Wastewater treatment and reuse in Lebanon: key factors for future agricultural uses

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WASTEWATER TREATMENT AND REUSE IN LEBANON: KEY FACTORS FOR FUTURE AGRICULTURAL USES

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ABSTRACT – In Lebanon, like in any other Mediterranean country, the use of wastewater is becoming practical in agriculture, but without any awareness from users about their side effects on human health and crop production. This non-point source of pollution constitutes a direct threat to the vulnerable underground water. Due to this situation, corrective attempts are now being taken into accounts, such as integrated water resource management and reuse strategy of treated wastewater. This paper aims to (i) describe the current problems deriving from the use of untreated wastewater in agriculture and their disposal into natural water bodies; (ii) review and evaluate the national policy for wastewater treatment and (iii) develop practical recommendations for reuse of treated wastewater in Lebanon. Impacts in terms of water savings, socio-economical and environmental benefits are also documented. Finally, the case of Baalbeck Water and Wastewater Environmental Assessment (BWWEA) will be discussed.

Key words: Lebanon, wastewater, agriculture, policies, Baalbeck

1. INTRODUCTION

Due to the absence of institutional control of public authorities during the war period (1975-1990), domestic wastewater in Lebanon was discharged directly into the sea with no treatment prior to disposal. Environmental impacts associated with open sea disposal of untreated wastewater had gained international and local concerns in recent years, particularly with the ever continuing increase of the population and the enlargement of coastal cities. In the post-war period, several actions have been undertaken by the Government to find out immediate short-run corrective solutions and long-run planning strategies for the whole country. The need for rehabilitating the already existing wastewater collection and disposal systems, and the construction of new treatment facilities were the Government's major concerns.

The disposal of sewage and industrial effluents into the sea and rivers is frequently practiced and followed by abstraction from the rivers at downstream level for irrigation uses. The latter are in some cases extended to salad vegetables. Discharge of untreated sewage water into the sea was the common practice being used (World Bank, 1994). Other sources of marine pollution included solid waste, industrial effluents and excessive levels of nutrients and agro-chemicals with irrigation waters. Data of the World Bank (1994) focused on the construction of sewage treatment plants for cities with population higher than 100,000 inhabitants as a solution to combat the continuous contamination of the sea and the groundwater. Fig. 1 shows the distribution of wastewater outfalls into the Mediterranean Sea along the Lebanese coast. The number of sea outfalls in each Caza is indicated between parentheses (CDR/LACECO, 2000c). As indicated in Fig. 1, there are approximately 53 outfalls along the coast, 16 of which are located in Greater Beirut between Dbayeh (Northern Beirut) and Ghadir (Southern Beirut).

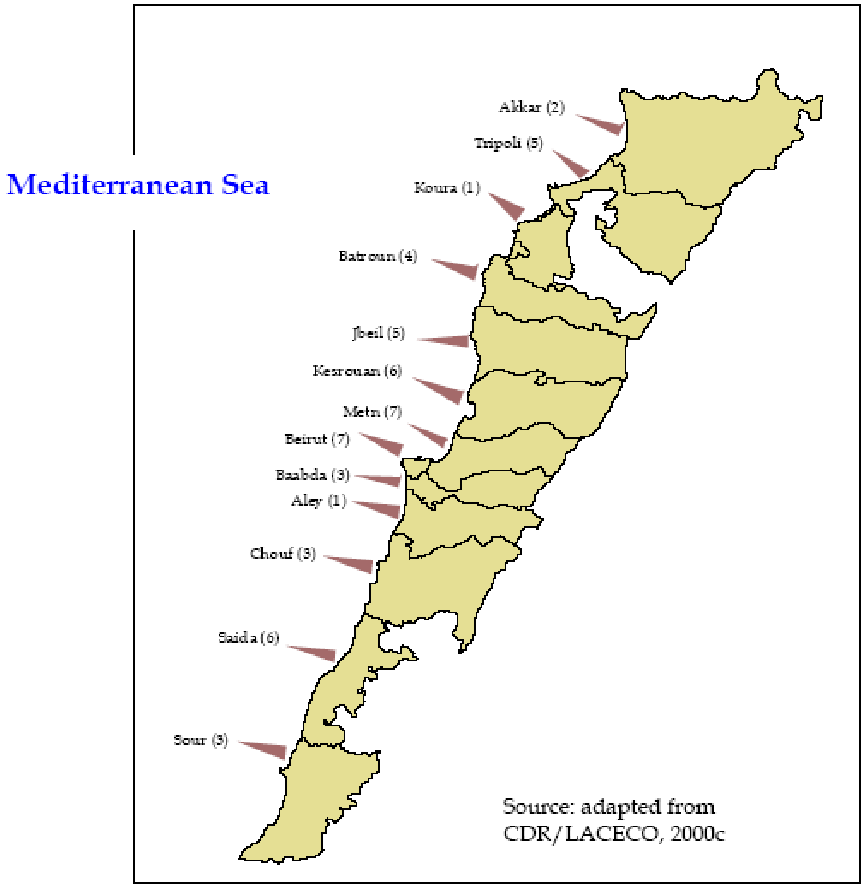

Figure 1. Distribution of wastewater outfalls into the Mediterranean Sea along the Lebanese coast

Lebanon generates an estimated 249 Mm^3 of wastewater per year, with a total BOD load of 99,960 tones. In addition, industries generated an estimated 61 Mm^3 of wastewater in 1994 and are expected to reach 192 Mm^3 by the year 2020. In the absence of waste surveys and industrial production statistics, it is difficult to estimate the composition and BOD load of the industrial wastewater. Total BOD load of industrial wastewater is about 5,000 tones per year (METAP/Tebodin, 1998 a and b). Fig. 2 depicts total wastewater generation in Lebanon.

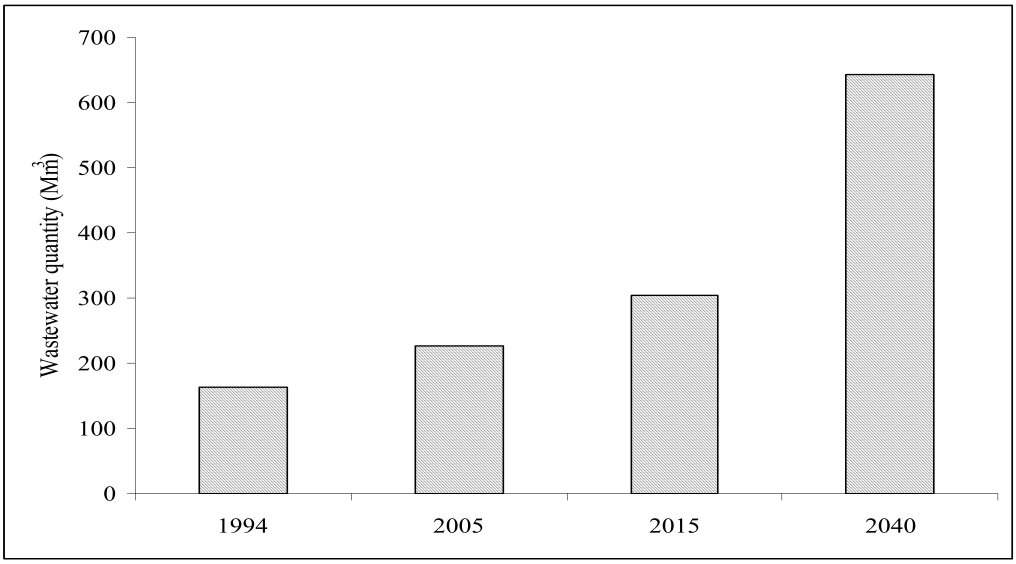

Figure 2. Estimated and expected wastewater generation in Lebanon (CDR, 2001)

Nowadays, numerous projects are underway to construct treatment plants around the country. While the type and level of treatment will vary depending on the location, the majority of these facilities involve aerobic processes which are typically associated with little to no methane emissions. At some facilities, anaerobic processes may be introduced in a hybrid fashion with aerobic ones. Moreover, most of these treatment plants will provide secondary treatment by using a combination of extended aeration and activated sludge treatment technologies, which results in water quality suitable for irrigation. As such, it is assumed in this paper that aerobic processes will be adopted for wastewater treatment.

2. NATIONAL POLICY OF WASTEWATER COLLECTION AND TREATMENT

A National Emergency Reconstruction Program (NERP) was launched in Lebanon in early ninety's, which conceived the design and construction of discharge networks of wastewater and the implementation of treatment plants in almost all the Lebanese coastal and inland cities. The program was funded through a World Bank loan. A Damage Assessment Report also was prepared in 1995 to formulate a policy framework for the wastewater sector in Lebanon. The results of the NERP were at the basis of two programs:

- Coastal Pollution Control Program (CPCP); and
- Water Resources Protection Program (WRPP).

Achievements under the NERP include the rehabilitation of two wastewater-pumping stations in El-Mina near to Tripoli in the northern coast and in Jounieh in the central coast, along with the rehabilitation and construction of 820 kilometers of sewer networks in different areas of the country. The construction of the first large-scale wastewater pre-treatment plant in Lebanon was completed in Ghadir, few kilometers south of Beirut, as well as the rehabilitation of the associated sea outfall. This plant was brought into service in November 1997. The Ghadir plant provides only preliminary treatment (i.e., grit and scum removal).

A current study is exploring the economic feasibility of upgrading the Ghadir wastewater treatment plant to provide secondary treatment before discharge into the sea. Achievements under NERP also include installation and rehabilitation of sewer networks to serve the North Beirut area as well as the northern suburbs of the Capital.

Thirty-five wastewater treatment plants (WWTP) are currently planned or under construction: seven under construction, 18 under preparation and funded, and 10 with no funding secured to date (Table 1). The Government of Lebanon initiated the construction of seven wastewater treatment plants in 2001 along the Mediterranean coast and in the inland: Saida, Chekka, Batroun, Jbeil, Chouf coastal area, Baalbeck and Nabatiyeh.

Table 1. Current status of wastewater treatment plants

Caza	Location/Name	Implementation status		
		Under Execution	Under Preparation	No Funding Secured
Akkar	Jebrayal			X
	Abdeh			X
	Michmich		X	
Minieh-Dinnieh	Bakhoun		X	
Tripoli	Tripoli		X	
Becharre	Becharre			X
	Hasroun			X
Koura	Amioun			X
Batroun	Chikka	X		
	Batroun	X		
Jbeil	Jbeil	X		
	Kartaba		X	
Kesrouane	Khanchara			X
	Harajel		X	
	Kesrouane/Tabarja			X
Metn	Dora			X

Caza	Location/Name	Implementation status		
		Under Execution	Under Preparation	No Funding Secured
Aley	Ghadir			X
Chouf	Chouf coastal area	X		
	Mazraat el Chouf		X	
South	Saida	X		
	Sour			X
Hermel	Hermel		X	
Baalbeck	Laboue		X	
	Yammouneh		X	
	Baalbeck	X		
Zahle	Zahle		X	
	Aanjar		X	
West Bekaa	Jib Jinnine/ Deir Tahnich		X	
	Karoun		X	
	Sohmor/Yohmor		X	
Hasbaya	Hasbaya		X	
Nabatiyeh	Jbaa		X	
	Nabatiyeh	X		
Bint Jbeil	Shakra		X	
	Bint Jbeil		X	

Source: Adapted from CDR, 2001

3. REGULATORY FRAMEWORK FOR ENVIRONMENTAL IMPACT ASSESSMENT IN LEBANON

The environmental framework of Lebanon is managed and supervised by the Ministry of Environment (MOE) that was created by law 216 of April 2nd 1993, to be the Government institution responsible for the development of a national strategy for sustainable development. The MOE is undergoing several review procedures to up-date the country's environmental policies and regulations including the preparation of an Environmental Impact Assessment (EIA) decree, as well as norms and standards for environmental protection.

Existing laws and regulations for environmental protection in Lebanon date as back as 1925. Ground and surface water resources have been protected since the introduction of Order No. 144 dated June 1925, which covered the major springs that supply the country's potable and irrigation needs. Protection against pollution was first addressed by Decree No. 8735 of October 1974 that prohibited the digging of wells for the disposal of raw sewage, banned infiltration from septic tanks, and the use of sewage for the irrigation of vegetables and some fruit trees.

Similar to solid waste, municipal wastewater management in Lebanon has been absent particularly during the war period, where existing treatment plants were destroyed and/or put out of operation. Decision No. 52/1 of July 1996 introduced measures to deal with the pollution of the air, water and soil, including national standards for drinking water, bathing waters and wastewater quality. Recently, Decision No. 8/1 dated March 2001 reviewed the previously issued wastewater standards to cover the discharge of wastewater to the sea, to surface water and to sewerage systems. However, standards for the reuse of treated effluents have not being addressed. Moreover for both drinking water and treated wastewater the Government did not develop any requirements with respect to sampling methods, locations, and frequency of analyses.

Wastewater is typically characterized in terms of several parameters such as: biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), and total dissolved solids (TDS). Determining the concentration of other parameters, such as nutrients (phosphorus, nitrate) and toxic metals, also prove helpful in evaluating the methods of treatment, effluent disposal, and sludge management. Table 2 gives the standards of Environmental Limit Values (ELV) for wastewater discharges into surface water in Lebanon.

Table 2. Standards of Environmental Limit Values (ELV) for wastewater discharges into surface water

Parameter	For discharge to the sea	For discharge to surface watercourses[3]	For discharge to downstream sewer networks
pH	6-9	6-9	6-9
Temperature °C	35	30	35
BOD mg O_2/l	25	25	125
COD mg O_2/l	125	125	500
Total Phosphorus mg/l	10	10	10
Total Nitrogen mg/l[1]	30	30	60
Suspended Solids mg/l	60	60	600
AOX	5	5	5
Detergents mg/l	3	3	No ELV
Coliform Bacteria 37°C in 100ml[2]	2000	2000	No ELV
Salmonellae	Absence	Absence	Absence
Hydrocarbons mg/l	20	20	20
Phenol index mg/l	0.3	0.3	5
Oil and Gease mg/l	30	30	50
Total Organic Carbon mg/l	75	75	750
Ammonia mg/l	10	10	-
Silver mg/l	0.1	0.1	0.1
Aluminuim mg/l	10	10	10
Arsenic mg/l	0.1	0.1	0.1
Barium mg/l	2	2	2
Cadmium mg/l	0.2	0.2	0.2
Cobalt mg/l	0.5	0.5	1
Chromium total mg/l	2	2	2
Hexavalent Chromium mg/l	0.2	0.2	0.2
Copper total mg/l	1.5	0.5	1
Iron total mg/l	5	5	5
Mercury total mg/l	0.05	0.05	0.05
Manganese mg/l	1	1	1
Nickel total mg/l	0.5	0.5	2
Lead total mg/l	0.5	0.5	1
Antimony mg/l	0.3	0.3	0.3
Tin total mg/l	2	2	2
Zinc total mg/l	5	5	10
Active Chlorine mg/l	1	1	No ELV
Cyanides mg/l	0.1	0.1	1
Fluoride mg/l	25	25	15
Nitrate mg/l	90	90	No ELV
Phosphate mg/l	5	5	No ELV
Sulphate mg/l	1000	1000	1000
Sulphide mg/l	1	1	1

Source: Ministry of Environment, Decision 8/1/2001

[1] Sum of Kjeldahl-N (organic N + NH3), NO3-N, NO2-N

[2] For discharges in the vicinity of bathing waters a more stringent standard may be necessary.

[3] The ELVs are for discharge into a surface water flow of not less than 0.1 l/sec.

4. WASTEWATER GENERATION RATES

Wastewater rate can be estimated using a daily per capita average wastewater generation rate multiplied by the number of population. The daily per capita average rate can vary with location and season. In 1994, wastewater generation rate for Lebanon was about 120 l/capita/day. A likely increase rate of 1.5% will bring the average wastewater generation rate to 238 liter/capita/day by year 2040.

Using this average per capita wastewater generation rate and the average wastewater characteristics with the population estimates mentioned above, the total yearly quantity of domestic wastewater generated for the baseline scenario is summarized in Table 3 for the different regions in Lebanon.

Table 3. Quantity of wastewater generation in Lebanon

Region	Population '000	Wastewater Mm^3	BOD '000 ton	COD '000 ton	N '000 ton
		1994			
Greater Beirut area	1165	51	6.5	32.1	5.1
Mount Lebanon	695	30	3.9	19.2	3.0
Bekaa	460	20	2.6	12.7	2.0
North Lebanon	770	34	4.3	21.2	3.4
South Lebanon	635	28	3.6	17.5	2.8
Total Lebanon	3725	163	20.9	102.8	16.3
		2005			
Greater Beirut area	1372	71	9.1	44.6	7.1
Mount Lebanon	919	42	5.4	26.6	4.2
Bekaa	542	28	3.6	17.6	2.8
North Lebanon	907	47	6.0	29.5	4.7
South Lebanon	750	39	5.0	24.4	3.9
Total Lebanon	4390	226	29.0	142.7	22.6
		2015			
Greater Beirut area	1593	95	12.2	60.1	9.5
Mount Lebanon	950	57	7.3	35.8	5.7
Bekaa	629	38	4.8	23.7	3.8
North Lebanon	1053	63	8.1	39.7	6.3
South Lebanon	868	52	6.7	32.7	5.2
Total Lebanon	5092	305	39.0	192.1	30.5
		2040			
Greater Beirut area	2311	201	25.7	126.5	20.1
Mount Lebanon	1378	120	15.3	75.4	12.0
Bekaa	912	79	10.1	49.9	7.9
North Lebanon	1527	133	17.0	83.6	13.3
South Lebanon	1260	109	14.0	69.0	10.9
Total Lebanon	7388	642	82.1	404.3	64.2

Source: CDR, 2001

Table 3 represents only domestic and commercial wastewater quantities. Industrial wastewater quantities are highly variable and depend on the type of industry as well as the industrial process itself. At present, these quantities can be estimated with little degree of certainty because of the general lack of regulatory monitoring and enforcement.

4.1. Effluent Discharge Standards

In coastal areas, the ultimate disposal of treated wastewater is primarily to the sea. Pretreatment of wastewater before discharge into the marine environment through ocean outfalls could be performed with different degrees of complexity (preliminary, primary, secondary, or tertiary). Aquifer recharge is a possibility, which can be considered to alleviate the problem of seawater intrusion into coastal aquifers resulting from indiscriminate tapping into these aquifers. Table 4 summarizes the marine wastewater discharge standards in Lebanon.

Table 4. Proposed Lebanese marine wastewater discharge standards

Parameter	Limiting value*	Parameter	Limiting value	Parameter	Limiting value
BOD	60.0	Aluminum	3.000	Zinc	5.000
COD	100.0	Ammonium	3.000	Silver	0.100
TDS	200.0	Mercury	0.005	Barium	2.000
TSS	60.0	Lead	0.500	Cobalt	2.000
Sulfur	1.0	Cadmium	0.050	Pesticides	0.200
Grease	15.0	Arsenic	0.050	Cyanide	0.100
Hydrocarbons	0.50	Chromium	1.000	Temperature	35°C
Phosphate	5.0	Copper	1.500	pH, unit	6-9
Nitrate	40.0	Nickel	0.100	Turbidity, NTU	50
Phenols	1.0	Iron	1.500		
Fluorides	1.5	Manganese	1.000		

Source: Ministry of Environment, 1996

* All units in mg/l unless specified otherwise

Wastewater reclamation and usage for irrigation purposes is another possibility for effluent management. A number of constraints, such as difficulty in finding suitable sites with ample areas for secondary treatment and limited financial resources available for initial investment as well as for operation and maintenance, basically narrow down the alternatives to no more than secondary treatment, all while minimizing the amount if surface area required. Table 5 illustrates the assessment of wastewater treatment and disposal alternatives.

Table 5. Assessment of wastewater treatment and disposal alternatives

Alternative	Treatment description
Maintain the same offshore disposal method	None
Preliminary treatment and offshore disposal	Includes measurement and regulation of incoming flow and removal of large floating, solids, grit and perhaps grease. Typical utilities used at this stage include coarse screens, commonutors, grit and grease removal tanks skimming or vacuum flotation tanks), pre-aeration and equalization tanks.
Primary treatment and offshore disposal	Includes the removal of suspended solids. In addition to the preliminary utilities, it consists of clarifiers with mechanical sludge removal. It also includes chemical coagulation to remove finer and dissolved solids such as phosphorus.
Secondary treatment and offshore disposal	Known as biological treatment and intended for the removal of soluble and colloidal organic matter, which remains after primary treatment. This treatment alternative is designed to maintain a large mass of bacteria within the system confines to biodegrade soluble and colloidal organic material. There are two main techniques to carry out this process namely the attached (sand or tricking filters, rotating biological contactors) or suspended (activate sludge) growth process.
Secondary treatment and land irrigation	Same as above
Secondary treatment and aquifer recharge	Same as above
Tertiary treatment and aquifer recharge	Typically performed if the effluents are intended for domestic reuse instead of disposal. May include the addition of chemicals or complex biological activities and advanced treatment systems such as activated carbon and reverse osmosis. Removes excess nutrients and heavy metals.
Tertiary treatment and municipal reuse	Same as above

Source: El Fadel and Sadek, 2000

4.2. Wastewater Reuse

It may be feasible to utilize effluent from large coastal plants to irrigate large acreages of crops or to artificially recharge ground water to arrest saline intrusion. Saline intrusion is of increasing concern in several coastal areas. However, only secondary treatment to render the wastewater acceptable for discharge to the sea is proposed for the large coastal plants. Effluent reuse for irrigation or for combating saline intrusion would require at least tertiary treatment, which could, if required, be added at a later stage. The relatively small quantities of effluent from individual rural plants will be insufficient for large reuse schemes and options will be limited to the irrigation of public planting, such as highway central reservations, and tree crops during the summer months, with discharge to watercourses during the winter. In forested areas, effluent storage ponds might be provided for fire fighting.

Permitted levels of reuse for four classes of reclaimed wastewater are shown in Table 6. Not withstanding these permitted uses, wastewater reuse of any class is prohibited in sensitive areas and to reduce environmental impacts:

- Effluent shall not be used to spray irrigate food crops;
- Effluent shall only be applied to slopes greater than 15° by trickle irrigation;
- Effluent shall be applied so both direct and windblown spray remains within the area approved for application
- No irrigation shall take place within 400 m of surface waters used for potable supply; and
- The depth to ground water below irrigated areas shall be 3 m or more.

Table 6. Permitted uses of treated wastewater

Class	Approved Uses
Class 1A	• All Class 1 uses with no setback to dwelling unit or occupied establishment; • Compaction of backfill around potable water pipes; • Irrigation of food crops where there is no contact between the edible portion of the crop and the wastewater. No spray irrigation for food crops.
Class 1B	• Impoundment, recreational or ornamental; • Irrigation of parks and golf courses with setback limitation • Irrigation of urban landscaping with setback limitation • Street cleaning • Toilet flushing.
Class 2	• Concrete mixing; • Dust suppression; • Irrigation of fodder, fibre and seed crops for milk producing animals; • Irrigation of roadway median landscapes; • Livestock watering; • Soil compaction.
Class 3	• Irrigation of fodder, fibre and seed crops for non-milk producing animals; • Irrigation of forest trees.

5. CASE STUDY: THE BAALBECK WATER AND WASTEWATER ENVIRONMENTAL ASSESSMENT (BWWEA)

The BWWEA project is expected to have major beneficial impacts on the environment, as it would provide proper collection of wastewater of Baalbeck city and its surrounding rural areas in Northern Bekaa Valley, thus reducing surface and groundwater contamination. The project will also provide controlled water supply connections to the households and will reduce overdraft of the aquifer. It also will improve health conditions of the rural population by providing them with good quality domestic water from storage facilities. These potential benefits should outweigh the magnitude of the adverse environmental impacts arising from the construction of the water distribution and wastewater collection networks. The project is designed to improve the quality and security of water supply and the collection and disposal of wastewater. A significant improvement in the chemical, biological and microbiological quality of the surface and ground water resources is expected. This will lead to considerable public health benefits for the residents of the area. In particular, it is expected to result in a reduction in the incidences of water born diseases.

Water demands in the project area have been estimated at 34,452 m^3/day for a total population of 246,000 inhabitants in year 2000 and are expected to increase to 54,173 m^3/day for an estimated population of 403,000 inhabitants by year 2015.

The wastewater treatment plant consists of secondary treatment using sludge activated process plus chlorination. The capacity of the BWWEA is 12,500 m^3/day with the possibility of extension to 25,000 m^3/day after the year 2008. The treatment plant is designed to give a treated effluent that would conform to the Lebanese standards with BOD = 35 mg/l and SS = 30 mg/l. Treated effluent will be discharged by gravity into an open ditch by means of a pipeline outfall, 800 mm diameter and 1.2 km long from the treatment plant. Manholes have been installed along the outfall to enable pumping of the treated effluent for irrigation purposes. The open ditch has the capacity to flow the additional effluent into an appropriate water body. Moreover, an allocation for extending the outfall from the treatment plant and discharging the treated effluent into drainage channel with suitable capacity has been made.

In view of the water scarcity and the high demand for irrigation water in the project area, there is a great possibility that treated effluent would be reused for irrigation purposes. Table 7 presents the monitoring program during the operation of the BWWEA.

Table 7. Monitoring program during the operation of the BWWEA

Parameters to be monitored	Frequency	Standard
BOD	every week	25 mg/l
COD	every week	125 mg/l
pH	every week	6 - 9
Oil and grease	every week	10 mg/l
TSS Every day	every week	50 mg/l
Nematode eggs	every week	< 1 egg/liter
Fecal coliform	every week	200 MPN/I00 ml
Heavy metals	every week	10 mg/l
Phosphate	every week	5 mg/l
Ammonia	every week	10 mg/l
Nitrate	every week	90 mg/l
Fluoride	every week	20 mg/l
Sulfate	every week	500 mg/l
Sulfide	every week	1 mg/l
Chlorine, total residual	every week	0.2 mg/l
Phenols	every week	0.5 mg/l
Arsenic	every week	0.0 mg/l
Cadmium	every week	0.1 mg/l
Chromium	every week	0.1 mg/l
Copper	every week	0.5 mg/l
Iron	every month	3.5 mg/l
Lead	every month	0.1 mg/l
Selenium	every month	0.1 mg/l
Silver	every month	0.5 mg/l
Zinc	every month	2.0 mg/l
Chlorine	every week	0.2 mg/l

[*] At the discharge from the outfall or at 1 km from the BWWEA

Once operational, the BWWEA will provide secondary treated effluent that could be reused for irrigating about 225 hectares. Consequently, the effluent should be of acceptable quality so that it can be safely reused for agriculture irrigation. In the absence of national standards for treated wastewater re-use, the effluent will have to meet the WHO quality guidelines for use in agriculture. One of the major parameter of concern is the level of nematodes, which should be less than one egg per liter for water used in agriculture. Another major concern is the concentration of toxics such as cadmium and lead. The existing treatment plant can ensure the removal of nematodes to less than one percent of the concentration in the raw wastewater entering the treatment plant. Therefore the presence of nematodes in the treated effluent will be directly related to their concentration in the raw wastewater. During the operation phase, monitoring of nematodes in the influent and effluent will be conducted. An allocation for the installation of filters for the removal of nematodes has been made in case the treated effluent does not meet the required standards with respect to nematodes.

5.1. Advanced wastewater treatment process

Simpler and less costly alternative systems have been tested, which eliminate clari-flocculation, but include the coagulation and flocculation stages in line. The disinfection processes and the removal of suspended solids are especially important as many pathogenic agents are closely attached to solid particles or to colloidal agglomerates in suspension. It is essential that suspended solids are efficiently removed in order to ensure that the wastewater has been satisfactorily disinfected. The removal of phosphorus, when required, implies additional operating costs, as the precipitation and disposal of chemical sludge (Boari and Trulli, 1997).

The clari-flocculation stage, achieved through the processes of coagulation, flocculation and sedimentation, permits the removal of solids, principally of organic nature, which are present in the secondary effluent. Filtration, following sedimentation or an alternative method, is an indispensable stage as it renders the wastewater limpid and therefore perfectly suitable for disinfection. Moreover, this is an essential condition for the destruction of viruses and parasites, which are extremely resistant to disinfectants. Filtration is more commonly achieved by using homogeneous, single layered sand filters or the dual-media type filters, containing a mixture of sand and anthracite, which also permit the removal of soluble organic compounds, at moderate, rather than high, operating costs (Lopez and Liberty, 1992).

Disinfection takes on a very important role, especially with regard to the very restrictive limit values set by law concerning pathogenic loads. Disinfection is achieved through specific processes using radiation, such as UV rays, or chemical agents, including chlorine, ozone, bromine and iodine. The most frequently used disinfectant is chlorine because it is easily analyzed and economical to use.

Often, the destruction of the pathogenic load is inadequate, sometimes because of the limited diffusion of disinfectant in wastewater or because of the contact time with pathogenic organisms. It is often necessary to add high doses of chlorine in order to obtain acceptable levels. Consequently, it is necessary to operate a subsequent dechlorination stage to reduce the level of residual chlorine, which could damage the crops. Different agents can be used to achieve this process. Those must commonly used are sulphur dioxide, which has the advantage that it can be administered using the same apparatus used for chlorine and sodium sulphite, which is cheap and highly stable.

Intensive advanced treatment for secondary effluent involves all the processes described above. Both setting-up and operational costs are high, particularly those connected with the sedimentation tanks, with use of chemical coagulants and the handling of the quantities of sludge produced. Although complex systems, such as that illustrated, guarantee the standard of refinement, current tendencies prefer more simple systems, which may not involve the use of reactors in the coagulation-flocculation, sedimentation and dechlorination stages (Nurizzo and Mezzanotte, 1992).

The process of filtration by contact and direct filtration were experimented in California. The processes operated with dosages of aluminum salts in the 2-5 mg/l range and of chlorine in the 5-10 mg/L range, with 90 minutes of contact time (Asano and Levine, 1996). The results showed that the simplified systems adopted by the Department of Health of California as an alternative to the intensive process are efficient. A 10 NTU turbidity value can be considered the limit indicating the economic advantage between the intensive process and the contact or direct filtration processes.

6. FINAL RECOMMENDATIONS

Selection of the appropriate technology for treatment and disposal of wastewater requires an in-depth evaluation of the objectives that are to be achieved. Subject to technical and economical constraints, the general objectives outlined below could be regarded as guidelines set for process selection:

- Domestic water sources-aquifers, springs, wells, or surface-water-should be protected against contamination by wastewater.

- Irrigation of agricultural lands by treated wastewater and utilization of treated sludge as a soil conditioner should be promoted where it is cost-effective, but only when pathogens have been effectively removed. Pollution of irrigation supply sources by inadequately treated wastewater should be prevented.
- Water conservation by means of irrigation reuse, aquifer recharge, or industrial reuse of treated effluent should be practiced where it is cost-effective and water resources are otherwise inadequate.

Wastewater treatment facility is intended to treat domestic wastewater generated by inhabitants to secondary or tertiary treatment levels. The main advantage of such opportunity is to provide effluent and sludge reuse in agriculture. Furthermore, negative impacts resulting from the plant operation are kept far away from urban agglomerations. The disadvantages include odor nuisance and visual impact.

The reuse of effluent in irrigation would provide a valuable irrigation water source. The effluent quality criteria can be based on FAO or WHO standards (Marecos do Monte *et al.*, 1996) for effluent reuse. Strict standards for restricted irrigation reuse should be adopted and respected considering the agricultural practices in the concerned areas (FAO, 1992 a and b; FAO, 1993).

It is recommended that effluent reuse in agriculture be restricted to localized irrigation and spray methods for selected crops to minimize the risk of effluent contact with edible parts and to prevent deep water percolation. It is also recommended that effluent monitoring requirements include selected heavy metals and nematodes to ensure that the appropriate standards for reuse are met. Substantial data for influent nematode concentration is required to ascertain the treatment plant capability of achieving the WHO effluent standard for nematodes. It is recommended that funds be made available for constructing tertiary filters, pending the evaluation of the acquired data and establishing the need for tertiary treatment. The provision of long term storage is required for compliance with WHO microbial standards for nematodes and for proper sludge application management.

Alternative sludge disposal methods also have to be assessed. Sludge disposal by incineration and land filling is very costly. Application of sludge in agriculture as a fertilizer is the preferred method due to the sludge agronomic value and the economic savings in disposal. The potential for effluent and sludge reuse in agriculture revealed that nitrogen content is considerable. Therefore, considering that the cost of applying commercial fertilizers is more economical and has more agronomic value, it is recommended that the sludge be provided to the farmers at no cost initially.

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