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Energy Analysis of Water Supply Processing Plant using Osun State Water Corporation, Ede Nigeria as a Case Study

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Abstract – Energy is regarded as one of the major tools to which the economy of a nation depends and need to be effectively managed and utilized. This research addresses the energy utilization at a water supply station using Osun State Water Corporation in Ede, Nigeria as a case study. The sources of energy for the station include thermal, electrical and human energy to various units of operation, namely dam, low lift pump, aerator, clarifier, filter gallery, clear well and high lift pump. A total amount of $36591\ kJ$ energy was estimated within a period of 40 hours to supply $60\ km^3$ capacity of water with $0.61\ kJ/m^3$ specific energy. Electrical energy accounts for the highest share of about $99.59\ \%$ of the total energy while human labour is relatively low. The high lift pump utilizes the largest share of about $88\ \%$ of the total energy in the form of electrical energy, whereas the dam has the smallest specific energy of $3.75 \times 10^{-6}\ kJ/m^3$.

Keywords: **Aerator, Clarifier, Energy, Energy account, Filter gallery, Lift pump, Specific energy, Water resources.**

1. Introduction

The most important resource to both human and industrial activities is energy. The function of our technological society depends upon the production and use of large amounts of energy. Many of the world problems are closely related to the problem of energy distribution, dwindling fossil – fuel supplies, and environmental effects of various methods of energy production and utilization. In view of this, efforts should be made to ensure a better efficient utilization of fuel, electricity, thermal energy and labour; these being the major source of industrial energy in the form of fossil fuel, natural gas, coal and electricity generated by thermal and hydro – power station. The supply of electricity in the country is in acute shortage and epileptic due to the dearth of underlying power stations and the problems in the transmission is the distribution of the energy (Oyedepo et al., 2018). As a result, most companies in the country now rely on the use of heavy-duty generating plant for supply of their electric energy which is used for operations such as air conditioning, lighting and some machining processes.

Energy is consumed at every stage of the water production system (Wakeel and Chen, 2016), including exploration, treatment and distribution. Copeland and Carter (2019) reported that the intensity of energy consumption depends upon the specific technologies applied at each stage of the water process. For some technologies, the intensity may be relatively low, whereas the intensity of other technologies is substantially greater. Due to the adopting of energy consumption measures, it is necessary to make a detail of the process involved and equipment use in the water process operation. This analysis identifies the amount, type and quality of energy required for the operation. Water processing is a less sophisticated activity which implies a certain number of operations from dam, pump, aerator, clarifier, filter gallery, clear well and transports to the users which require different types of energy.

Sparn and Hunsberger (2019) report shows that most of the water processing operations are electrically performed and therefore it required a great amount of energy in accomplishing. Operations such as the opening of the dam, pumping, etc. are energy demanding tasks, owning to the fact that they are electrically performed, their productivity is very large and high thereby demanding high amount of energy. Various approaches have been used by many researchers in determining the required rate. Burhan et al., 2004, Asakereh et al., 2010, Srivastava, 2006, Olafimihan, 1998, Aiyedun and Onakoya, 2000 and Jekayinfa, 2006 reported on energy utilization pattern in various agricultural and mechanical operations or tasks. Others have used the heart rate approach in determining the energy requirement in performing various agricultural and mechanical tasks.

In addition, energy today is abundant, so we should be good steward of our energy resources trust as we provide wise management and use of our natural resources. This research examines the energy usage pattern as they relate to the individual works of water process operations. Increase in electricity consumption tariff rate and rising fuel cost and supply limitation plague industrial sector of the Nigeria economy sensing the energy related research to reduce costs through energy conservation and prevent possible shutdown consequent to reduce the availability of energy resources.

2. Methodology

2.1. Source of Data

The data were collected for energy used in five (5) complete consecutive water processing operations across various units in Osun State Water Works located in Ede, Nigeria at latitude 4.44° E and longitude 7.72° N. The available units/stages in the water supply station include dam, low lift pump, aerator, clarifier, filter gallery, clear well and high lift pump.

2.2. Analysis of Data

The data collected were averaged and computed with governing equations of required energy parameters as summarized in the Table 1.

Table 1: Energy Equations Used

S/N	Quantity	Symbol	Mathematical Expression	Unit	Remarks
1	Electrical Energy	E_e	$\int Ptdt$	kJ	Jekayinfa and Bamgboye (2004)
2	Thermal Energy	E_t	$C_f \times W$	kJ	Rajput (2001)
3	Human Energy	E_h	$0.075NM_h$	kWh	Odigboh (1998)
4	Specific Energy	E_s	$\frac{E}{V}$	kJ/m^3	

Where,

P is electrical power in Watts (W), t, is time taken in seconds (s), C_f is calorific value of chemical fuel in (J/kg), W is mass in kg, N is number of operators engaged, M_h is man-hour requirement for daily operation, E is the total energy consumed in Joules (J) and V is the volume of water in cubic metre m^3

Table 2: Time and Energy Use Data by Ede Water Corporation for Processing 60 km^3 of Water.

Unit Operation	Time (hours)	Thermal Energy (kJ)	Electrical Energy (kJ)	Human Energy (kJ)	Total (kJ)	% of Total	Specific Energy (kJ/m^3)
Dam	0.5	Nil	Nil	0.225	0.225	0.0006	3.75E-06
Low lift pump	12	Nil	4032	1.8	4033.8	11.0241	6.72E-02
Aerator	3	89.5	67.3	2.25	159.05	0.4347	2.65E-03
Clarifier	Nil	Nil	Nil	1.8	1.8	0.0049	3.00E-05
Filter gallery	12	Nil	87.79	3.6	91.39	0.2498	1.52E-03
Clear well	Nil	44.75	Nil	1.8	46.55	0.1272	7.76E-04
High lift pump	12	Nil	32256	1.8	32257.8	88.1587	5.38E-01
Total	39.5	134.25	36443.09	13.275	36590.615	100	6.10E-01
% of total		0.3669	99.60	0.0363	100		
Specific Energy (kJ/m^3)		2.24E-03	6.07E-01	2.21E-04	6.10E-01		

In order to process water of 60 km3 by volume, a total of specific energy of 0.61 kJ/m^3 was utilized. High lift pump consumes the largest amount of energy of 32257.8 KJ which represents about 88.16 % of the total energy used in the system because of the required height of the reservoir to supply water to the communities over a long distance travel, followed by the low lift pump with specific energy of 0.0672 kJ/m^3 while that of the dam operation is as low as 0.225 kJ.

It can also be deduced from Fig. 1 and Table 2 that electrical energy takes the largest share of specific energy of 0.607 kJ/m^3which represents 99.59 % of the total energy used. This implies that the process is majorly dependent on the availability of electrical energy. It more reason why a special consideration is given to water-works plants by making available electricity supply to the plant for regular water supply for the communities. The amount of energy dissipated by human labour is relatively low when compared to the total energy utilized. This is evidence that the process involves less human labour as the amount energy dissipated is as small as 0.036% of the total energy utilized. Few operations such as aerator and clear well require the use of thermal energy with about 0.37 % of the total energy.

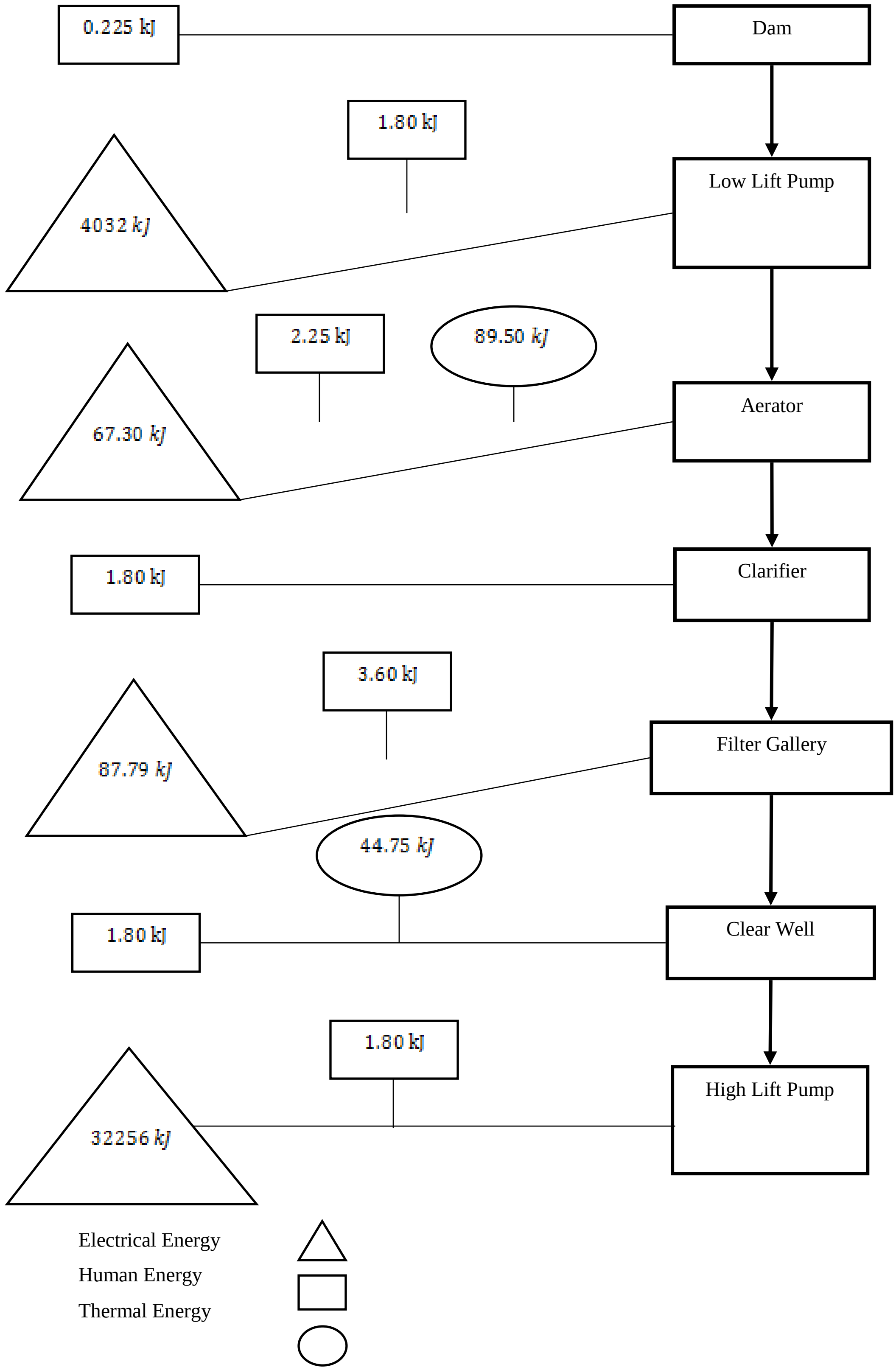
0.225 kJ
Dam
1.80 kJ
4032 kJ
Low Lift Pump
2.25 kJ
89.50 kJ
67.30 kJ
Aerator
1.80 kJ
Clarifier
3.60 kJ
87.79 kJ
Filter Gallery
44.75 kJ
1.80 kJ
Clear Well
1.80 kJ
32256 kJ
High Lift Pump
Electrical Energy
Human Energy
Thermal Energy

Fig. 1: Energy Accounting Diagram of Osun State Water Corporation, Ede, Nigeria

4. Conclusions

The study reveals that the energy consumed to produce 60 km3 of water in the Water Corporation was estimated to be 36591 kJ with an electrical energy account of about 99.59 % of the total energy consumption under an estimated period of 40 hours. Human labour takes the least of the energy, of less than 1% of the total energy. The total specific energy of 0.61 kJ/m3 was required for the process with high lift pump unit taking about 88 % of the total energy available. The total specific energy obtained can be used for other water supply stations having similar units of operation.

5. Recommendations

Based on the results of the findings, the following recommendations are made to future researchers and the water processing management:

i. Routine maintenance should be made both to the water processing system and community to minimize loss in energy within and outside the system respectively;
ii. The schedule of operations of pumps should be in line with best practices of energy conversion using smart systems. For instance, the pressure of the high lift pump should be reduced to the bare minimum for the off-peak periods.

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