AN MCDA APPROACH TO WASTEWATER TREATMENT DECISION MAKING: THE CASE OF A RURAL TOWN IN LEBANON

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ABSTRACT

Even though large-scale wastewater treatment plants were built next to the major coastal cities of Lebanon, most of the wastewater is being disposed in water bodies without prior treatment because of lack of sewage networks and operational funds. In this context, this project studies the different alternatives to solve the wastewater problem in Rmeich, a rural town in the South of Lebanon, where citizens rely on cesspits as the only disposal method.

The analysis used Multi-Criteria Decision Analysis (MCDA) as means to compare viable alternatives and determine the optimum solution. Four scenarios were considered: (1) individual septic tanks, (2) conventional wastewater treatment plant, (3) natural (reed bed) treatment system, and (4) conventional wastewater treatment plant with anaerobic co-digestion (of sludge and food waste). The data was collected through interviews with: (1) experts in the field of wastewater treatment in Lebanon, representing main stakeholders: Ministry of Environment (MoE), Ministry of Energy and Water (MoEW), the private sector, and a major water pollution project; (2) the citizens of Rmeich and members of the municipal council.

The most important criteria were found to be the economic and environmental, allowing scenario (1) to achieve the best score. Collective solutions came up short mainly due to the difficulty of securing investment funds, high operational costs, as well as high technical expertise requirements, compared to individual solutions.

The economic, technical and environmental criteria of the MCDA were evaluated only based on the feedback of experts. The results revealed that the most convenient approach is individual treatment (septic tanks) for separate houses. However, if collective solutions are to be used, the natural (reed bed) system would be the most convenient. The social criteria of the MCDA rely on the interviews with the citizens of Rmeish. Yet, due to the COVID-19 lockdown, the team was not able to complete the data collection. Hopefully, the data will be included in the final paper and the corresponding findings will be discussed.

KEYWORDS

Wastewater Treatment Plant; Multi-Criteria Decision Analysis;Water Scarcity

1. INTRODUCTION

Traditionally, Lebanon was considered among the few countries in the region with relatively abundant water resources. Yet, poor

management of the water resources, coupled with weak water governance, led to over-exploitation of groundwater resources through an excessive number of private and public wells, most of which are not officially permitted [1].

As to Bint Jbeil area, where the study city is located, water scarcity is a major challenge to the wellbeing of the citizens and to the agriculture sector. Although Lebanon has 22 rivers, this particular region in the south of Lebanon is geographically situated away from them. The nearest river is the Litani River, which is mostly polluted from industrial sources, untreated sewage, agriculture runoffs, and disposal of solid waste [2]. A recent hydrological assessment by the Ministry of Energy and Water showed that the region aquifers are under high stress [1]. Specifically, Rmeich, the studied town, is facing excessive water deficiency.

Currently, wastewater treatment plants are not available in the whole area of Bint Jbeil – despite the presence of few planned stations[3]. Even if those are constructed, the pollution problem may persists due to inadequate operation – a common problem in rural small-scale wastewater plants (personal contact with Mr. Najib Abi Chedid, MOE).

Commonly, most of wastewater projects in the country adopt traditional (secondary treatment) solutions without consideration other alternatives. Also, the reuse of wastewater plant effluent as an alternative water resource is seldom adopted in Lebanon. In comparison, this team used an MCDA approach to reach the optimum solution for the wastewater problem in Rmeish, based on environmental, technical, economic and social criteria. MCDA was selected because it is a feasible tool for complex decisions where multiple alternatives are to be considered [4].

2. METHODOLOGY

The MCDA method was used to compare viable alternatives and determine the best solution. Four scenarios were evaluated, in addition to the base (business-as-usual) scenario whereby wastewater is sent to individual (leaking) cesspits.

- Scenario 1 explores the possibility of relying on house-level treatment through adequately designed and maintained septic tanks whereby treatment occurs through two successive sedimentation basins, followed by a soil diffusion system.
- Scenario 2 consists of constructing a conventional (secondary) wastewater treatment plant, along with a city-wide collection network. Sludge is sent to the nearest disposal site.
- Scenario 3 consists of replacing the conventional treatment plant with natural treatment system consisting of an artificial (reed bed) wetland.
- Scenario 4 adds to scenario 2 a sludge treatment step consisting of an anaerobic digester. This scenario aims at providing a sufficient capacity to co-digest the sludge with the organic waste generated in Rmeich.

The MCDA was based on four categories of criteria: technical (Table 1), Environmental (Table 2), Economic (Table 3), and social (Table 4). The relative percentages of each category, and of each criterion within a category, as well as the scores for each alternative were calculated as the average of values provided by the following experts:

- Suzy Hoayek: Lebanon crisis response plan coordinator, MoEW
- Najib Abi Chedid: Environmental expert, MoE
- Joseph Kassab: Manager, Saida and Bkassine wastewater treatment plants
- Rachid Mbarak: Municipality engineer and designer of Bkaatouta natural (reed-bed) wastewater treatment system
- Charbel Rizk: Civic Engagement Team Leader, Lebanon Water Project
- Hani Karameh: Partner/Manager at UNITECH-RBM – a wastewater treatment consulting company

In addition, the input of the citizens of Rmeich and the members of the municipal council will be collected, once the COVID-19 lockdown is eased, for social criteria scoring.

Table 1. Technical Criteria with definitions

Criterion	*Definition*
Local expertise	Availability of local experts capable of accomplishing the different tasks: design, execution, procurement, startup, operation and maintenance
Availability of spare parts	Availability of spare parts, or the possibility of manufacturing them, in Lebanon
Adaptability to the local conditions	Suitability to local conditions (topography, site location, etc.) and existing infrastructure
Durability	Related to the length of the operational period, prior to the need for major replacements or upgrading. The impact on cost is not considered here. For example: wetlands require replacement of the whole bed and the membrane every 10-15 years
Easiness of maintenance and cleaning	Expresses how easy and fast can maintenance and cleaning be done. This includes: washing of clogged parts, replacement of submerged parts, restarting a system after maintenance events, etc.

Table 2. Environmental Criteria with definitions

Criterion	*Definition*
Impact on soil quality	Contamination of top soil
Availability of spare parts	Availability of spare parts, or the possibility of manufacturing them, in Lebanon
Impact on water quality	Contamination of ground water and surface water bodies (both natural and man made). This includes removal of: pathogens, COD/BOD, total and suspended solids, and nutrients (Nitrogen and Phosphorus)
Impact on air quality	Associated with air emissions from treatment units
Noise pollution	Associated with noise pollution usually caused by: trucks, pumps, etc.
Deviation from dumpsites	Possibility to deviate waste material (sludge, food waste) from open dumps
Visual Pollution	Related to visual and aesthetic impacts
Water reuse	Potential to reuse the treated water for irrigation

Table 3. Economic Criteria with definitions

Criterion	*Definition*
Total investment cost (paid by the municipality or funding agency)	The total cost incurred by the municipality when implementing an alternative
Operation and maintenance cost	Operational costs include: energy, maintenance, cleaning, replacements, etc.
Land requirement	Size of land plot or the footprint of the facility

Table 4. Social Criteria with definitions

Criterion	*Definition*
Harmonization with the existing legislative	Covers two main aspects: (1) Availability of needed regulations; and (2) conformity with existing

framework	laws and regulatory framework
Accordance with priorities of national and local authorities	Level of importance within the priorities of the municipality (and/or the concerned ministry)
Social Acceptance	It includes five aspects that relates to the people of Rmeich: (1) Smell emitted, (2) Depriciation in value of land near the facility, (3) Loss of land to build the facility, (4) Willingness to excavate in their backyard, (5) How much do they accept the current consequences of the management of their wastewater
Willingness to pay	It has two components: (1) capital cost to be paid by the owner to build an individual facility; (2) monthly fees to be paid by the citizen to cover the operational costs of central facilities. The results need to be validated by the municipality.
Creation of new jobs	Direct employment opportunities created when implementing an alternative
Local development	Developmental impacts, such as: providing infrastructure for new industrial activities, etc.

3. RESULTS AND DISCUSSION

3.1 Results of the MCDA

The environmental and economic criteria were found to be more influential than others, with a weight of 30% for each. Among technical criteria, local expertise and easiness of maintenance and cleaning were assigned high weights of 22% and 24% respectively. In the environmental category, impact on water quality was found to be the most important criterion, with a weight of 31%. In the economic category, operation and maintenance cost was the determining criterion with a weight of 42%. Finally, in the social category, harmonization with the existing legislative framework and social acceptance are the most important criteria, with weights of 22% and 20% respectively. The weights of MCDA categories and individual criteria are shown in Table 5.

The MCDA results showed that Scenario 1 (septic tanks) has the highest score (3.31 over 5). It out-competed collective solutions mainly due concerns of securing appropriate funding for the initial investment, as well as economic sustainability – considering the commonly high operational and maintenance costs. Furthermore, collective solutions are considered “advanced”, compared to simple individual alternatives, thus requiring highly skilled and experienced technical personnel – often not available locally. The final MCDA scores are provided in Table 6.

Table 5. MCDA Weights

Group	***Group Weight***	***Criterion***	***Weight of criterion within group***
Technical	25%	Local expertise	22%
		Availability of spare parts	16%
		Adaptability to the local conditions	20%
		Durability	18%
		Easiness of maintenance and cleaning	24%
Environmental	30%	Impacts on soil quality	16%
		Impact on Water quality	31%
		Impact on Air quality	10%

		Noise pollution	9%
		Deviation from dumpsites	10%
		Visual Pollution	11%
		Water reuse	13%
Economic	30%	Total investment cost (paid by the municipality or funding agency)	33%
		Operation and maintenance cost	42%
		Land requirement	25%

Table 5 – cont. MCDA Weights (continued)

Group	***Weight***	***Criterion***	***Weight of criterion within group***
Social	15%	Harmonization with the existing legislative framework	22%
		Accordance with priorities of national and local authorities	17%
		Social Acceptance	20%
		Willingness to pay	16%
		Creation of new jobs	12%
		Local development	13%

Table 6. Final MCDA Scores

Scenarios	***Final Score (Over 5)***
Base Scenario	3.24
Scenario 1 *(Individual Septic tank)*	3.31
Scenario 2 *(Conventional WWTP)*	2.91
Scenario 3 *(Reed Bed System)*	3.05
Scenario 4 *(Conventional WWTP + Anaerobic Co-Digestion)*	2.68

4. CONCLUSIONS

In conclusion, the results of the MCDA exercise revealed that the most convenient approach for the city of Rmeish is individual treatment (septic tanks). This result is based on the feedback of experts that evaluated the economic, technical and environmental criteria of the MCDA. However, among collective solutions, the natural (reed bed) system was found to be the most suitable. The evaluation of the social criteria, which requires interviews with local people, was delayed due to the COVID-19 lockdown.

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