments may be assisted to decrease additional investment in energy efficiency [26]. On the environmental side, energy efficiency helps in reducing pollution and emissions from power plants [27, 28].

Daw et al. [29] noted that water treatment and sanitation are important energy consumers with an estimated consumption of 3% to 4% of total US consumption of electricity used in water transfer and treatment. Energy is becoming increasingly important in the light of acute water shortages and high-energy costs. Making energy improvements in water plants is one of the most important ways in which energy managers can identify opportunities to save money, energy, and water at the same time.

As shown above, the previous studies discussed in this section are relatively recent. Studies on QTs are more numerous than those focused on improving the OPs in WTPs. This is due to the fact that researches on enhancing the OPs in WTPs are relatively few. Moreover, to the best of our knowledge, there are no studies that combine QTs and improvement of OPs in WTPs.

This is an obvious indication that the use of QTs to improve OPs in WTPs is of paramount importance in this study. It is clear from the following: (1) the previous studies on QTs and planning used the Seven Basic Tools for Quality as well as the Seven New Tools for Management and Planning, the present study focuses on employing the tools of these two groups together. The previous studies also dealt with the definition and explanation of QTs and how to use them without being applied in practice through problem-solving or improvement in processes or development. (2) Studies on the improvement of OPs are very few, and all are looking for an energy efficiency assessment that makes them consistent with this study.

5. Methodology of the Study

This work relies on quantitative analytical method, where the data were collected through the monthly reports of the stations studied in 2017. The power consumption rates for each station were also followed during this year; therefore, the stations were compared with each other to see the higher power consumption compared to the production per cubic meter per station. The average annual consumption of all stations studied is shown in Table 1. Figure 1 shows a diagram illustrating the proportion of the most power consumption stations. Figure 2 shows a diagram illustrating the average station consumption compared to the approved indicator (2.75 kW/m^3).

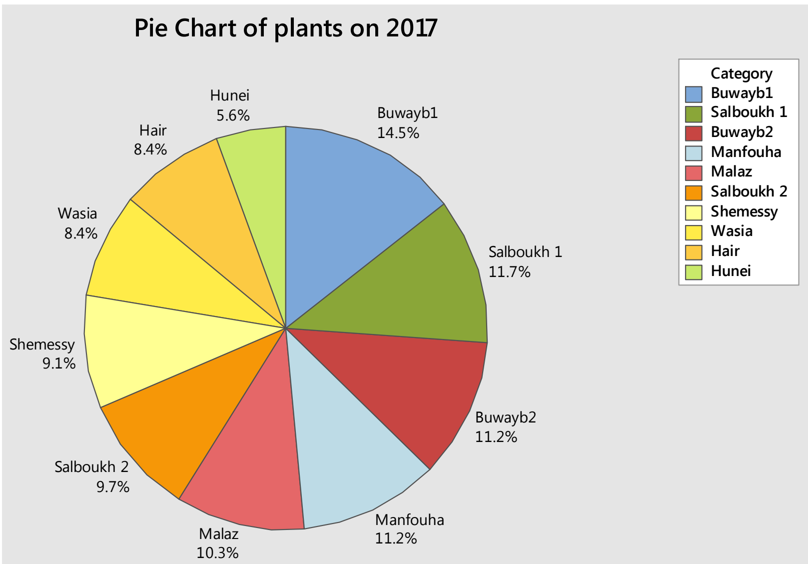

Figure 1. *Diagram showing the proportion of the most power consumption stations.*

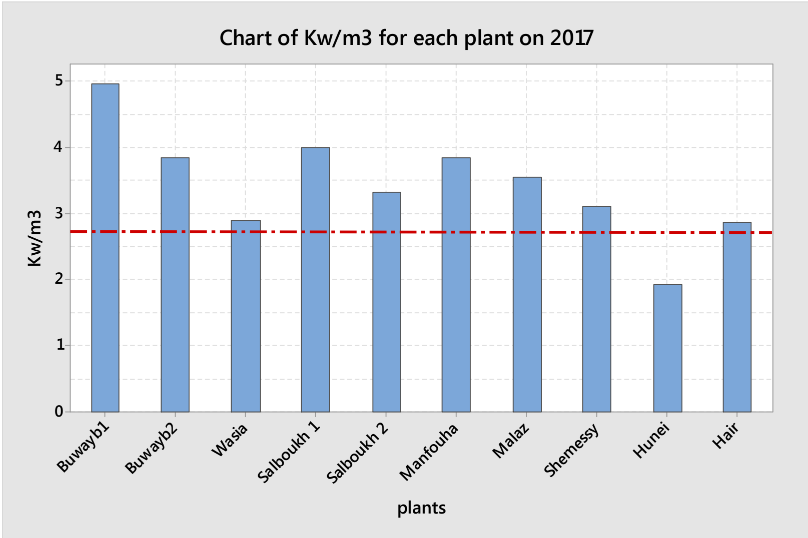

Figure 2. *Diagram showing the average station consumption compared to the approved indicator (2.75 kW/m³).*

An inventory and identification of the equipment that is believed to have a major role in the high consumption of electrical energy and assessment of the amount of public consumption in all the stations covered by the study are performed. A special focus was accorded the most important case study, Buwayb Station 1, by assessing its energy efficiency. All this was done using QTs to reach concrete solutions to improve OPs in WTPs and discuss results using the Minitab program.

The study sample includes ten WTPs of the NWC in Riyadh. These stations were selected in a simple sampling manner, as these stations are the basis for water production at the NWC. In addition, their number is very suitable for the application of QTs selected in this study.

6. Results and Discussion

6.1. Identifying the Most Energy Consuming Stations

As seen in Table 1, showing the annual consumption rates of the stations during 2017, and illustrated in Figure 1, illustrating the proportion of the most power consumption stations, it is observed that the Buwayb Station 1 is considered as the most power consumption stations compared to the rest of the stations, followed by the Salboukh 1 and Buwayb 2. Therefore, the concern will be accorded to search for all the reasons that led to high consumption rates of these stations.

A comparison of the average consumption of these stations with the approved indicator of the kilowatts per cubic meter of water production plants, which, according to an expert at the NWC [30], is 2.75 kW/m^3 (Figure 2). As shown in Figure 2, an increase up to 200% is noted for Buwayb 1 Station. This unreasonable rise calls for its treatment and finding solutions as soon as possible to avoid further waste of energy.

6.2. Identifying the Most Energy Consuming Equipment

By studying and analyzing the data of the equipment of the stations covered by the study, as well as the application of the dispersion or dispersion scheme as shown in Figure 3, a positive and clear linear relationship is shown between the total consumption of the stations and the consumption of the following equipment and components:

Submersible pumps of wells;
High-pressure pumps;
Flushing pumps;
Booster pumps.

Since the above-mentioned equipment is the most energy-consuming equipment in all stations studied, the CC for variables is applied to assess the extent to which these equipment affect the general consumption of the stations studied.

6.2.1. Submersible Pumps of Wells

Using observation maps for individual values on submersible pumps of wells, as shown in Figure 4, all the points of the submersible pumps of wells in the stations covered by the search are found within the control limits and that there is no indication of the out of control statistics. Consequently, the process is statistically stable.

6.2.2. High-Pressure Pumps

By applying observation maps to individual values on high-pressure pumps, as shown in Figure 5, not all the points of the high-pressure pumps in the stations covered by the search are within the control limits and that there is one point outside the control limits. This is an indication of the state of exit from statistical control. Accordingly, the process is considered statistically unstable. The reasons for this should be sought and plans and solutions should be found.

6.2.3. Flushing Pumps

By applying observation maps to individual values on the washing pumps, as shown in Figure 6, not all the points of the washing pumps at the stations covered by the search were within the orbital boundaries and that there was a single point outside the control limits. This is an indication of the state of exit from statistical control. Accordingly, the process is considered statistically unstable, the reasons for this should be sought, and plans and solutions developed.

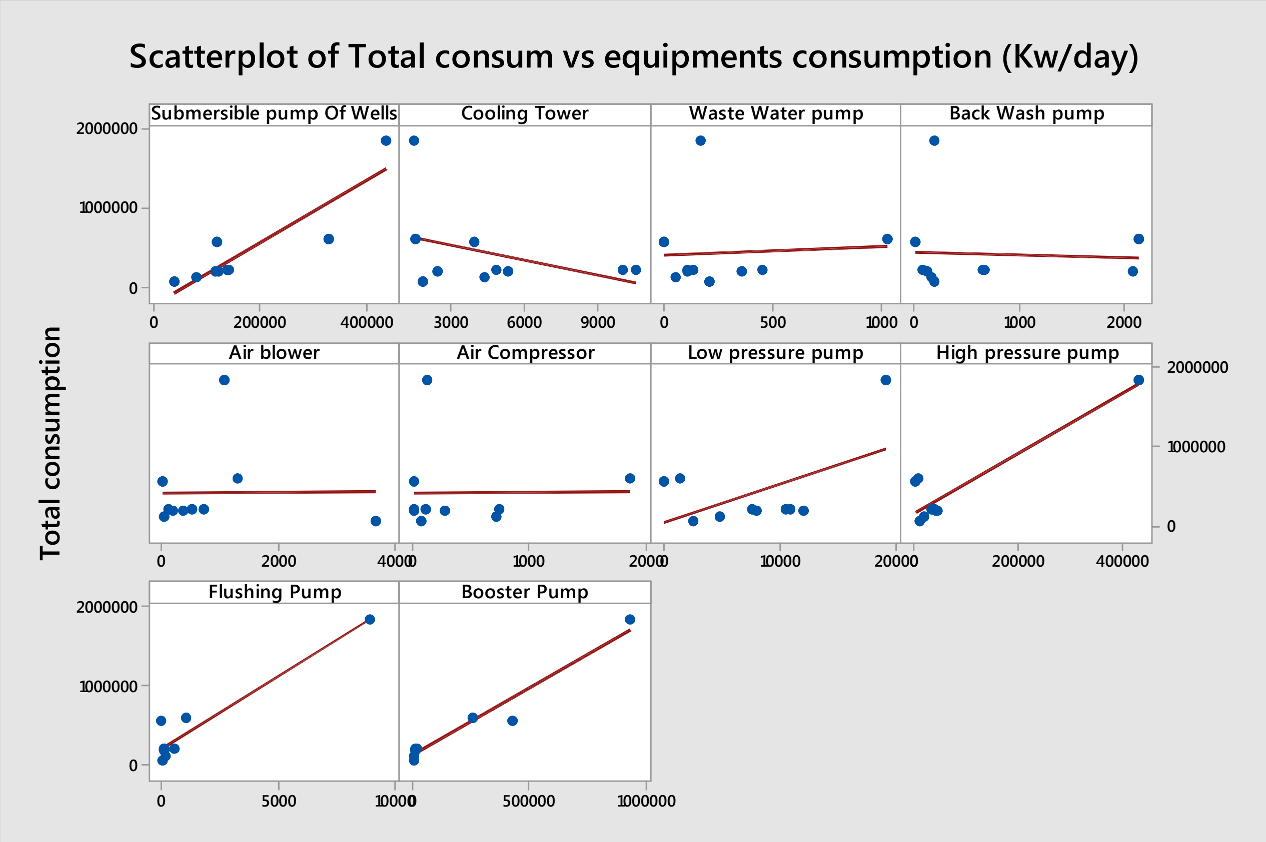

Figure 3. SD to study the relationship between the total consumption of stations with consumption of equipment.

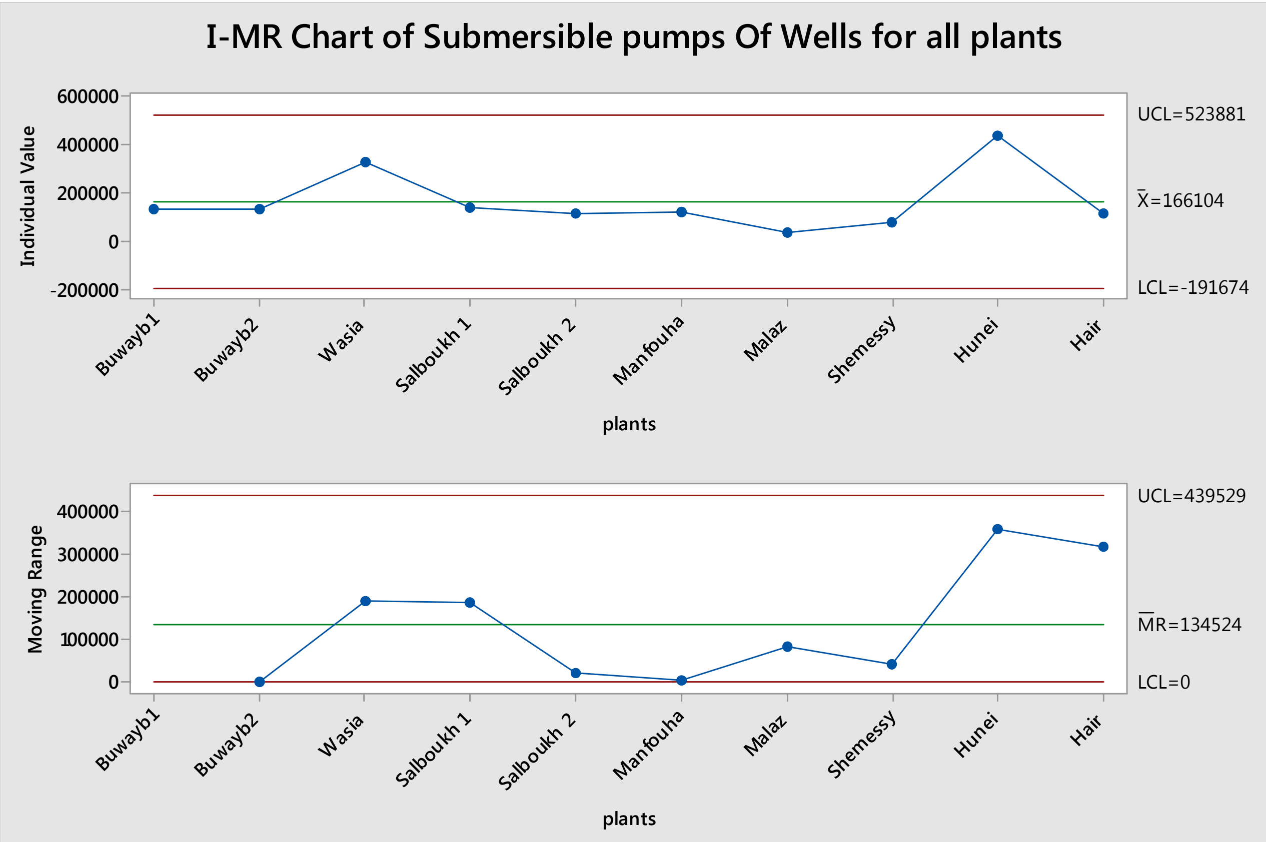

Figure 4. Application of observation maps of individual values to submersible pumps of wells.

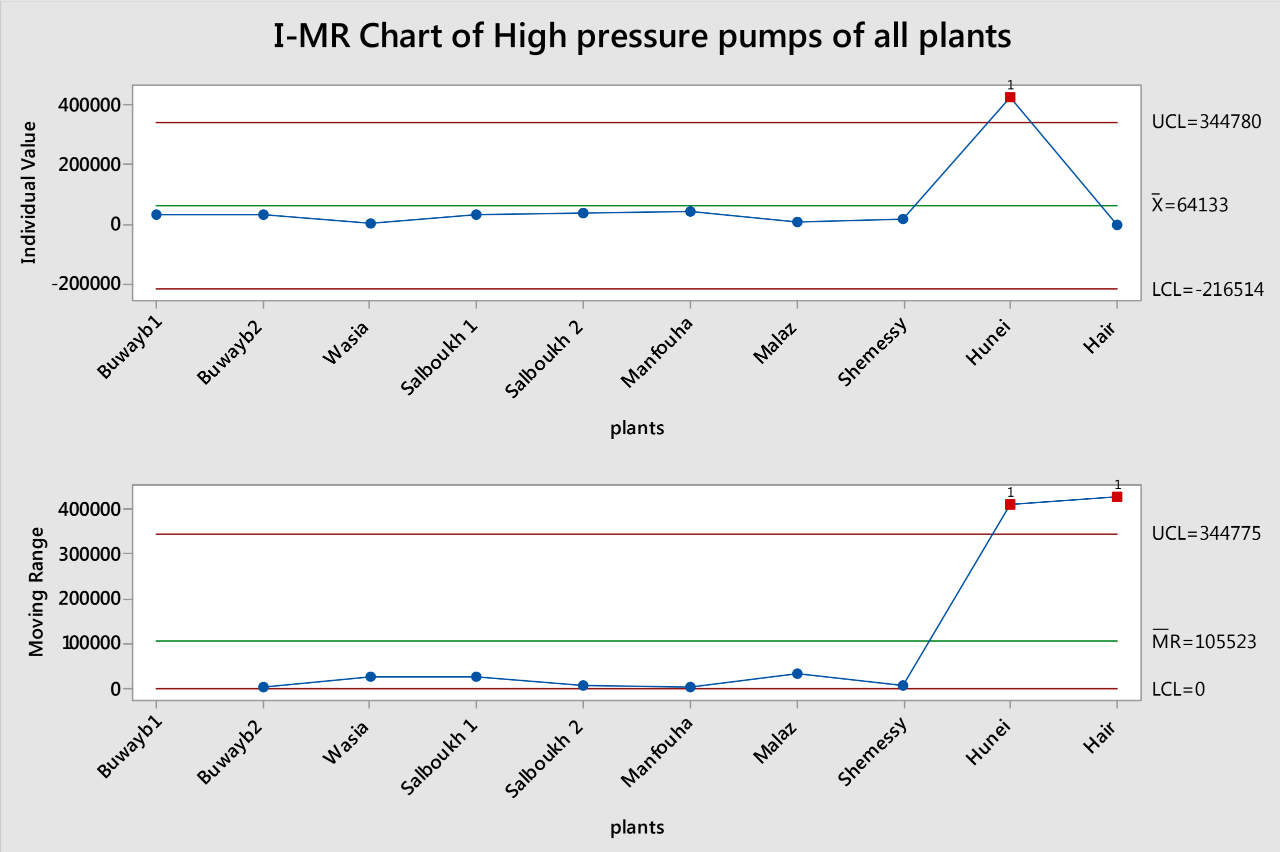

__Figure 5.__ Application of CCs of individual values to high-pressure pumps.

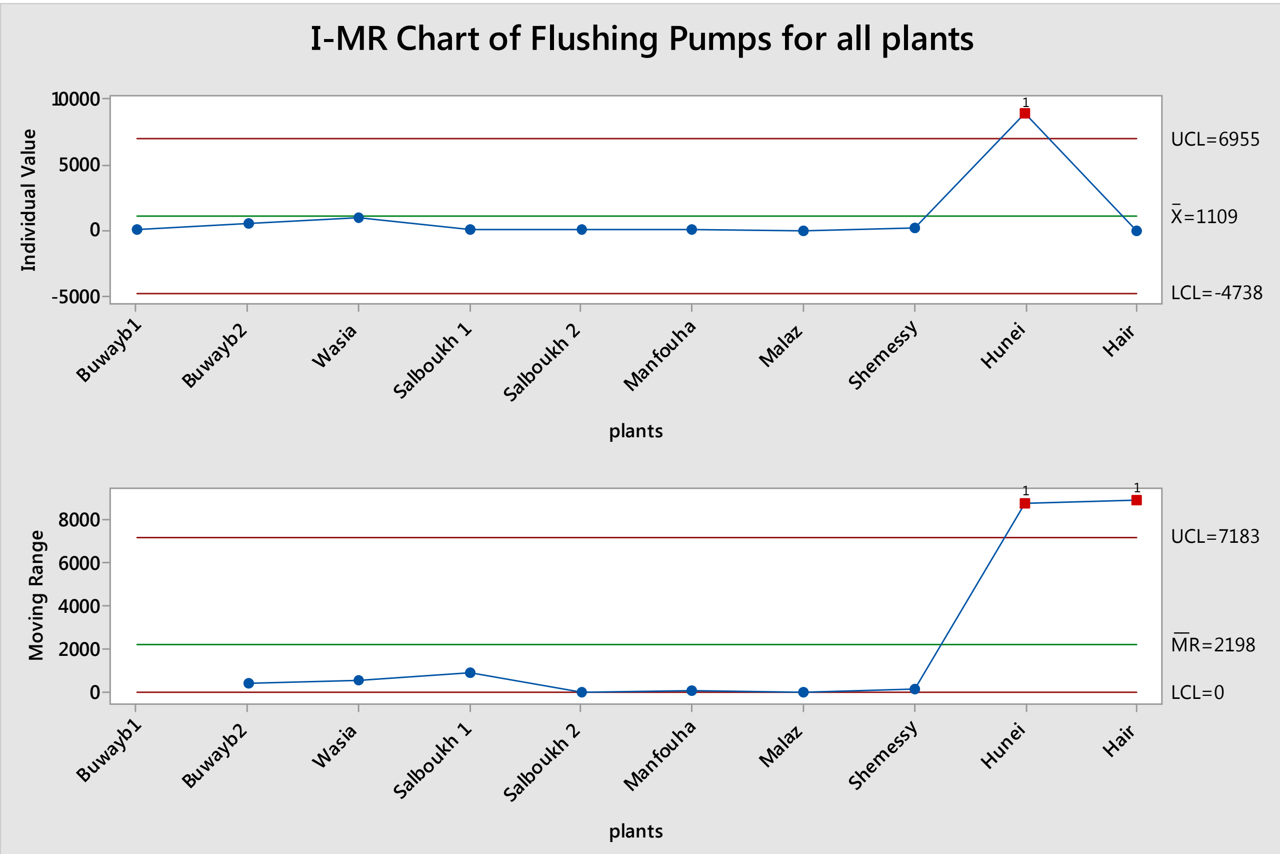

__Figure 6.__ Application of CCs for individual values on washing pumps.

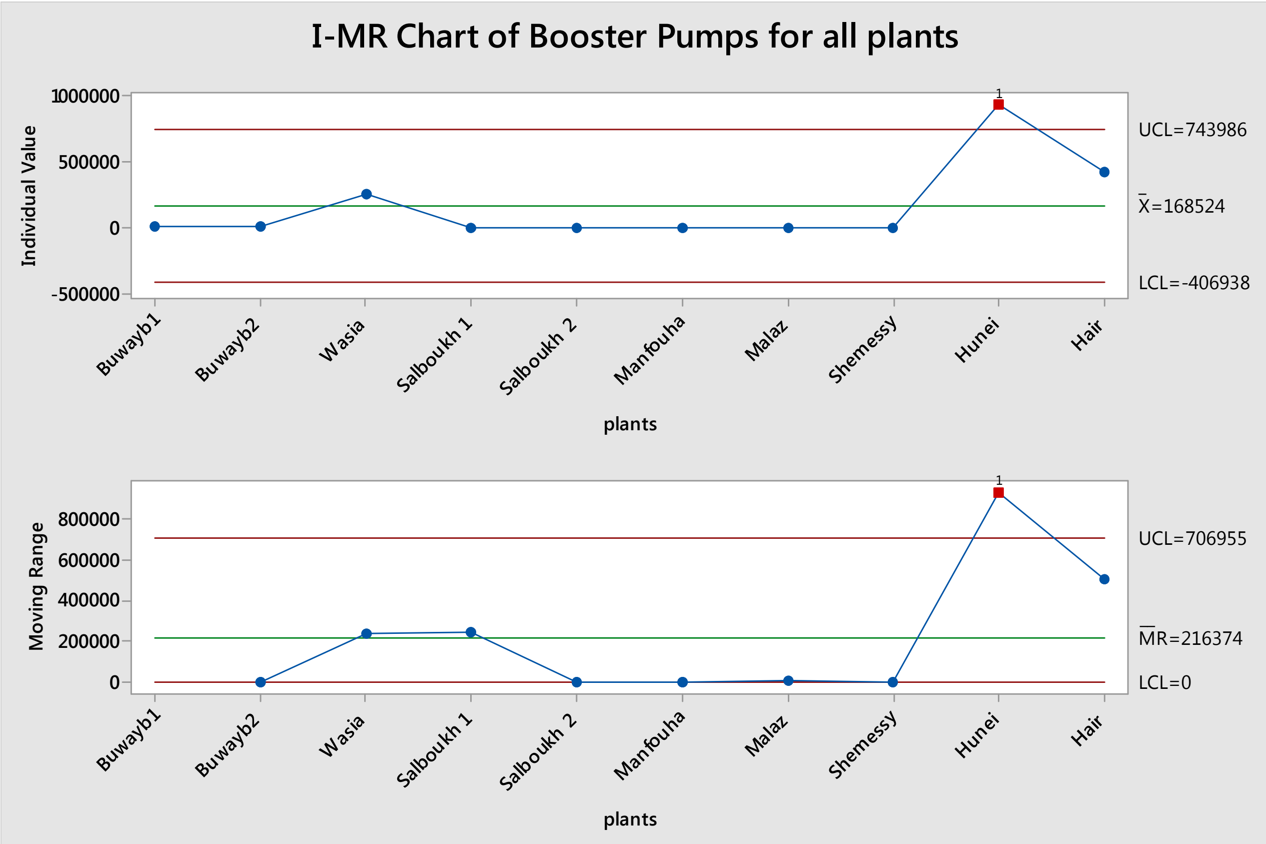

Figure 7. *Application of observation maps to individual values on booster pumps.*

6.2.4. Booster Pumps

By applying observation maps to individual values on the booster pumps, as shown in Figure 7, not all the points on the booster pumps covered in the search stations are within the control limits and that there is a single point outside the control limits. This is an indication of the state of exit from statistical control. Accordingly, the process is considered statistically unstable, the reasons for this should be sought,

Since Buwayb 1 Station is the highest in the average energy consumption, it will be taken as a sample for the application of the study and identification of the potentialities for energy savings.

6.3. Buwayb 1 Station

6.3.1. A Brief Description of the Buwayb 1 Station

Buwayb 1 Station was set up and introduced into service in 1980, with a production capacity of 60000 m^3 per day. The plant supplies water to the Riyadh area through the wells field around the station. This field was created specifically for the plant, with a total of 12 wells with submersible pumps with a capacity of about 523 kW. After pumping water into the plant, the processes of treatment and purification of water are realized through several stages, thus: (1) Cooling phase; (2) Sedimentation phase and chemical dosage; (3) Filtering stage through sand filters; (4) Reverse osmosis (RO) stage, which includes low pressure pumps and high-pressure as well as RO units; (5) Finished product stage; and (6) Pumping stage.

6.3.2. Energy Efficiency Assessment

In this section, the power consumption of the Buwayb 1 Station is assessed according to the operational data [9] for calculating the average energy consumption during the period from January 2017 to December 2017. As shown in Table 2, it is apparent that the calculated power consumption of the Buwayb 1 Station in the year 2107 is higher than the approved index of 2.75 kW/m^3. Therefore, it is necessary to know the most important stages of this station for the consumption of energy through the equipment used at each stage.

Table 2. *Average energy consumption during the period January 2017 - December 2017 for the Buwayb 1 Station.*

Month	Energy consumption during the period January 2017 - December 2017 for the Buwayb 1 Station		
	Volume (m^3)	Energy consumption (kW)	Average energy consumption (kW/m^3)
January	1187355	6030000	5.08
February	1172921	5814000	4.96
March	1166471	5598600	4.80
April	1145555	5100000	4.45
May	1214396	6033000	4.97
June	1357757	6676000	4.92

Month	Energy consumption during the period January 2017 - December 2017 for the Buwayb 1 Station		
	Volume (m^3)	Energy consumption (kW)	Average energy consumption (kW/m^3)
July	1401385	6819000	4.87
August	1267323	6268000	4.95
September	1317062	6482735	4.92
October	1218699	6171581	5.06
November	1019360	5073000	4.98
December	1075756	6030000	5.61

Based on the data collected in Table 3, PD is used to inventory the most energy-intensive equipment and to make plans and solutions to them as shown in Figure 8.

***Table 3.** Comparison of the daily energy consumption by equipment to the general consumption of the Buwayb 1 Station.*

Item	Equipment name	Buwayb 1 Station	
		Average daily consumption (kW/day)	Buwayb 1 Station general consumption (kW/day)
1	Submersible pump of wells	138112.13	209308.3
2	Cooling towers	10065.56	
3	Water return pump	134.58	
4	Reverse washing pump	656.95	
5	Air blower	725.88	
6	Air compressor	739.16	
7	Low pressure pump	10869.94	
8	High-pressure pump	35753.70	
9	Washing pump	90.74	
10	Pumping pump	12159.71	

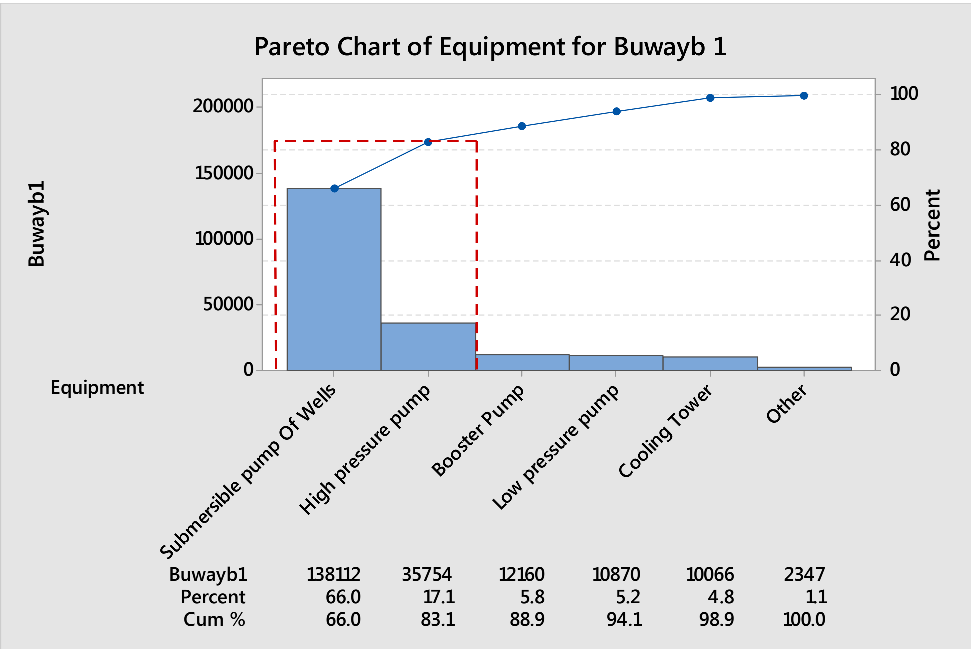

***Figure 8.** PD for finding out the most energy-consuming equipment at the Buwayb 1 Station.*

In PD, as shown in Figure 8, it is clear that the general consumption of the plant is due to two main reasons: submersible well pumps (62%) and high-pressure pumps (18%). Therefore, these pumps are considered the most energy consuming equipment. Through this analysis, it is also clear that the focus must be accorded to improving these pumps energy consumption.

Thus, appropriate plans and improvements should be made in each of this equipment through the operation and maintenance sections of the plant or through the company's planning department and finding solutions for repairs and modernization.

6.4. Results Discussion

In this Section, the obtained results are presented and assessed through answering the questions presented at the beginning of the study and discussing them as follows:

6.4.1. Question 1: Causes of Excessive Consumption of Electrical Energy and Increase Maintenance and Operation Costs in WTPs

In order to answer this question, the brainstorming tool and the CED are used. As mentioned above, these two methods brainstorming and the CED - have very great benefits in compiling the basic information and working to arrange it, showing problems and reasons clearly and understanding the dimensions of the problem in more than one point of view. Indeed, six pre-selected members of the working group have been asked to perform this task. In the beginning, the problem was identified and a name was chosen, namely, "Reasons for high power consumption and increased maintenance and operating costs". Then, the team brainstormed and limited all the reasons for the increase in power consumption in the WTPs by writing all the ideas on the labels so that each reason and the idea of the ideas are recorded on one card only. After completing the writing of the reasons, the ideas were limited and the duplicates deleted. The number of ideas and the reasons written by the members of the team was 30 as listed in Table 4.

Table 4. *Main reasons for the high consumption of electricity and increase the costs of maintenance and operation using the brainstorming tool.*

Lack of maintenance tools	Lack of specialized technicians	Frequent maintenance requests	Delayed maintenance	Not updated equipment
Weak coordination	Lack of warehouses	Equipment aging	Communicating difficulty	Hardware aging
Misuse of devices	Non-compliance with employment conditions	Simple problems not solved	Badness of some devices	Malfunction notification delaying
Assign staff to additional work	Receive commands from more than one destination	Non-rotation in equipment operation	Unfair distribution of tasks	Non-conformity of equipment during supply
Not updated the SCADA system	Different qualifications for work requirements	Difficulty in sharing tasks	Not calibrated devices	No budget
Lack of training	Poor hardware maintenance	Lack of experience	Delayed availability of spare parts	Lack of training courses

As shown in Table 4, the problems leading to high power consumption and increasing maintenance and operation costs are numerous and varied. These problems may be related to:

(1) the nature of the work itself, such as delays in maintenance, poor coordination, late arrival of a malfunction or related to

(2) the personnel, such as the difficulty of exchanging and assigning additional tasks, or because of

(3) machinery and equipment, such as aging of the vehicle, the lack of modernization or non-rotation, the supply of spare parts and the lack of maintenance tools required to maintain the equipment.

After enumerating the causes and problems, the CED is used in order to classify the reasons that the team extracted in the brainstorming session into four main groups: machines and equipment, materials, methods of work and finally employment. Figure 9 shows the CED to classify the causes and problems that cause high power consumption and increase maintenance and operation costs in WTPs.

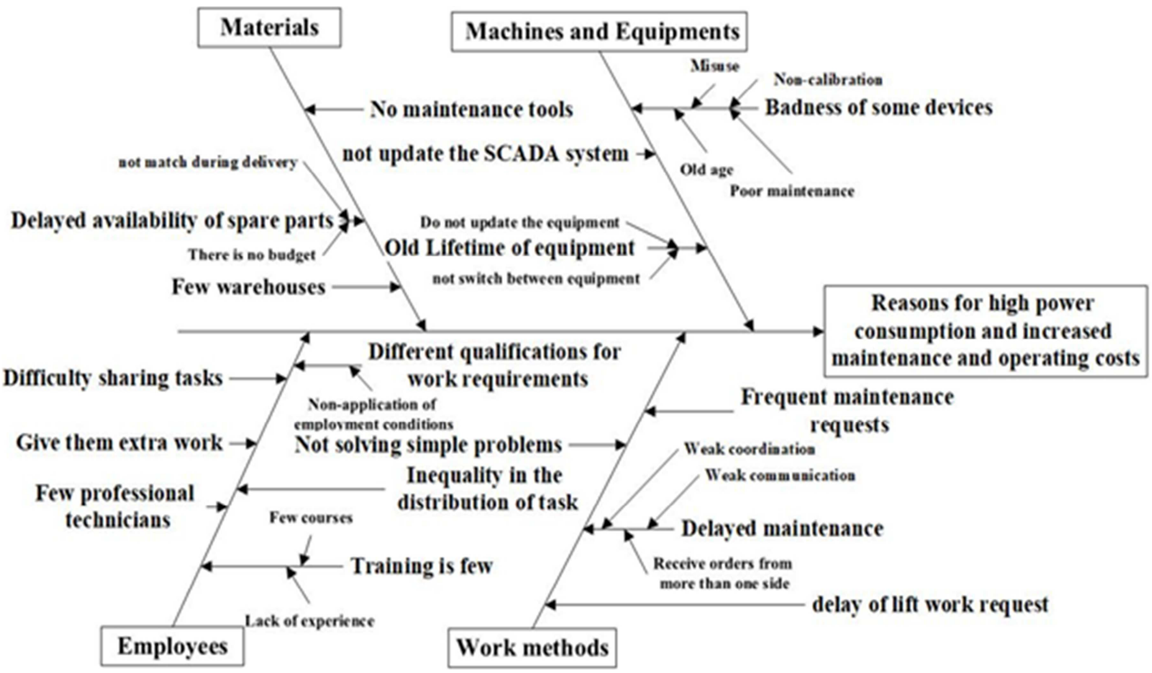

Figure 9. *Reasons for high power consumption and increased maintenance and operation costs using the CED.*

Figure 9 illustrates that there are four main reasons for the increase in electricity consumption and the increase in maintenance and operating costs, which, as mentioned earlier, are machinery and equipment, materials, methods of work and finally labor. On the other hand, these causes are subdivided into other sub-factors, as shown in Figure 9. It is also noted that some causes may be the result of other factors. For example, delays in maintenance operations are due to poor communication and coordination or due to orders from more than one destination. In addition, spare parts were delayed due to insufficient budget or lack of conformity of spare parts during the supply of equipment at the sites, which resulted in the return of suppliers and the waiting for identical parts to arrive.

6.4.2. Question 2: How Well Do QTs Affect OPs in WTPs

To answer this question, QTs are used to achieve a specific goal, i.e., to improve the OPs in WTPs, which in turn will clearly contribute to the reduction of electricity consumption. As mentioned previously, QTs are tools that prioritize and identify problems accurately and thus make it easier for the enterprise or institution to reach concrete solutions that may save them from collapse or loss. Ishikawa [11] stated that a very large percentage, perhaps 95%, of quality problems in all organizations could be solved by optimizing the seven QTs.

This has already been applied in this study. Indeed, after identifying the causes, proposed solutions were developed to improve the OPs of the studied stations using the TD as described in Figure 10.

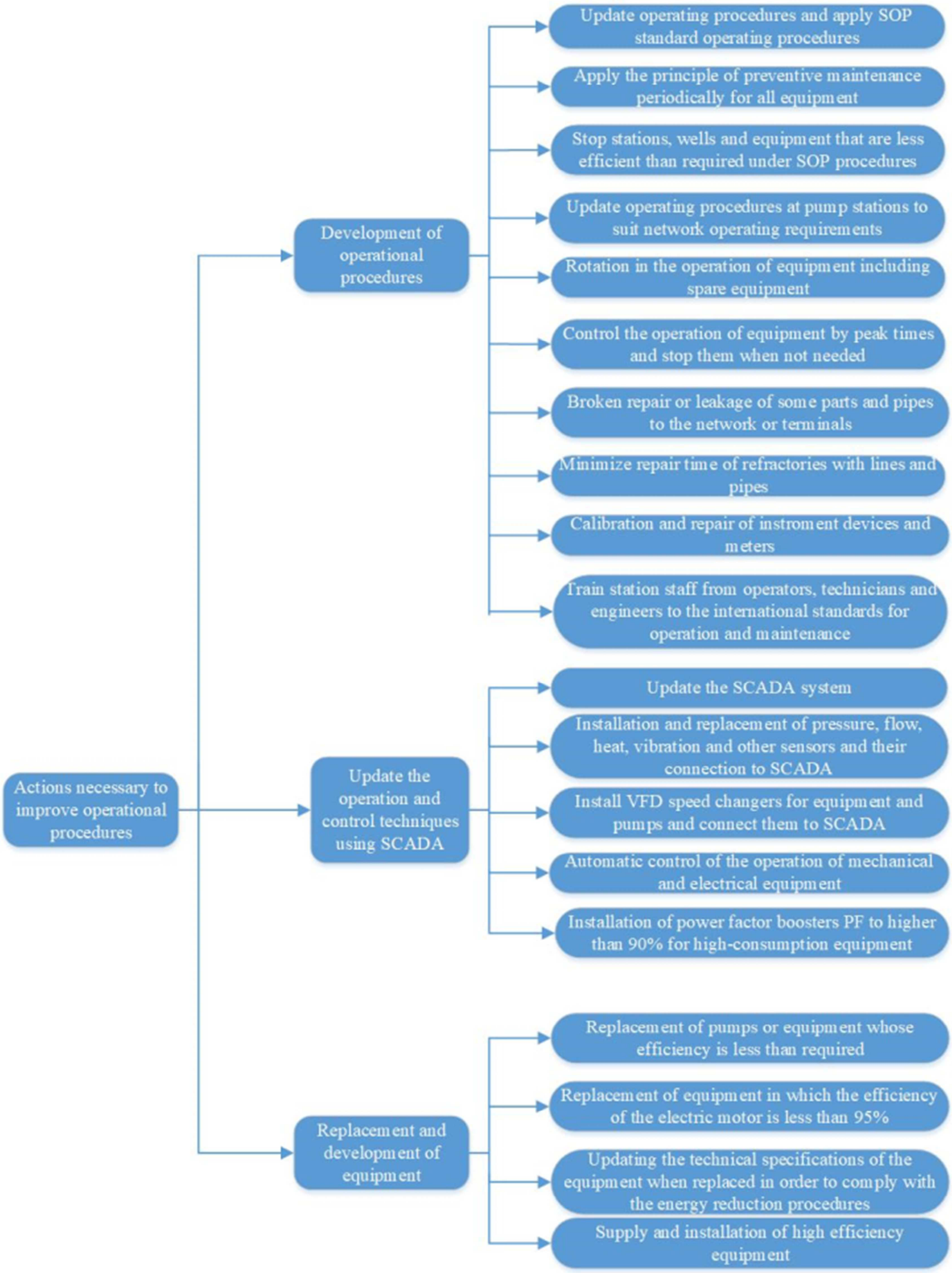

Figure 10. *Proposed solutions to improve OPs in WTPs using TD.*

7. Conclusions and Recommendations

7.1. Conclusions

In this part of the study, the main findings of the study are presented. The study showed a high consumption of electrical energy in most of the water stations covered by this study. Indeed, the consumption rate in some stations has reached 15% of the value of the general consumption of the company, such as Buwayb 1 Station, for example. This percentage is very high, with a general consumption rate of 200% compared to the approved index of kilowatt per cubic meter, which is 2.75 kW/m^3.

In the course of getting to know the equipment that has the most impact on the consumption of general stations, submersible pumps and high-pressure pumps have the lion's share in the value of consumption in all the stations studied.

Accordingly, a teamwork was selected to inventory and record the reasons that are believed to be a major cause of excessive consumption of electrical energy and increased maintenance and operational costs. Indeed, the team members have come up with some thirty reasons that may be a factor in high power consumption (Figure 10).

7.2. Recommendations

Through this study results and discussion, several recommendations are reached and summarized in Table 5.

***Table 5.** Recommendations obtained from this work to reduce electrical energy consumption through WTPs.*

Recommendation	Description
Recommendation #1	Establishment of a Department concerned with "Energy Management" to collect, analyze and follow up energy consumption and work to reduce it and prepare the necessary periodic reports for decision makers to take the necessary actions in time and to develop plans, strategies and policies to reduce energy consumption.
Recommendation #2	Studying the possibility of low-productivity stations and the implications thereof, with the preparation and study of possible alternatives with specialists.
Recommendation #3	Implementing the procedures necessary to improve the OPs referred to above in this study, especially with respect to updating the operating procedures of all sites in accordance with the operational requirements.
Recommendation #4	Follow up the implementation of preventive and corrective maintenance procedures, review maintenance plans and develop their operational plans.
Recommendation #5	Increasing the level of integration between the maintenance and operation departments and assets and to link activities and coordination among them, by linking them to a clear and understandable automated system.
Recommendation #6	Updating the technical specifications of the equipment in coordination with the Asset Management and Operation and Maintenance Department to take into consideration the energy efficiency of the equipment.
Recommendation #7	Preparation of technical regulations according to international standards, taking into account the efficiency of electric power and work on the application of the International Standard for Management of Energy ISO 50001.
Recommendation #8	Updating, developing and replacing SCADA automation systems and control systems with changing and replacing precision devices, instrumentation and control.
Recommendation #9	Updating the technical specifications of the SCADA system to take into consideration the consumption of electrical energy for equipment including flow, pressure, voltage, ampere and finally energy consumption.
Recommendation #10	Organizing the management and operation of SCADA systems and addressing the imbalance in the development of operational requirements, specifications and inputs in coordination with the concerned departments.
Recommendation #11	Asset valuation "All Company Equipment" through preparing and implementing procedures for replacement of less efficient equipment, inventory of less efficient and productive assets and development and modernization plans.
Recommendation #12	Fully upgrade and develop Enterprise Asset Management (EAM) with a time plan.
Recommendation #13	Establishment of mechanisms and programs to encourage site workers in the event of savings in electricity consumption.
Recommendation #14	Activating the role of energy coordinators in the stations and establish procedures, work tasks and training plans suitable for technicians and workers.
Recommendation #15	Modifying the operational status of the equipment, so that it operates in the medium term design, this gives the highest possible efficiency of the machine.

Acknowledgements

This study was supported by the Saudi Ministry of Education under the framework of the National Initiative on Creativity and Innovation in Saudi Universities. The authors gratefully acknowledge the support of their research program.

References

[1] D. Ghernaout, B. Ghernaout, M.W. Naceur, Embodying the chemical water treatment in the green chemistry – A review, Desalination 271 (2011) 1-10.

[2] D. Ghernaout, B. Ghernaout, On the concept of the future drinking water treatment plant: Algae harvesting from the algal biomass for biodiesel production—A Review, Desalin. Water Treat. 49 (2012) 1-18.

[3] D. Ghernaout, Environmental principles in the Holy Koran and the Sayings of the Prophet Muhammad, Am. J. Environ. Prot. 6 (2017) 75-79.

[4] J. Dai, S. Wu, G. Han, J. Weinberg, X. Xie, X. Wu, X. Song, B. Jia, W. Xue, Q. Yang, Water-energy nexus: A review of methods and tools for macro-assessment, Appl. Energ. 210 (2018) 393-408.

[5] V. Puleo, V. Notaro, G. Freni, G. La Loggia, Water and energy saving in urban water systems: the ALADIN project, Procedia Engineer. 162 (2016) 396-402.

[6] V. Notaro, V. Puleo, C.M. Fontanazza, M. Sambito, G. La Loggia, A decision support tool for water and energy saving in the integrated water system, Procedia Engineer. 119 (2015) 1109-1118.

[7] Energy, J. Energ. Environ. Chem. Eng. 3 (2018) 1-8.

[8] D. Ghernaout, M. Aichouni, A. Alghamdi, Applying Big Data (BD) in water treatment industry: A new era of advance, Int. J. Adv. Appl. Sci. 5 (2018) 89-97.

[9] D. Ghernaout, M. Aichouni, A. Alghamdi, N. Ait Messaoudene, Big Data: Myths, realities and perspectives - A remote look, Am. J. Inform. Sci. Technol. 2 (2018) 1-8.

[10] D. Ghernaout, M. Aichouni, A. Alghamdi, Overlapping ISO/IEC 17025:2017 into Big Data: A review and perspectives, Intern. J. Sci. Qualit. Anal. 4 (2018) 83-92.

[11] K. Ishikawa, Guide to quality control, Asian Productivity Organization, Tokyo, 1976.

[12] S. Feudo, A. Corsini, F. Bonacina, E. Tortora, E. Cima, Energy rating of a water pumping station using multivariate analysis, Energy Procedia 126 (2017) 385-391.

[13] O. Maaß, P. Grundmann, Added-value from linking the value chains of wastewater treatment, crop production and bioenergy production: A case study on reusing wastewater and sludge in crop production in Braunschweig (Germany), Resour. Conserv. Recy. 107 (2016) 195-211.

[14] J. Henriques, J. Catarino, Sustainable value - An energy efficiency indicator in wastewater treatment plants, J. Clean. Prod. 142 (2017) 323-330.

[15] D. Ghernaout, The best available technology of water/wastewater treatment and seawater desalination: Simulation of the open sky seawater distillation, Green Sustain. Chem. 3 (2013) 68-88.

[16] L. Castellet, M. Molinos-Senante, Efficiency assessment of wastewater treatment plants: A data envelopment analysis approach integrating technical, economic, and environmental issues, J. Environ. Manage. 167 (2016) 160-166.

[17] S. Longo, B.M. d'Antoni, M. Bongards, A. Chaparro, A. Cronrath, F. Fatone, J.M. Lema, M. Mauricio-Iglesias, A. Soares, A. Hospido, Monitoring and diagnosis of energy consumption in wastewater treatment plants. A state of the art and proposals for improvement, Appl. Energ. 179 (2016) 1251-1268.

[18] D. Ghernaout, Water reuse (WR): The ultimate and vital solution for water supply issues, Intern. J. Sustain. Develop. Res. 3 (2017) 36-46.

[19] D. Torregrossa, F. Hernández-Sancho, J. Hansen, A. Cornelissen, T. Popov, G. Schutz, Energy saving in wastewater treatment plants: A plant-generic cooperative decision support system, J. Clean. Prod. 167 (2017) 601-609.

[20] D. Ghernaout, Increasing trends towards drinking water reclamation from treated wastewater, World J. Appl. Chem. 3 (2018) 1-9.

[21] E. Benetto, D. Nguyen, T. Lohmann, B. Schmitt, P. Schosseler, Life cycle assessment of ecological sanitation system for small-scale wastewater treatment, Sci. Total Environ. 407 (2009) 1506-1516.

[22] M. Meneses, J.C. Pasqualino, F. Castells, Environmental assessment of urban wastewater reuse: Treatment alternatives and applications, Chemosphere 81 (2010) 266-272.

[23] Q.H. Zhang, X.C. Wang, J.Q. Xiong, R. Chen, B. Cao, Application of life cycle assessment for an evaluation of wastewater treatment and reuse project – Case study of Xi'an, China, Bioresource Technol. 101 (2010) 1421-1425.

[24] WWAP (United Nations World Water Assessment Programme). 2014. The United Nations World Water Development Report 2014: Water and Energy. Paris, UNESCO, http://unesdoc.unesco.org/images/0022/002257/225741E.pdf (Accessed on 02/08/18).

[25] US Environmental Protection Agency, Energy efficiency in water and wastewater facilities, A guide to developing and implementing greenhouse gas reduction programs, 2013, https://www.epa.gov/sites/production/files/2015-08/documents/wastewater-guide.pdf (Accessed on 01/08/18).

[26] J.A. Barry, WATERGY: Energy and water efficiency in municipal water supply and wastewater treatment, cost-effective savings of water and energy, The Alliance to Save Energy, February 2007.

[27] M. Schoen, T. Hawkins, X. Xue, C. Ma, J. Garland, N.J. Ashbolt, Technologic resilience assessment of coastal community water and wastewater service options, Sustain. Water Qual. Ecol. 6 (2015) 75-87.

[28] F. Friedler, Process integration, modelling and optimisation for energy saving and pollution reduction, Appl. Therm. Eng. 30 (2010) 2270-2280.

[29] J. Daw, K. Hallett, J. DeWolfe, I. Venner, Energy efficiency strategies for municipal wastewater treatment facilities, Technical Report, NREL/TP-7A30-53341, National Renewable Energy Laboratory, Golden, Colorado, January 2012, https://www.nrel.gov/docs/fy12osti/53341.pdf (Accessed on 02/08/18).

[30] H. Bajaoui, Indicator of consumption rate per cubic meter per kilowatt, NWC Internal document (March, 2017).