Maintenance Performance of the Kwanyaku Water Treatment Plant

E. A. Duodu and J.D. Owusu-Sekyere

Department of Agricultural Engineering, University of Cape Coast, Ghana

E-mail: enock.duodu@ucc.edu.gh

Abstract

The study assessed the Maintenance Performance of the Kwanyaku Water Treatment Plant. Availability and reliability of eleven facilities from the old and Jubilee treatment plants were compared. Twenty respondents view on the Maintenance Schedule at the Kwanyaku Headworks was also obtained. The t-test was the main statistical tool used with an alpha level of 0.05. There were significant differences in the availability of the equipment at the two treatment plants where the old recorded 93.33% better than the jubilee 77.50%. Also, there were significant differences in the average reliability of 48.20 days and 11.00 days for the facilities at the old and the jubilee plants respectively which fell below the GWCL benchmark and plant manufactures' standard. The assessment further revealed significant differences in the maintainability of the two plants which were within the GWCL benchmark of 1 – 5 hours. Finally, the study revealed that the main causes of frequent plants and equipment failure at the treatment plant were power outages and instrumentation issues.

Key words: Water treatment, Kwanyaku

Introduction

Public water industries in the developing countries are often associated with poor operation and maintenance of infrastructural facilities. Thus more than half of the water produced is unaccounted for (Kendie, 2002 and Ittisa, 1991). According to Yepes (1990), the major contributing factors to the high unaccounted water are high levels of leakage and pipe burst. This is estimated as four (4) times higher than normal level in developing world. Also, lack of modern facilities to reduce the complexity of maintenance and computerized systems to facilitate and properly monitor the distribution net work contribute to the poor maintenance situation (World Bank, 1999).According to World Health Organization (2000), it is estimated that 30%-60% of existing water supply systems are not operational due to ineffective planned maintenance management system.

The growing attention to maintenance has not only occurred because investment in machinery, instrument and equipment in water treatment plant forms a significant part of the company's assets, but also because it is now realized that the cost of maintenance must be justified by the utilization of these equipment. Because of automation of the water treatment plant, the production equipment must be operated efficiently and without any unscheduled stoppages. It is therefore becoming more and more necessary to exercise a close control over the frequency of maintenance required by these plants. To ensure maximum plants availability, utilization and reliability, there must be an effective planned maintenance management system in place. Implementing preventive maintenance requires a great amount of time and effort to be invested on plants and equipment. This will ensure that the maintenance effort is concentrated on the areas where it will be most beneficial (Mather, 2002a; Harms and Kroon, 1992).

The aim of this study was to assess the Maintenance Performance of the Kwanyaku Water Treatment Plant. It is also to compare the performance of the two plants (old and jubilee plants) at the headworks against the GWCL benchmarks.

Materials and methods

Study Area

The Kwanyaku water treatment plant supplies portable water to eight districts in the central region. The Kwanyaku water supply system with present capacity of 35,000m^3/d(7,700,000gal/d) located about 10km east of Agona Swedru, was built in 1964 to supply water to Kwanyaku and other surrounding towns and villages (GWCL, 2007). It is a conventional treatment plant which takes the raw water from the Ayesu River, is impounded, treated and transmitted through a distance of about 300km to serve a population of over 750,000 inhabitants.

Research Design

Comparative research method was used in this study without manipulating any variable.

Population and Sample

All seventy-eight (78) plants and equipment at the Kwanyaku Headworks formed the population of the study. Purposive non-random sample was used to select eleven (11) facilities each from the old plant and the jubilee plant. Also, purposive non-random sample was used to select twenty (20) respondents, made up of maintenance and production departments for the study.

Instrumentation

Two main instruments were used for the study. A questionnaire was used to collect information on maintenance management activities at the treatment plant. Another instrument, the performance checklist was used to collect data on the performance of all the plants and equipment at the headworks for the most recent six (6) months.

Data Analysis

Independent samples t-test technique was used in analyzing the data.

Results

This section attempts to ascertain if there was any significant difference between the old plant and jubilee plant with regards to plant availability. From table 1, the independent samples t-test was used to determine whether the difference in availability of the two plants was significant. The results indicated that all the equipment on the old plant recorded higher availability than those on the jubilee plant and the differences in the availability levels were significant at 1% level of probability. The minimum and maximum plant availability values for the equipment installed on the old plant were 85.67% and 94.0%, respectively. In the case of the equipment installed on the jubilee plant, the minimum and maximum availability values were found to be 69.83% and 78.0%, respectively. The test indicated that the difference for the two plants in the case of low lift pumps were statistically significant ($t = 5.034$, $p < 0.05$). Similar results were indicated by the aerators ($t = 4.956$, $p < 0.05$).The result was significantly the same in the case of the overhead cranes (t

= 5.146, p < 0.05). The results showed the same trend for the clari-flocculators (t = 4.876, p < 0.05).The high lift pumps were significant at (t = 4.951, p < 0.05). Similar difference of (t = 4.951, p < 0.05) was recorded for air blower pumps while the control panels recorded a significance of (t =4.991, p < 0.05.

Table 1. Plant Availability for old and Jubilee plants

	Old Plant		Jubilee Plant			
Plant Description	**M**	**SD**	**M**	**SD**	**t-test**	**p-value**
Low lift pumps	93.33	0.0345	77.50	0.0689	5.034	0.01*
Aerators	93.33	0.0345	77.33	0.0712	4.956	0.01*
Clari-flocculators	93.50	0.0288	77.50	0.0750	4.876	0.01*
High lift pumps	93.33	0.0345	75.50	0.0704	4.951	0.01*
Air blower pumps	93.50	0.0362	77.67	0.0695	4.951	0.01*
Control panels	94.00	0.0323	77.67	0.0734	4.991	0.01*
Overhead cranes	94.00	0.0323	78.00	0.0690	5.146	0.00*
Rapid gravity filters	85.67	0.0327	69.83	0.0725	4.877	0.01*
Wash water pumps	94.00	0.0323	78.17	0.0720	4.919	0.01*
Chemical dosing pumps	85.67	0.0327	69.83	0.0725	4.877	0.01*
Transformers	93.83	0.0306	78.00	0.0729	4.903	0.01*

* Significant level 0.05 M = Mean; SD = Standard deviation

The results indicated the same significant difference of (t = 4.877, p < 0.05) for the rapid gravity filters and the chemical dosing pumps. The wash water pumps and the transformers recorded a significant difference of (t = 4.919, p < 0.05 and t = 4.903, p < 0.05) respectively.

This section considers differences between reliability of the old plant and the jubilee plant. The results of the analysis as shown in table 2 indicated that there was a significant difference between the old plant and the jubilee plant in terms of plant reliability. The results showed that all the equipment on the old plant recorded higher reliability than those on the jubilee plant and the differences in the reliability levels were significant at one level of probability. The minimum and maximum plant reliability values for the equipment installed on the old plant were 14.15 days and 57.93 days, respectively. In the case of the equipment installed on the jubilee plant, the minimum and maximum reliability values were found to be 6.45 days and 12.32 days, respectively. The results showed that the aerators and the clari-flocculator were highly significant at (t = 3.552, p <0.05 and t =3.199, p < 0.05) respectively. Similar results were noted in the high lift pumps and the air blower pumps at (t = 3.516, p < 0.05 and t = 3.652, p < 0.05) respectively. The analysis registered another statistically significant difference, t =2.998, p < 0.05 on the control panels.

Table 2. Plant Reliability for old and jubilee plants

	Old Plant		Jubilee Plant			
Plant Description	**M**	**SD**	**M**	**SD**	**t-test**	**p-value**
Low lift pumps	40.900	17.160	11.000	4.521	4.127	0.070
Aerators	39.400	18.420	11.683	5.094	3.552	0.013*
Clari-flocculators	57.933	35.941	11.700	5.151	3.119	0.025*
High lift pumps	39.400	18.420	12.317	4.077	3.516	0.015*
Air blower pumps	39.467	18.479	11.083	4.567	3.652	0.012*
Control panels	55.900	35.968	11.467	4.925	2.998	0.029*
Overhead cranes	56.467	35.811	11.985	5.349	3.009	0.028*
Rapid gravity filters	14.150	2.8381	6.450	1.946	5.481	0.000*
Wash water pumps	56.500	35.784	11.983	5.348	3.014	0.028*
Chemical dosing pumps	14.150	2.8381	6.450	1.946	5.481	0.000*
Transformers	56.871	35.319	11.983	5.371	3.078	0.026*

* Significant level 0.05 M = Mean; SD = Standard deviation

The results indicated statistical significant difference for the overhead cranes at $t = 3.009$, $p < 0.05$ whilst similar difference was noted in the wash water pumps, $t = 3.014$ $p < 0.05$. Again, both the rapid gravity filters and the chemical dosing pumps showed a statistically significant difference at $t = 5.481$, $p < 0.05$. The transformers also recorded significant difference ($t = 3.078$, $p < 0.05$).

This section seeks to determine whether there was any significant difference between maintainability of old plant and jubilee plant. The results revealed that all the equipment on the old plant recorded higher maintainability than those on the jubilee plant and the differences in the maintainability levels were significant at one level of probability. The minimum and maximum plant maintainability values for the equipment installed on the old plant were 2.18 hours and 2.87hours, respectively. In the case of the equipment installed on the jubilee plant, the minimum and maximum maintainability values were found to be 2.65hours and 3.42hours, respectively. The results in table 3 revealed that there was a statistically significant difference between the old plant and the jubilee plant in terms of plant maintainability. A statistically significant difference was noted in terms of aerators, $t = -3.579$, $p < 0.005$. The results indicated that the rapid gravity filters and the chemical dosing pumps were statistically significant at ($t = -2.427$, $p < 0.05$).

Table 3. Plant Maintainability for old and Jubilee plants

	Old Plant		Jubilee Plant			
Plant Description	**M**	**SD**	**M**	**SD**	**t-test**	**p-value**
Low lift pumps	2.3500	0.5320	2.883	0.4021	-1.959	0.081
Aerators	2.1833	0.4708	3.083	0.3971	-3.519	0.005*
Clari-flocculators	3.1833	0.9928	3.050	0.5505	0.288	0.781
High lift pumps	2.3333	0.5391	3.417	1.2400	-1.963	0.078
Air blower pumps	2.3333	0.5391	2.900	0.3464	-2.166	0.060
Control panels	2.7667	0.4676	2.983	0.3971	0.865	0.408
Overhead cranes	2.7167	0.4834	3.000	0.3899	-1.118	0.291
Rapid gravity filters	2.2667	0.2582	2.650	0.2881	-2.427	0.036*
Wash water pumps	2.7333	0.4803	2.983	0.4021	-0.978	0.352
Chemical dosing pumps	2.2667	0.2582	2.650	0.2881	-2.427	0.036*
Transformers	2.8667	0.5317	3.017	0.4262	-0.539	0.602

* Significant level 0.05 M = Mean; SD = Standard deviation

Table 4 shows the frequency at which plants and equipment were maintained at the treatment plant. From table 4, respondents were asked to indicate the frequency at which maintenance was carried out at the treatment plant. Most of the respondents (80%; n = 16 and 85%; n = 17) indicated that the clear wells and the transformers respectively were maintained annually per the planned maintenance schedule. Three-fifth (60%; n = 12) of the respondents indicated that both the electric and induction motors were monthly inspected and defects corrected. Almost (90% n = 18) all the respondents showed that the chemical dosing systems, aerators and clari-flocculators were monthly inspected and maintenance carried out. In terms of the rapid gravity pumps, half (50%; n = 10) stated that planned maintenance is carried quarterly. Majority (85%; n = 17) of the respondents reported that the low lift pumps, high lift pumps and sludge pumps were inspected and maintenance carried out monthly per the planned maintenance schedule at the headworks. More than two-thirds of the respondents (75% n = 15) showed that the cranes and the hoist were inspected and maintained annually. With the control panels, three-fifth (60%; n = 12) of the respondents indicated that the maintenance crew quarterly inspects and reconditioning the system.

Table 4. Respondents View on the Maintenance Schedule at the Kwanyaku Headworks

Plants and Equipment	Frequency			
	Monthly	**Quarterly**	**Half-yearly**	**Yearly**
Clear wells/reservoirs		10%	10%	80%
Transformers		5%	10%	85%
Motors	60%	30%	10%	
Rapid gravity filters	25%	50%	25%	
Chemical dosing systems	90%	10%		
Air blowers or compressors			15%	85%
Low lift pumps	85%	15%		
High lift pumps	85%	15%		
Sludge pump	85%	15%		
Aerators	90%	10%		
Clari-flocculators	90%	10%		
Cranes/Hoists			25%	75%
Control panels		60%	40%	

Table 5. Staff Responses on Possible Causes of Maintenance Outages

Maintenance Outages	Frequency		
	Major Causes	**Minor Causes**	**Total**
Mechanical Outage	25%	75%	100%
Power Outage	90%	10%	100%
Instrumentation Outage	60%	40%	100%

As showed in table 5, respondents were asked to indicate the causes of frequent maintenance outages with respect to the Kwanyaku Headworks. Three-forth (75%; n = 15) of the respondents perceived mechanical outage as a minor cause of frequent breakdowns of plants and equipment at the headworks. Majority (90%; n = 18) of the respondents indicated that electrical outage was the main cause of frequent breakdown of the treatment plant. More than half (60%; n = 12) of the respondents showed that instrumentation outage also contributes to the frequent downtimes of the treatment plant.

Discussions

With regards to plant availability, the study found a significant relationship between the old plant and the jubilee plant at the headworks. The finding confirms the assertions made by Robinson (1993), Simpson (2006), Atepor (2005a) and Clifton (1987) that plants must be made available to operate in an efficient manner at the required level of production and there must be no unscheduled stoppages. This difference in plant availability could be attributed to certain situational factors. For instance, data indicated that the jubilee plant experienced frequent power outages which forced the plant out of production for several hours as compared to the old plant. The reason could be the frequent interruption of power supply to the jubilee plant which can only operates on 33kVA power supply. This finding corresponds to the research conducted by (Davis, 2003; Mather, 2002c; Dunn, 1997) who submitted that every plant or equipment is unique and acts and behaves differently in different environments and that a piece of equipment cannot be compared with another equipment but can only be benchmarked against its own performance. For example at the old plant, the low lift pumps and the high lift pumps were available at 93.33% for production while 6.67% downtime was recorded for preventive maintenance and breakdown maintenance. This means that very little maintenance was undertaken and the danger is that major plant failure could occur due to lack of maintenance. For the jubilee plant at the same period, the low lift pumps and the high lift pumps were operated at 77.50% plant availability while 22.50% downtime was recorded for maintenance outages. This also implies that planned maintenance was not practiced. This finding was inconsistent according to GWCL benchmark of 90%, which is 7% for preventive maintenance and 3% for breakdown maintenance.

The study reveals that there was a significant difference between the old plant and the jubilee plant in terms of plant reliability. This finding collaborates with the study conducted by Mather (2002b) and Camp (1989) that plant must operate continuously without failing during a specified time schedule. This difference in plant reliability could be the same as indicated in plant availability. For example in the old plant, the high lift pumps and the wash water pumps were reliable at 39.40 days and 56.50 days, respectively. This implies that the high lift pumps and the wash water pumps could only trip or fail every 39.40 days and 56.50 days, respectively. The situation at the jubilee plant was different as plant reliability of 12.32 days and 11.98 days were recorded for the high lift pumps and the wash water pumps respectively. This shows that the high lift pumps and the wash water pumps were continuously operated for 12.32 days and 11.98 days respectively without failure. Both findings were at variance with GWCL target of 264 - 336 hours (11 - 14 days) of low mean time between failures (MTBF).

The study further revealed that there was no significant correlation between maintainability of the old plant and the jubilee plant. It is not surprising therefore that no difference in the maintenance of the two treatment plants at the headworks was observed, since the lifespan of equipment depends to a large extent on the maintenance services offered, simply because maintenance poses a lot of challenges to management. However, results recorded at the two plants (old plant and jubilee plant) were in agreement with GWCL benchmark of 1 - 5 hours of low mean time to repairs (MTTR). This implies that maintenance services at the headworks were carried out between 2 – 3 hours. For instance, maintenance services on the high lift pumps were completed within 2.33 hours and 3.42 hours for the old plant and the jubilee plant respectively. According to Simpson (2006) and Atepor (2005b) plants must operate efficiently and accurately at the required level of production and there must be no unscheduled stoppages. This empirical revelation is in conformity with O’Conner’s (1999), Campbell’s (1995), Dilworth’s (1993), Dunlop’s (1990) and Clifton’s (1987) findings that maintenance activities are designed to keep plants and equipment in good operating condition or to restore it to accept standard after it has failed. This refers to the activities aimed at keeping existing capital assets in serviceable conditions. That is, the activities required to sustain plant in proper working conditions. The report argued that the purpose of maintenance is to provide safe, enhanced and efficacious maintenance service to obtain optimum plant availability factors, which will be cost effective and harmonious.

Results indicated that the main causes of plant failure at the headworks especially at the jubilee plant were the frequent power and instrumentation outages. This finding statistically confirms the hypotheses. Moreover, findings from respondents indicated that maintenance was most often carried out per the planned maintenance schedules of the company. This affirms an assertion made by Clifton (1987) and Lindley and Hinggins (1988) that planned maintenance prevent unscheduled stoppages and thereby increase the lifespan of plant and equipment. The assertion added that the benefits of planned maintenance include greater plant availability and reliability, effective tools, materials and labour utilization, improved budgetary control, improved stock control of spares and provision of information upon which management can make realistic forecasts and decisions.

Conclusions

The study has established that statistically significant differences exist between the two plants. The areas of differences are: majority of facilities at the old plant operated above the required duration in the months as against the jubilee plant facilities which operated slightly below the designed capacity. Again, the average low mean time between failures (MTBF) of facilities at both plants fell below GWCL benchmarks and plant manufactures' standards. However, the low mean time to repairs (MTTR) of the two plants was carried out within the GWCL benchmarks and plant manufactures' standards as the treatment plant has only one maintenance personnel.

References

Atepor , L. (2005a). *Plant maintenance and work services*: *Plant I (Lecture note).* Cape Coast, Ghana. Cape Coast Polytechnic, Mechanical Department.

Atepor , L. (2005b). *Plant maintenance and work services*: *Plant II (Lecture note).* Cape Coast, Ghana. Cape Coast Polytechnic, Mechanical Department.

Camp, R. C. (1989). *Benchmarking: the search for industry best practice that lead to superior performance.* Milwaukee,WI: Quality Press, pp.168-170.

Campbell, J. D. (1995). *Uptime - Strategies for excellence in maintenance management.* London: Productivity Press.

Clifton, R. H. (1987). *Principles of planned maintenance*. London: Edward Arnold (Publishers) Ltd., pp.1-75.

Davis, M. et. al.(2003). *Fundamentals of operation management (4thed*). New York, NY: McGraw-Hill Companies Inc., pp. 167-171.

Dilworth, J. B. (1993). *Production and operations management: Manufacturing and services* (5thed). Birmingham: McGraw-Hill, Inc., pp 451-459.

Dunlop, C. L. (1990). *A practical guide to maintenance engineering*. Borough Green: Butterworth & Co. (Publishers) Ltd., pp. 29-41.

Dunn, S. (1997). *Practice maintenance strategies for mobile equipment.*Retrieved January 23, 2011 from http://www.maintananceworld.com/htm.pdf.

GWCL (2007).*Commissioning ceremony, Kwanyaku drinking water supply rehabilitation and expansion project.*KwanyakuHeadworks, Kwanyaku.20th November, 2004, p. 3.

Harms, H. R. and Kroon, D. K. (1992). *Production system technology*. Peoria, California: Glencoe Division of Macmillan/McGraw-Hill Publishing Company, pp. 461-463.

IttisaAtto, B. (1991). *Towards a new philosophy on operation and maintenance of water lines.* 10(2), pp 25-28.

Kendie, S. B. (2002). *Linking water supply, sanitation and hygiene in Northern Ghana*. Cape Coast: Catholic Mission Press.

Lindley, R. and Higgins, P. E. (1988). *Maintenance engineering handbook.* London: McGraw-Hill Inc., pp 67- 88.

Mather, D. (2002a). *Calculating the savings from implementation of the CMMS.*Retrieved March 25, 2011 from http://www.maintenanceworld.com/

Mather, D. (2002b*). Planning and scheduling*. Retrieved March 25, 2011 from http://www.maintenanceworld.com/

Mather, D. (2002c). *The planned state: Maintenance management*. Retrieved March 25, 2011 from http://www.maintenanceworld.com/

O'Conner, P. D. T. (1999). *Practical reliability engineering (3rd ed).* Wiley: Prentice Hall.

Robinson, P. (1993). *Maintenance*. *In* K. D. Derri (Eds). Water treatment plant operation: *A field study training program.* California State University: Sacramento Foundation, Vol. 2 (5th), pp. 213-339.

Simpson, K. (2006). *Plant maintenance and work services*. *Plant III & IV (Lecture note*). Cape Coast, Ghana. Cape Coast Polytechnic, Mechanical Department.

World Bank (1999).*World development report: Knowledge for development*. Oxford: Oxford University Press.

World Health Organization (2000). *Proceedings of annual meetings of the OMWG.* Geneva, Switzerland: World Health Organization.

Yepes, G. (1990). *Water supply and sanitation sector maintenance: The cost of neglecting and option to improve it*. (Washington DC: World Bank Latin America and Caribbean Region Technical Department).