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Economic Analysis of Wastewater Reuse in Covenant University

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Economic Analysis of Wastewater Reuse in Covenant University

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Abstract. Wastewater reuse is a vital technique to supplement existing water resources for both developing and developed nations. However, the economic research into the design and implementation of a wastewater reuse scheme is required in order to determine the feasibility of any wastewater reuse project from an economic stand point. There are numerous benefits of wastewater recycling. However, these benefits are often not evaluated due to several factors. Nevertheless, the valuation of these benefits is required to justify investment decisions. This research uses cost-benefit analysis to evaluate the benefits of implementing a wastewater reuse scheme in a university community. The investment decision is influenced by the result obtained from the cost benefit analysis calculation. The result of the Net Present Value of this research showed that, the University could recoup its initial investments and also realize huge profits implementing a wastewater reuse scheme. Meaning that the research is or would be feasible financially. This research also shows that with the use of constructed wetland, an extensive method of wastewater treatment, the energy costs accrued per year by the University community would be reduced by millions of naira. Furthermore, the environmental and social benefits of the projects were also considered to complete an economic analysis. The results showed that there are significant environmental and social benefits which includes sustainable groundwater withdrawal, the avoidance of land subsidence and corporate social responsibility.
Keywords: Wastewater, reuse, Valuation, Expenditure.

1. Introduction

The term "wastewater" signifies any water that is never again needed, as no further advantages can be obtained out of it. Wastewater is a complex blend of inorganic and organic materials [1]. In an expansive sense, wastewater can be classified into domestic wastewater (otherwise called sewage), industrial wastewater, and municipal wastewater, which is a mix of the two [1]. Wastewater is water that contains solids which exist as settleable particles or dispersed as colloids [2]. Wastewater reuse on the other hand, is a practice that has evolved and advanced throughout human history. As a result of rapid urbanization, there is even a greater demand and attention given to waste water reclamation and reuse [3], [4].

The importance of wastewater reuse cannot be overemphasized. Therefore, it is important to recognise that wastewater is an economic resource which could serve as a source of nutrients, energy, and even water supply [5]. Studies have shown that the total demand for freshwater far exceeds the supply of freshwater in most regions of the world which is mainly as a result of the uneven distribution of freshwater resource on earth [6]. About 97% of water on the earth is present in oceans (salt water), only about 3% of the total volume of water on earth is fresh[7]. Of most of this fresh water, about 70%, is stored in glaciers and permanent snow making it inaccessible, 29.5% of the fresh water on earth is stored as groundwater, the remaining 0.5% is present in lakes, rivers, soil moisture etc[6], [8]. The population of urban dwellers where water consumption is relatively very high and constantly rising. Some modeled results have shown that about 150 million people who live in cities are faced with perennial water shortage and this value is expected to rise to about 1 billion people by 2050 [9]. Water demand is predicted to be on the rise globally as a result of agricultural activities which presently accounts for 70% of water abstractions and accelerated urbanization[10]. In Europe alone, over 200 water reuse projects have been identified with a water reuse potential estimated to about 3000M m^3/yr[11]. In the Can Tho City of Vietnam, [12] it was proven that wastewater could be used for the irrigation of about 22,719 ha (16%) paddy of rice per year and similarly provide up to 22% of water for dry season rice production. It is not a surprise that water reuse is an economically viable activity as previous studies have also revealed this. Wastewater reclamation in Beijing was shown to generate a net annual benefit of 712 million CNY [13]. In the United States, agricultural potentials of states like Hawaii and Florida have been maximized from wastewater reuse and millions of dollars have been saved from those projects [14]. In as much as wastewater treatment and reuse is highly beneficial both economically and environmentally, studies have shown that Nigerian institutions and organisations have been plagued with mismanagement of treatment facilities, and also cost of development. Studies by [15], [16] revealed that only the Nigerian Brewery in Kaduna state has a functional wastewater treatment facility in the Northern region of Nigeria and Abuja can boast of a functional wastewater treatment facility in the middle belt region of Nigeria. States like Benue, Kogi, Kwara, Niger and Plateau states are said to have non-functional Wastewater treatment/reuse facilities. States such as Abia, Anambra, Akwa Ibom Bayelsa, Cross river, Ebonyi, Imo and Ondo are reported to have either no wastewater treatment/reuse facilities or dysfunctional facilities [16]. Given such issues and potentials, wastewater reuse cannot be overlooked.

However, unmanaged wastewater has been linked to increased child mortality rate and reduced labour productivity. At least 1.8 million children under the age of five years die every year due to water related disease, or one every 20 seconds [17], [18]. Similarly, 5 million deaths have been reported annually as a result of water related diseases of which 84% are children between the ages of 0-14 [19], [20]. Untreated waste water discharged into waterways by industries contains contaminants such as heavy metals and this poses significant threat to humans and animals in the areas of food production, health and ultimately this action destroys the environment[21].
Investments in wastewater management are required both in developed and developing countries. Recycled water can supplement freshwater in conventional practices for example, horticultural and landscape irrigation, industrial applications, ecological applications (surface water renewal and aquifer recharge), recreational exercises, urban cleaning, firefighting, infrastructural development, and so forth [22].

Economic Evaluation on the other hand, is the examination/assessment of at least two interventions with respect to the cost and consequences of any project. It is the assessment or appraisal of various projects using the information given against results produced. Economic evaluation is also known as economic appraisal [23]. In order for a government or an organization to undertake a comprehensive water reuse scheme, thorough cost-benefit analysis is necessary to be carried out so as to determine the potential benefits of the project. Similar studies have been conducted using the cost benefit analysis (CBA) as a tool for analysis. In Morocco, [24] demonstrated that 2.035 Billion USD, which was about 1.62% of Morocco's GDP as of 2008, can be generated from a Wastewater Reuse (WWR) scheme if implemented. Using similar approach for the determination of WWR potentials for irrigation agriculture in Cyprus, [25] discovered that although farmers gained direct benefits from WWR, residents who gained indirect benefits from reuse schemes were significantly more than farmers. This results correlated with [26] who reported that farmers may derive benefits ranging from 0.20 to 0.22

Euros/m^3 via WWR schemes. Benefits ranging from better crop yield, employment opportunities for irrigation staff and pollutant reduction were identified by [26] using CBA.
In the current study, benefits of two different proposals (action and no action) are compared with their costs, using a common analytical methodology. The benefits are usually measured in different physical quantities, whereas comparison is made in common monetary terms. Proposals are economically viable only when they generate net profit. The best option offers the highest net profit [27].

1.1 Background
Covenant University, which is the main focus of this research work is situated in Canaanland, Ota Ogun State, and home to the Living Faith Tabernacle, the erstwhile largest Church Auditorium in the world. Canaanland is located within latitude 6° 40' North and longitude 3°10' East. It is on an area of 236 hectares in the Ado-Odo/Ota Local Government area of Ogun State.

Figure 1: Aerial view of Covenant University

Wastewater generated within the community has increased during recent times and it has been discovered that Covenant University (CU) Community generates over 800,000 litres of wastewater per day [28]. Effluent of the treated wastewater is discharged into a gully that drains into River Iju (River Atuwara) and there were intermittent reports from downstream neighbouring communities on the presence of faecal matter in their surface water supply. In addition, the rapid population growth on campus, which has led to round-the-clock extraction of groundwater sources from multiple industrial sized boreholes calls for a review, considering sustainable production principles. As at the time of this study, there were 24 boreholes of which 14 of those boreholes are in service. The energy requirement for powering these wells, the equipment investment, and the rate of daily groundwater withdrawal justifies the need to consider WWR [28]. About 1.5 million litres of water is pumped every day in order to meet the water demand of the community which is anticipated to rise due to population increase. There have been frequent reports of failed wells and groundwater contamination as a result of indiscriminate exploitation of groundwater sources [29].

2. Methodology
Data used in this research, were obtained from the Physical Planning and Development (PPD) department of Covenant University and the operational and maintenance expense utilized was estimated as 2% of capital expenses except for the carwash and constructed wetland. However, costs

that could not be obtained from the PPD were obtained from other reliable sources. Furthermore, Cost Benefit Analysis (CBA) was used in this study to evaluate how beneficial the project would be, by taking into consideration the cost of no action, which involves the capital expenditures (CAPEX) and operational expenditures (OPEX). The cost of no action, which refers to the opportunity cost of not implementing a wastewater reuse scheme was also considered. Figure 2 below gives a summary of the approach utilized:

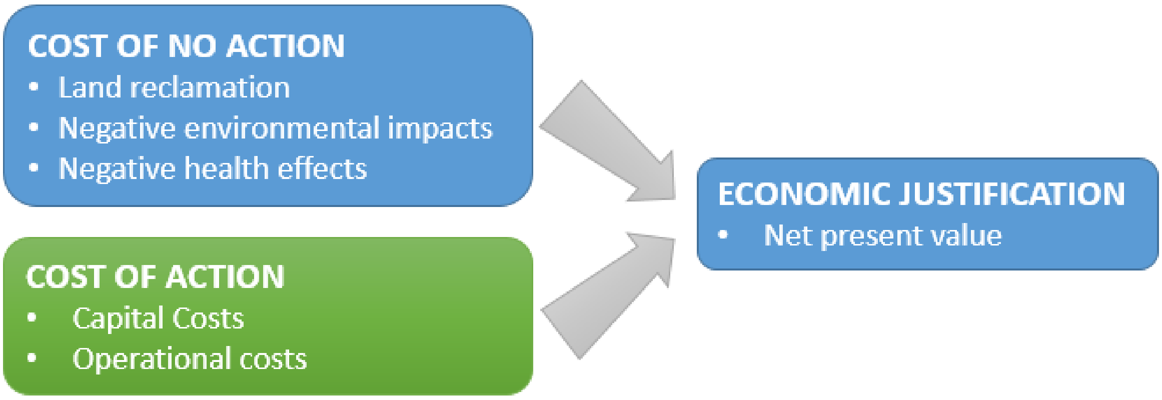

Figure 2: Schematic diagram showing the approach followed to economically justify the wastewater reuse proposal

The Net Present Value, which is defined as the difference between the present value of cash inflows and the present value of cash outflows was determined via the following equations:

$$NPV = PB - PC \tag{1}$$

Where

PB = present value of benefits

PC = present value of costs

$$PB = \sum_{t=0}^{T} B_t \, (1+r)^{-t} \tag{2}$$

$$PC = \sum_{t=0}^{T} C_t \, (1+r)^{-t} \tag{3}$$

$B_t =$ benefits at time t,

$C_t =$ the costs at time t;

r = discount rate (inflation rate)

T = lifespan of the project.

The Net Uniform Value equation given below was used to determine the OPEX and benefits

$$NUV = A\left(\frac{(1+r)^T - 1}{(1+r)^T}\right) \tag{4}$$

NUV, is the net uniform value of a series of cash flow, A. The value, A represents the net cash flow for a particular year and T is the number of periods or years in consideration.

Results here are presented in three main categories. The first includes the cost of action which includes both the capital and operational costs. The second part deals with the cost of no action which are

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essentially the benefits, both monetary and non-monetary benefits derived from the projects and finally, a comparison between the cost of action and the cost of no action was made by calculating the net present value of the project.

3. Results

The result of variables considered are presented as follows:

3.1 Cost of action

The capital cost that is associated with this research includes the cost of construction of wastewater treatment system. The wastewater treatment system will involve the construction of the following:

1. Constructed wetland expansion
2. Overhead steel tank
3. Underground water storage: The total volume of concrete used to construct the tank used for this project is 254m^3 and the internal volume of the tank is 496m^3.

The treated water can be used for flushing, irrigation etc. However, other sub-projects have been proposed that would generate revenue for the University. These research include; a car wash and an artificial river which will serve as a recreational park

The summary of Capital Expenditure (CAPEX), and Operating Expenditure (OPEX) for the proposed projects is given in Table 1 below:

Table 1: Value of costs incurred over time as a result of the reuse scheme

COSTS	CAPEX (₦)	OPEX (₦/yr.)	Total costs for lifespan (₦) r = 14%
Artificial River	30,464,391	609,290	34,651,997
Underground storage tank	14,228,920	284,580	16,184,818
Overhead Steel tank	38,001,350	760,027	43,224,960
Constructed Wetland Expansion	47,543,480	89,000	475,869,376
Car wash	1,400,000	1,060,000	8,685,303
TOTAL	**131,638,141**	**2,802,897**	**578,616,450**

A discount rate (r) of 14% was used. From Table 1, the total cost incurred during the operation at a discount rate of 14% is ₦578,616,450 i.e. **PC = ₦578,616,450**

3.2 Cost of no action (Opportunity costs)

The reuse of wastewater involves significant benefits. Therefore, the cost of no action can be interpreted as the benefits not achieved if the wastewater is disposed indiscriminately without reuse. There are two categories of benefits: market and non-market benefits. Most environmental and health benefits are non-market benefits because unlike most benefits, the forces of demand and supply do not play a role in determining the value of these benefits.

3.2.1 Energy Savings potential

The Energy saving potentials of reusing wastewater within the covenant University campus is perhaps the most striking. Table 2 gives a comparison between total dependence on groundwater sources versus dependence on recycled water.

Table 2: Amount of savings realized per day and per year when recycled wastewater is used as a complementary water source

	Exclusive dependence on groundwater	**When recycled wastewater is used**	**Savings**
Energy cost per day	₦ 117,960	₦ 57,800	**₦ 60,160**
Energy cost per session	₦ 28,782,240	₦ 14,103,300	**₦ 14,678,940**

It is important to note from table 2 that when recycled water is used to complement the existing ground water source, the cost of energy per day is only about 49% of the cost of relying completely on ground water sources.

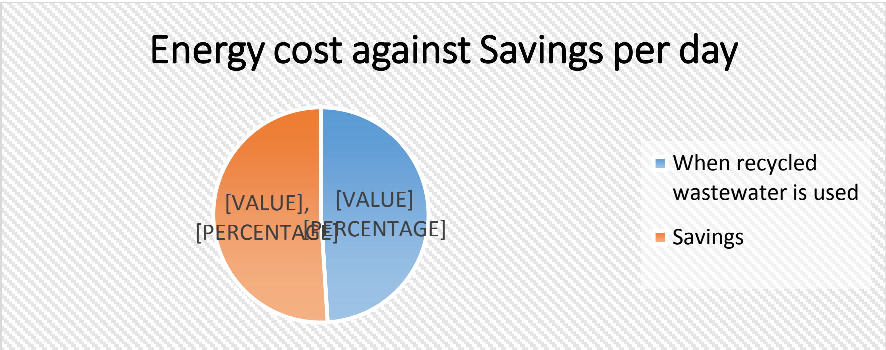

Figure 3: Pie chart comparing the energy cost to savings when recycled wastewater is used as a complementary source

In summary, Figure 3 shows that the University could potentially save ₦60,160 per day which is a whopping 51% of the total energy cost of water supply if recycled wastewater is used as a complementary source of water supply. This totals to about ₦ 14,678,940 saved per year. Breaking things down further, the university incurs about ₦ 4,915 per hour and ₦ 1.37 every second relying only on ground water sources. On the flip side, the University would potentially incur only about ₦2410 per hour and ₦0.67 per second adding a complementary source of water which is recycled wastewater in this case.

Table 3 gives a summary of the total value of benefits that would be derived from wastewater recycling

Table 3: Value of benefits derived from wastewater recycling

BENEFITS	**Fixed Benefit (₦)**	**Benefit (₦/yr)**	**Total Benefit (₦) r = 14%**
Carwash		11,049,000	75,938,980
Arobieye Land		26,700,000	183,507,160
Parks and gardens	250,000	36,630,000	252,005,330
Energy Savings		14,678,940	100,887,290
Environmental Benefit		1,140,000	7,835,140
TOTAL	**250000**	**90,197,940**	**620,173,900**

From Table 2 above, the net benefits realized at a discount rate of 14% is ₦620,173,900 i.e.

PB = ₦620,173,900

3.3 Net Present Value

Net present value is computed using the equation:

- $NPV = PB - PC$ = 620,173,900 – 578,616,450 = ₦41,557,450

The value for the NPV is summarized in table 4.

Table 4: Net Present Value

Total Benefits (₦) r=14%	**Total costs (₦) r=14%**	**NPV**
620173900	**578,616,450**	**41557450**

From calculations, the NPV is a positive ₦41,557,450 which means that the university would definitely recoup its initial investment.

3.4 Non-Monetary Benefits

The direct cost of WWR schemes are often quite well known, this is usually less the case for the benefits aspect [30]. WWR projects can be linked to significant social and environmental benefits which cannot readily be quantified monetarily [30]. Some of which include:
Sustainable surface and groundwater withdrawal: When the rate of withdrawal from aquifers is greater than the rate at which the aquifer can replenish its supply through natural processes, water shortage is inevitable. WWR creates an alternative source of water for activities and thus decreases the need to divert fresh water from sensitive ecosystems [31], [32].

Corporate Social Responsibility: CSR is carried out by organizations present in any community around the world. It is an impact initiative that requires an organization to be helpful to the close community around them. Excess recycled wastewater could be supplied to nearby villages to be used for irrigation on their farms. The most important thing an organization can do for a society or community is to contribute to a prosperous economy [33].

3.5 Discussion

With a discount rate of 14.00%, the projected cash flows are worth ₦620,173,900 today, which is greater than the initial ₦578,616,450 invested into the projects. The resulting positive NPV of the projects above is ₦41,557,450 which indicates that pursuing the above projects may be optimal.

4. Conclusion

In order to preserve available resources and ensure long term environmental sustainability, the idea of water recycling has proven to be a lasting solution. This research has been able to determine related costs associated with operating a wastewater reuse scheme, Determine the potential benefits in monetary and non-monetary terms that can be realized from executing a wastewater reuse scheme in Covenant University, Determine the opportunity cost (cost of no action) of not implementing a wastewater reuse scheme and also been able to utilize cost benefit analysis methodology and NPV (Net present value) method to determine the feasibility of the scheme in Covenant University.

Covenant University currently is moving towards being one of the first ten universities in the world, a vision tagged "vision of ten in ten". For the university to actualize this vision, many areas of the university have to be improved to acceptable standards and one of those areas is wastewater management. The result of this research has proven that if due attention is given to the water resource sector of the university, then the vision is much closer to becoming a reality.

In addition, several criteria could have been adopted for the decision making process. However, the economic criterion was chosen because it considers not only the monetary benefits but also the long term social and environmental impact a project like this would have on the community. The recycling of wastewater generated in the university provides many benefits including those related to health and to the environment however, many developing communities fail to implement projects like this because only the cost component of the project is usually considered. This is why a country like Nigeria, although blessed with sufficient water resources still faces problems with water scarcity. Proper wastewater management is the key to preserving our existing water resources. Furthermore, there is a need to invest the time and resources to fill the global data gap as better data will enable researchers and policy makers to enhance and craft solutions that will be of benefit to millions of people [34].

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Conflicts of Interest

The Authors declare no conflicts of interest

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