ENVIRONMENTAL IMPACT ASSESSMENT

WASTEWATER TREATMENT PLANTS
HASBAIYA MUNICIPALITIES
CAZA OF HASBAIYA

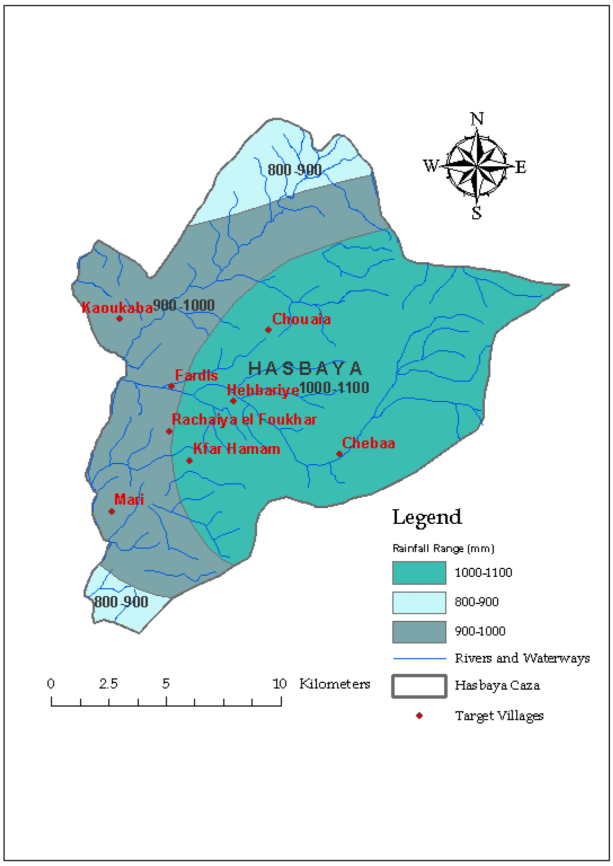

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TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

LIST OF PHOTOGRAPHS

PHOTOGRAPH **PAGE**

LIST OF ABBREVIATIONS

ELARD	Earth Link and Advanced Resources Development
ACDI	Agricultural Cooperatives Development International
As	Arsenic
AUB	American University of Beirut
BIA	Beirut International Airport
BOD_5	5-day Biochemical Oxygen Demand
BMLWWE	Beirut and Mount Lebanon Water and Wastewater Establishment
C	Composite Sample
C_3	Hammana Formation
C_{2b}	Mdairej Formation
C_4	Sannine Formation
Cd	Cadmium
CDR	Council for Development and Reconstruction
CNEWA\PM	Catholic Near East Welfare Association \ Pontifical Mission
Co	Cobalt
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DMR	Discharge Monitoring Report
E	East
EAAS	Combined UASB and EAAS
EIA	Environmental Impact Assessment
ELV	Environmental Limit Values
EMP	Environmental Management Plan
ES	Environmental Statement
Fe	Iron
G	Grab Sample
GAS	General Awareness Seminar
GBA	Greater Beirut Area
GDP	Gross Domestic Product
Hg	Mercury
HL	Hydraulic Loading
ISWMP	Integrated Solid Waste Management Plan

M	Monthly
MCI	Mercy Corps International
METAP	Mediterranean Technical Assistance Program
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
Mn	Manganese
Mo	Molybdenum
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoIM	Ministry of Interior and Municipalities
MoI	Ministry of Industry
MoPH	Ministry of Public Health
MoPWT	Ministry of Public Works and Transport
MSW	Municipal Solid Waste
NGO	Non-Governmental Organization
NWMP	National Wastewater Management Plan
NH_3	Ammonia
Ni	Nickel
NNE	North Northeast
ON	Organic Nitrogen
Pb	Lead
PC	Process Control
PCB	Polychlorinated Biphenyls
PP	Process Performance
Se	Selenium
Sn	Tin
SWTP	Solid Waste Treatment Plant
SOP	Standard Operating Protocol
SPASI	Strengthening the Permitting and Auditing System for Industries
SRI	Stanford Research Institute
SRT	Solids Retention Time
SSW	South Southwest
STW	Specialized Training Workshop
SWEMP	Solid Waste Environmental Management Plan
TSS	Total Suspended Solids
UNDP	United Nations Development Program

UPP	Unit of Planning and Programming
VOCA	Volunteers in Overseas Cooperative Assistance (VOCA)
VSS	Volatile Suspended Solids
W	West
WB	World Bank
WWTP	Waste Water Treatment Plant
Zn	Zinc
1/W	Once per Week
1/2W	Once per Two Weeks
^{0} C	Degrees centigrade
cm	Centimeter
hr	Hour
km	Kilometer
m	Meter
m^3	Cubic meters
m^3/day	Cubic meters per day
m^3/s	Cubic meter per second
mg/L	Milligrams per liter
mL	Milliliter
mm/year	millimeters per year
ppm	Parts per million

NON-TECHNICAL SUMMARY

INTRODUCTION

This Environmental Impact Assessment (EIA) has been prepared to address the potential environmental impacts that could arise from the construction and operation of eight Wastewater Treatment Plants (WWTPs). The intended plants will be located in the villages of Chebaa, Chouaia, El Fardis, Hebbariye, Kaoukaba, Kafar Hamam, Mari and Rachaiya el Foukhar in the Caza of Hasbaya, South Lebanon. Additionally, the EIA evaluates various alternative treatment technologies and presents technical criteria on which to base the selection of the most suitable technology.

The purpose of the project is to alleviate the severe impacts of uncontrolled sewage discharges into the environment. Proper design/selection, construction, and management of the Wastewater Treatment Plants (and upgrading/construction of wastewater collection networks) would mitigate such negative impacts. The main sections of the EIA include *definition of the legal and institutional frameworks, description of the project and the environment, impacts assessment, and presentation of an environmental management plan (EMP).*

LEGAL AND INSTITUTIONAL FRAMEWORKS

In the legal framework, the draft EIA decree has been revised by the Unit of Planning and Programming (UPP) at the Ministry of Environment (MoE), and is waiting for legislative approval. This draft decree sets the procedures and guidelines for the proponent of every proposed project that could have significant impacts on the environment, to prepare its own EIA or Environmental Statement (ES). The MoE is the main institution responsible for the revision and approval of the EIA.

Institutionally, the project mainly involves the eight villages' corresponding municipalities, the Ministry of Interior and Municipalities (MoIM) and the MoE, in addition to MCI.

PUBLIC INVOLVEMENT

The project is the foremost issue being requested by the eight concerned municipalities of Hebbariye. During this study, the consultant and MCI, working hand in hand, met frequently with representatives of all municipalities and with technology providers. During that meeting, the forecasted projects for the area were presented to the public. Many other meetings, presentation, and workshops relevant for each specific project are yet to be implemented as well. In compliance with EIA guidelines, a notice was posted at the concerned Municipalities offices in early May 2004 informing the public of the EIA study, the proposed WWTP, and soliciting comments. Remarks would be welcome and clarifications would be made for all interested parties for the 18 days during which the notice was publicized and an additional 7 days following its removal.

DESCRIPTION OF THE PROJECT

Currently, untreated sewage generated in the Hasbaiya area is directly being disposed of in the environment. This situation is exposing the public to the associated negative health impacts and is leading to deterioration of water quality in the area. Proper conveyance and treatment of sewage is of utmost importance to avoid such impacts and will be addressed by the construction of eight WWTPs (and collection networks) to serve this area.

It is essential to note that potable water is being contaminated by the ingress of wastewater into the water springs distributed in the Hasbaiya area. In general, wastewater is being discharged directly into run-off ditches and storm water galleries as well as uncontrolled septic tanks.

In the context of analysis, the following six alternative wastewater treatment schemes were screened: (1) Preliminary treatment, (2) Primary treatment alone, (3) Secondary aerobic biological treatment through suspended growth process, (4) Secondary aerobic biological treatment through attached growth process, (5) Combined attached and suspended aerobic biological treatment, and (6) Tertiary treatment through aerobic suspended biological treatment with additional disinfection and filtration. The "Do Nothing" scenario is not considered as a legitimate option, since wastewater is currently being discharged without treatment into the environment.

The plants were divided into 2 groups based on the process selected, which is directly linked to the site characteristics, primarily based on geological and hydrogeological considerations. **Group I** plants include the WWTPs of El Fardis, Kaoukaba and Mari. **Alternative 3** was selected as the most appropriate, whereby in that case, advanced treatments levels are not required. The three sites' underlying geological formations, and most importantly, their proximity to the Hasbani River will make the expected quality of effluent discharge meet the Environmental Limit Value (ELV) standards published by the Ministry of Environment (MoE) (Decision 8/1/2001). Moreover, the Hasbani River flow reaches more than the standard dilution factor of 0.1 m^3/sec. However, the Kaoukaba and El Fardis plants will require additional network infrastructure (between 500 – 1000 meters) for direct discharge into the perennial Hasbani River.

Group II plants include the WWTPs of Chebaa, Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar. Here, **Alternative 6** was selected as the most appropriate one where advanced treatment levels are required while considering the underlying geological formations in each case and the lack of a suitable water body to discharge the treated effluent. After meeting stringent quality standards, tertiary treated liquid effluent will be discharged into a nearby seasonal river, usually a tributary that leads downstream to the Hasbani River. The expected quality of the liquid effluents shall meet better values than the standards of effluent discharge to surface water recently published by MoE. Table A presents the main relevant effluent standards.

All proposed WWTPs will generate two main types of effluents: waste sludge and treated liquid effluent. After on-site dewatering, the stabilized sludge shall be landfilled at the nearest authorized disposal site according to the standards and guidelines of the Ministry of the Environment. Other debris and solid wastes produced from the plant should be disposed of in MoE approved landfills. Saturated media filter and activated carbon in the case of tertiary treatment will be returned to the supplier.

Table A. Effluent Standards of Treated Wastewater*

Parameter	*Effluent Standards*
PH	6 – 9
BOD_5	25
COD	125
Suspended Solids	60
Ammonia-Nitrogen as N	10
Nitrate	90
Total Phosphorus	10

* All units in mg/L except for pH (unit less)

DESCRIPTION OF THE ENVIRONMENT

The Hasbaiya Caza is located in the Nabatiyeh Governorate, with land elevations ranging between less than 800 m and 1200 m above sea level. A generally good road network connects all eight villages under study.

The total annual precipitation in the area is ranges between 660- 985 mm. Temperature ranges from a minimum of 8 ºC in winter to a maximum of 23 ºC. Dominant winds are West and Northwesterly. Continental east and southeasterly winds are also frequent.

In El Fardis, Kaoukaba and Mari, the Hasbani River flows around 500 -700 meters downstream those villages. Other sites usually have an intermittent river crossing a nearby valley; the Chebaa Valley seasonal flow for the villages of Chebaa and Hebbariye, the Abou Aamte Valley seasonal flow for Chouaia, Ras-en-Nemer Valley for Kfar Hamam, and the Fraidiss Valley for Rachaiya el Foukhar.

Geological formations in the study area range from the Jurassic Period to some Quaternary deposits. Jurassic formations were found mainly underneath the sites of Chebaa, Chouaia, Hebbariye and Rachaiya el Foukhar. In Kfar Hamam and Rachaiya el Foukhar, five formations belonging to the Cretaceous Period were identified (Shouf Sandstone, Abeih, Mdairej, Hammana and Sannine). Volcanic basalts are present in Kaoukaba, Fardis, Kfar Hamam and Mari sites. Finally, quaternary deposits were identified in areas nearby the Hasbani River (Kaoukaba, El Fardis, Mari and Kfar Hamam).

The major aquifers existing in the study area are divided on one hand between the karstic, very permeable aquifers such as the Kesrouane karstic Aquifer (in Chebaa) and the Mdairej karstic aquifer (such as in Hebbariye), and the other hand the impermeable formations acting as protective seals, such as the Chekka formation in Kaoukaba, the Bhannes formation in Kfar Hamam, and the Hammana formation in Rachaiya el Foukhar.

The main supply of potable water is being conveyed from Chebaa through the potable water distribution network to all eight Hasbaiya villages under study. Additionally, wastewater is being discharged directly from residences into run-off ditches and storm water galleries, which in turn conveys the wastewater into open land, agricultural fields, and surface water bodies. Developed infrastructure within all villages is mainly limited to road network, telephone, electricity, and water supply. A local solid waste management system does not exist; most villages in the Caza of Hasbaiya rely on municipal waste collection, open dumping and burning.

Local habitants are mainly members of the active population (between 18 and 50 years old). The economy in most municipalities of the Hasbaiya region is driven by agriculture, trade and services and money sent by expatriates. Average household income within the region amounts to less than six million Lebanese pounds annually.

IMPACT ASSESSMENT

Negative impacts are likely to occur on groundwater resources whenever uncontrolled tank leakages take place or more importantly, in the case of plant malfunction or insufficient treatment. Risks of groundwater contamination are increased whenever the geological formation is considered relatively permeable, leading to possible wastewater percolation though channels and fissures in the case of the presence of karstic formations. On the other hand, if well operated, all WWTPs are expected to improve the quality of the downstream water resources, notably the Hasbani River. The assessment of impacts indicated that negative impacts should not be significant as long as process performance is continuously controlled. Other positive impacts include improved public health and living standards, these are considered as a direct consequence and key goals of the project implementation.

Note that in the worst case scenario, in the case of a WWTP, the treatment plant is not operating properly due to malfunction of the EAAS for example, and the impacts will be amplified due to sewage collection network that is expected to be built, leading to a point source of pollution. However, based on the reliability of the technologies selected, the likelihood of this situation is minimal.

ENVIRONMENTAL MANAGEMENT PLAN

In order to ensure the proper operation of the eight WWTPs, an environmental management plan (EMP) system must be implemented. The EMP shall assure mitigating potential impacts, monitoring of effluent quality, proper staff training, organized record keeping, and the provision of effective contingency measures. Mitigation measures to reduce the likelihood and magnitude of the above-described impacts induced by the construction and operation of the proposed WWTPs are described in Table B.

Table B. Summary of Main Mitigation Measures

Impact	*Mitigation Measures*
Dust Emissions	♦ Dust emissions from piles of soil or from any other material during earthwork, excavation, and transportation should be controlled by wetting surfaces, using temporary wind breaks, and covering truck loads ♦ Piles and heaps of soil should not be left over by contractors after construction is completed. Also excavated sites should be covered with suitable solid material and vegetation growth induced
Noise Generation	♦ Temporary noise pollution due to construction works should be controlled by proper maintenance of equipment and vehicles, and tuning of engines and mufflers. Construction works should be completed in as short a period as possible by assigning qualified engineers and foremen ♦ Noise pollution during operation would be generated by mechanical equipment, namely transfer pumps, air blowers, and sludge dewatering units. Noise problems should be reduced to normally acceptable levels by incorporating low-noise equipment in the design and/or locating such mechanical equipment in properly acoustically lined buildings or enclosures
Odor Generation	♦ Store produced residuals in closed containers and transport them in enclosed container trucks ♦ Keep always an optimum aeration rate at the aeration tanks ♦ If possible, proper landscape around the facility may serve as a natural windbreaker and minimize potential odor dispersions, if present
Soil and Water Pollution	♦ Placing impermeable seal beneath the WWTP to avoid contamination of underlying aquifers in case of leakage (remove) ♦ Use corrosion resistant material in the reactor components to avoid leakage. ♦ Properly dispose of effluents; monitoring of effluents quality is essential to avoid misuse of the latter; re-use of effluents (sludge or treated wastewater) shall be performed as per appendix E

Monitoring of individual processes within each plant is of equal importance to allow identification of probable causes in case of unlikely process deficiencies.

Except during plant start-up, when a thorough monitoring schedule is recommended, monitoring efforts can be limited to regular checks (weekly or bi-weekly, as needed) of effluent quality for the following parameters:

- pH and temperature
- BOD_5 and COD
- Suspended Solids

- Total Nitrogen
- Total Phosphorus
- Ammonia-nitrogen
- Nitrate–nitrogen
- Phosphate
- Coliform bacteria

Sampling costs (including analysis at laboratory) would be manageable. If it is decided to reuse the effluent, fecal coliforms and chlorine residual should also be checked regularly. On-site monitoring of temperature, pH, and flow measurements would be continuous. Sludge monitoring becomes essential if it is re-used as soil fertilizer. If a more detailed monitoring scheme is judged necessary by the regulatory authorities, then a sustainable financial mechanism must be put in place to secure the necessary funds.

Impact detection monitoring shall be performed as well. Therefore, the tests performed over the various springs, wells and rivers in all studies, prior to the implementation of the various treatment plants, should be used as a basis in order to assess the expected positive effects or impacts of waste water management over the various receiving water bodies in the area subsequently over the environment. It is recommended to perform biannual monitoring (every six months) of the corresponding villages'springs and other water bodies such as intermittent rivers and the Hasbani River.

The following parameters should be monitored:

- Fecal coliforms
- BOD_5
- Residual chlorine

As for the responsibility of the different plant personnel, Table C describes the tasks and duties of the main staff that will be in charge of the proper operation of each plant.

Table C. Main Responsibilities of Plant's Personnel

Title	***Main Tasks***
Plant Manager (can be for more than one plant)	♦ Schedule sampling events and keep records of sampling results for compliance monitoring ♦ Prepare a report of plant's performance (accidents, compliance of effluent to standards, sludge quality, etc…) on a monthly basis during the first year, and bi-annually the following years ♦ Ascertain that mitigation measures are adhered to
Assistant plant manager	♦ Conduct sampling and follow-up with the off-site chemical laboratory for results ♦ Supervise the plant's performance on a daily basis
Mechanical Engineer (part-time)	♦ Ascertain the proper functioning of electro-mechanical equipment at the plant
Electrical Engineer (part-time)	♦ Ascertain the proper functioning of electro-mechanical equipment at the plant
Laborer	♦ Responsible for the day-to-day operation and maintenance of the plant; reports problems to management

Monitoring efforts would be in vain in the absence of an organized record keeping practice. It is the responsibility of the treatment plant management and the municipality to ensure the development of a database that includes a systematic tabulation of process indicators, performed computations, maintenance schedules and logbook, and process control and performance monitoring outcomes. Such a historical database benefits both the plant operator and design engineers in order to predict any adjustments needed to be performed ahead of time for example winter and summer adjustments for the variation in the hydraulic loading, temperature and even biological loadings. In addition, in accordance with the requirements of the regulatory authority, the treatment plant should submit a periodic Discharge Monitoring Report (DMR) to the assigned authority. The institutional setup for the project is proposed in Figure I.

The cost of the environmental management plan depends mainly on the monitoring scheme (sampling) and the cost of workshops for capacity building. On the other hand, the cost of the mitigation measures described to alleviate the negative environmental impacts is included in a general manner in the design and regular plant operation and management expenses.

The main supervising authority for all plants would be the corresponding municipalities. The municipality along with MCI and the selected contractor would supervise all the activities at each plant, starting from the design and construction phases, and continuing at the operation phase where it will be mandatory for the contractor to provide constant and regular technical checkups. The corresponding municipalities, however, would perform operation and day-to-day management. The MoE would have a regulatory role. The MoIM would have an enforcement role. Each plant's manager reports directly to the municipality as in the following illustration of the institutional arrangement that could be followed to ascertain the proper operation of the plant, and assist the implementation of the EMP. The coordination with the South Lebanon Water and Wastewater Establishment is also important since they are responsible for wastewater monitoring in their new mandate.

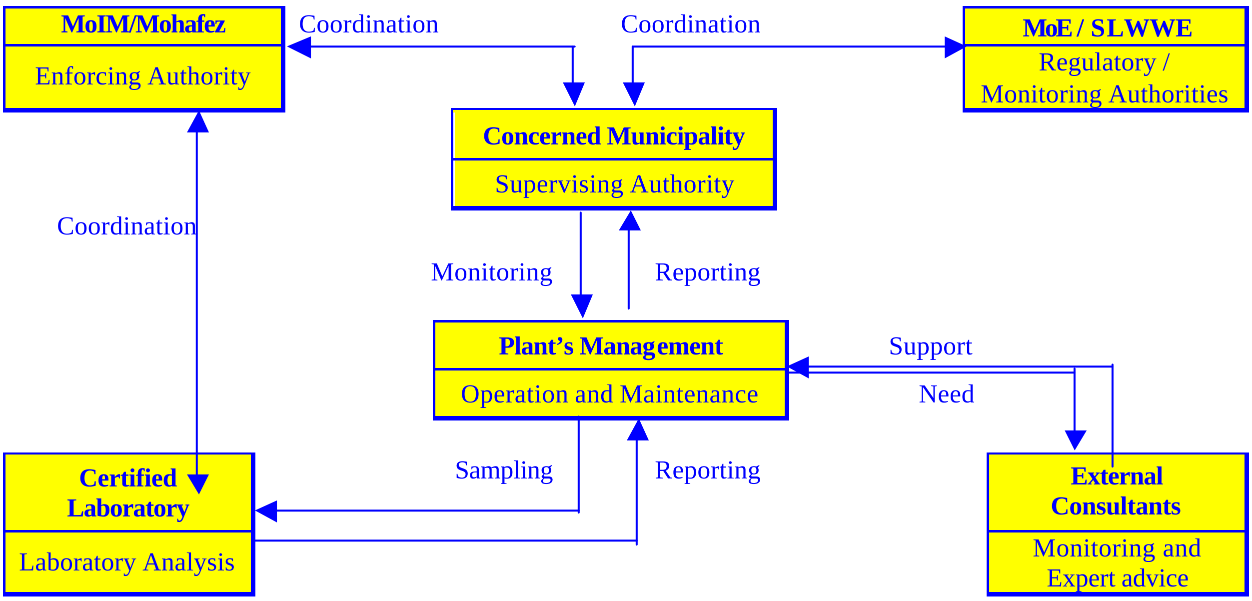


Figure I. Proposed Institutional Setting

1. INTRODUCTION

1.1. THE OVERALL CONTEXT

Lebanon has recently made significant progress towards sustainable development, and has paid more attention to environmental matters and the need to reduce the burden on the environment. In the last ten years, the Ministry of Environment (MoE) has been successful in considerably improving its capabilities to fulfill its main role of protecting the environment from the various sources of pollution. Financed by international organizations, several working units within the MoE are setting new environmental standards, building an informational database for the country, and providing the framework to prevent and control the spread of pollution in Lebanon.

In particular, the Unit of Planning and Programming (UPP) has revised and further developed the draft Decree for Environmental Impact Assessment (EIA) that is currently being considered for ratification by the Government. The draft decree states that any planned project that could cause significant environmental impacts should be subject to the preparation of an EIA that would anticipate these impacts and allow provision of mitigation measures to minimize the significance of these impacts, or even eliminate their likelihood. The draft decree also states that projects that could have some impacts on the environment should undergo an initial impact assessment.

1.2. BACKGROUND AND RATIONALE

Recent government initiatives in the fields of solid waste and wastewater management in Lebanon have primarily covered major cities and urban areas in the country. The Integrated Solid Waste Management Plan (ISWMP) that serves the Greater Beirut Area (GBA) and the National Wastewater Management Plan (NWMP) illustrates this challenge, for example. Limited achievements have been experienced so far in rural areas except for the community-based initiatives financed primarily by international donors.

The environmental pressure experienced in Lebanese rural areas can be illustrated by the fact that approximately 700,000 tons of municipal solid waste (MSW) and over 100 Mm^3 of raw municipal sewage are directly disposed off in the environment every year (MoE/

Ecodit, 2002). A wide range of environmental, public health and socio-economic impacts result from the current situation, some of which are listed below:

- *Contamination of water resources*: Lebanon's groundwater resources are mainly of karstic nature (over 75 percent of the resources), which offer limited possibility for natural attenuation of pollutants before reaching water resources; recent surveys and studies have shown that over 90 percent of the water resources below 600 meters of altitude are contaminated (Jurdi, 2000); surface water streams are also affected by the direct discharge of untreated wastewater. As water becomes polluted, expensive treatment to make it fit for use will inevitably lead to the increase in the price consumers will have to pay when privatization of water services occur and mechanisms such as full-cost accounting are adopted to set water prices.
- *Increased health problems among the population*: inadequate disposal of solid waste and wastewater lead to the release of numerous organic and non-organic contaminants that can eventually reach human beings through diverse pathways including direct ingestion of contaminated water, ingestion of crops contaminated with polluted irrigation water and inhalation of polluted air (from open waste burning activities); for example, it is estimated that 260 children die every year in Lebanon from diarrhea diseases due to poor sanitary conditions leading to the consumption of polluted water (MoH, 1996; CBS/Unicef, 2001).
- *Negative impact on local economic activities*: uncontrolled spread of solid waste and wastewater in valleys, water courses and along roads negatively affects economic activities such as those related to tourism development or eco-tourism by reducing the attractiveness of these areas; similarly, irrigated areas can be at risk if the source of irrigation water is polluted due to poor waste management practices, thus potentially affecting the agriculture sector in some areas; additional economic impacts are attributed to poor health conditions that can affect human productivity in addition to increasing social costs. *It has been recently estimated that the cost of inadequate potable water quality, sanitation and hygiene (largely due to inadequate waste management) could exceed 1 percent of national Gross Domestic Product (GDP), or as much as 170 million USD per year (World Bank/METAP, 2003).*

Overall development constraints and obstacles in Lebanon do not favor government assistance to rural areas. Political turmoil, regional instability, and huge public debt are affecting the smooth progress of planned projects in the country, most of which are stagnant with little achievement being made. This has lead for instance to the removal of the Solid Waste Environmental Management Plan (SWEMP) financed by the World Bank (WB), which has experienced limited progress since its inception in the late 1990s.

There are potential risks associated with poor waste management practices in rural areas, aggravated by the limited level of assistance from the central government. The result is that most of the rural areas in Lebanon are deprived of adequate sanitary infrastructure. A more consistent response with USAID strategic objectives would be to look for individual or cluster solutions.

A recent survey on waste management practices in 111 villages outside GBA (El-Fadel and Khoury, 2001) highlighted the following major challenges, in decreasing order of importance, budget deficit, lack of technical know-how, lack of equipment, lack of employees, negligence, mismanagement, lack of land and lack of public participation. These can be summarized in two major categories: 1) limited resources (financial and human) and 2) limited technical skills (technical know-how, management, and environmental awareness).

Another important issue highlighted by the survey was the high level of co-disposal of hazardous and special waste stream (over 75 percent). This significantly increases the health risk associated with poor MSW disposal. Rural areas do not have the needed infrastructure to deal with special wastes such as those generated by olive press mills, hospitals, or slaughterhouses. An additional challenge posed by these types of wastes is the low volume-generated which do not attract private sector investment for their treatment and/or valorization.

Financial support from international sources have assisted in supplying infrastructure and equipment to rural areas for solid waste and wastewater management, yet, additional challenges have been disclosed and lessons can be extracted from these experiences:

- Limited financial resources in municipalities can lead to poor operation of solid waste and wastewater technologies when funding is over;
- Insufficient training, know-how and/or commitment from municipalities can also lead to poor operation of technologies;

- Poor quality of compost, particularly due to the presence of inert materials, leads to significant problems in marketing the product to farmers; insufficient or no public participation in source separation activities contributed to this problem;

- Limited number of recycling factories in the country and the long distances usually existing between treatment facilities and these factories lead to very high and unaffordable transportation costs. Recyclable materials are poorly marketed to the consumers;

- Lack of public participation and public awareness or consensus can delay or even stop the execution of such infrastructure projects.

Another important challenge that rural cluster development programs may experience, is the need to obtain approval from the government. The government has demonstrated skepticism towards decentralized projects, fearing that these could be a short-term solution leading to long-term problems. Both the Ministry of Interior and Municipalities (MoIM) and the Ministry of Environment (MoE) have shown their reservations with respect to such initiatives, fearing that they could become out of their control due to difficulties in monitoring the performance of scattered projects across the country.

Implementing sustainable infrastructure projects in Lebanese rural areas requires a multi-disciplinary and clearly oriented approach with a long-sighted vision in order to overcome all the constraints presented above. Figure 1.1: summarizes the overall situation of rural areas with respect to such infrastructure projects.

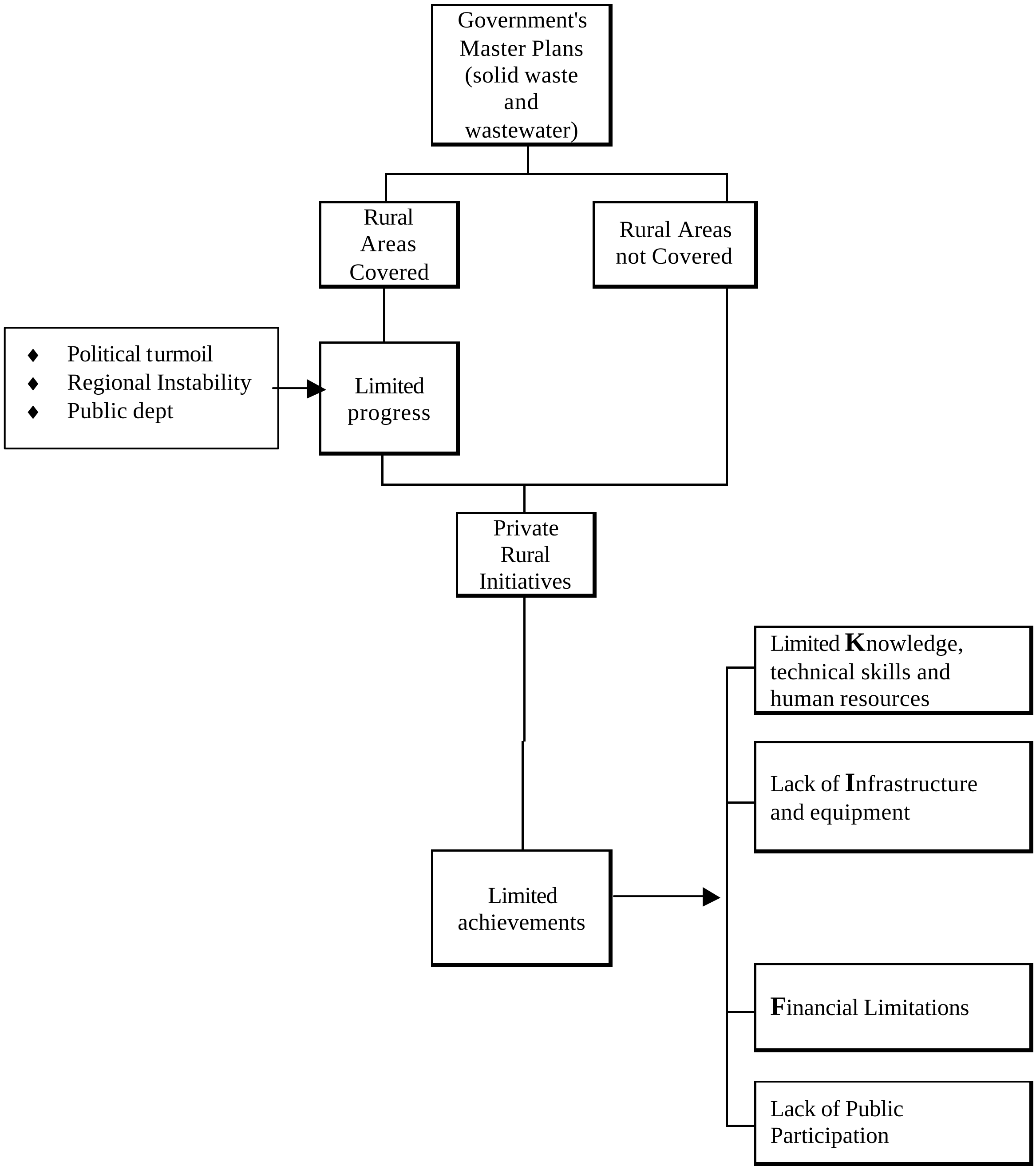


Figure 1.1. Constraints Hindering Infrastructure Development in Rural Communities in Lebanon

1.3. THE PROJECT

The project proposes eight Wastewater Treatment Plants to be established in eight villages in the Caza of Hasbaiya, Lebanon as part of Mercy Corps International (MCI) Improved Environmental Practices and Policies Program. Funded by the USAID, MCI is providing comprehensive domestic wastewater management solutions with the purpose of alleviating the severe impacts of uncontrolled sewage discharges in the eight Hasbaiya villages.

This EIA has been prepared to address the potential environmental impacts that could arise from the construction and operation of WWTPs planned to serve the villages in the Hasbaiya Caza.

Additionally, the EIA evaluates various alternative treatment technologies and presents technical criteria on which to base the selection of the most suitable one. Proper design selection, construction, and management of the WWTPs would mitigate such negative impacts.

1.4. THE PROJECT LOCATION

The WWTPs are to be located in the Hasbaiya Caza. The proposed locations of the eight plants are presented on the Geological Map that is included as Appendix A and on the Topographic Map presented in Appendix B of this report. In addition, Table 1.1 presents the geographical coordinates, the actual population served, the projected population (in both 2015 and 2030), and available land area for the proposed sites of each of the Hasbaiya villages WWTPs.

Table 1.1. Projected Populations, Property Location, and Available Acreage for the Eight WWTPs in Hasbaiya

Area Served	*Geographical Coordinates*	*Actual Population served Year 2004*	*Projected Population[1] Year2015*	*Projected Population Year 2030*	*Available Land area (m^2)*
Chebaa	N 154350km E 149000km	9,000	11,190	15,061	1000-1500[2]
Chouaia	N 162 000 -164 000 E 147 000 -149 000	700	870	1,170	1000 - 1500[3]
El Fardis	N 159800km E 141820km	700	870	1,171	1000-1500[4]
Hebbariye	N 159550km E 144500km	5,500	6,839	9,204	1000-1500[5]
Kaoukaba	X=141,550 Y=161,450 Z=525m	2,000	2,487	3,347	1000-1500[6]
Kfar Hamam	N 156 000 -158 000 E 141 000 -143 000	1,700	2,114	2,845	1000 - 1500[7]
Mari	N 153 000 -155 000 E 140 000 -142 000	1,300	1,616	2,175	1000 - 1500[8]
Rachaiya el Foukhar	X=141,550 Y=161,450 Z=670m	1,250	1,554	2,092	1000-1500[9]

[1] Considering approximate average population growth is 2 % (design assumption)
[2] Donated parcel to the municipality
[3] Municipal property
[4] Purchased parcel from Mr. Fares Chehadeh Slika by the municipality
[5] Purchased parcel from Mr. Mansour Ghanem by the municipality
[6] Municipal property
[7] Municipal property
[8] Municipal property
[9] Municipal property

1.5. THE STUDY AND THE EIA REPORT

This study was prepared in close collaboration with MCI and the municipalities of the eight concerned villages who contributed significantly to the overall quality of the report, the identification of the most feasible treatment systems and environmental management practices. The report was prepared through continuous and harmonious coordination with the municipality officials. It provides MCI, USAID and other stakeholders including the local community a thorough discussion of the significant environmental effects of the proposed interventions.

The purpose of this EIA study is to ensure that the potential impacts from the installation and operation of the eight Wastewater Treatment Plants are identified. The significance of the impacts is assessed, and appropriate mitigation measures are proposed in order to minimize or eliminate them.

Additionally, the EIA has been a catalyst for MCI and the different municipalities to review alternative treatment processes. *It was specifically successful in evaluating* ***the use of*** *alternative treatment technologies such as* ***trickling filters*** *and upflow anaerobic sludge blanket reactors as pretreatment prior to aerobic activated sludge treatment.*

The remainder of this EIA report is structured in seven main sections. Section 2 provides the legislative and institutional framework. Section 3 presents background information to this project. Section 4 describes the project and associated elements. Section 0 describes the environmental setting. Section 6 assesses the impacts. Section 7 presents an environmental management plan (EMP) that will allow managers of the facility to mitigate impacts and monitor the treatment activities to ensure process efficiency and environmental safety throughout the project's lifetime. Section 8 presents the public participation program implemented to allow direct involvement of the concerned community in the implementation of the projects.

2. LEGISLATIVE AND INSTITUTIONAL FRAMEWORKS

2.1. LEGISLATIVE FRAMEWORK

The MoE was created by *Law 216* of 2 April 1993 marking a significant step forward in the management of environmental affairs in Lebanon. *Article 2* of *Law No. 216* stipulate that the MoE should formulate a general environmental policy and propose measures for its implementation in coordination with the various concerned public administrations. It also indicates that the MoE should protect the natural and man-made environment in the interests of public health and welfare and fight pollution from whatever source by taking preventative and remedial action. Specifically, the MoE is charged with developing, among others, the following aspects of environmental management:

- A strategy for solid waste and wastewater disposal treatment, through participation in appropriate committees, conducting studies prepared for this purpose, and commissioning appropriate infrastructure works;

- *Permitting conditions for new industry*, agriculture, quarrying and mining, and the enforcement of appropriate remedial measures for installations existing before promulgation of this law;

- Conditions and regulations for the use of public land, marine and riverine resources, in such a way as to protect the environment;

- Encouragement of private and collective initiatives which improve environmental conditions; and

- Classification of natural sites, landscapes and setting decisions and decrees concerning their protection.

Furthermore, new emission standards for discharge into surface water and air have been established by the MoE (ministerial decision no. 8/1/2001), through the assistance of the SPASI (Strengthening the Permitting & Auditing System for Industry) unit at the MoE, to update the previous standards set by Law 52/1. These standards will be used as a basis to control pollution loads in the country.

Table 2.1 describes the main categories of legislation in Lebanon. In terms of environmental legislation, Table 2.2 presents the existing and proposed legislation pertinent to WWTPs.

Table 2.1. Categories of Legislation in Lebanon

Laws	Laws are passed by the Lebanese parliament. The council of ministers or deputies can propose a project of law that should pass through the appropriate parliamentary committee. In the case of environmental legislation, this committee is generally the Agriculture, Tourism, Environment and Municipalities Committee, the Public Works, Transport, Electric and Hydraulic Resources Committee, or the Planning and Development Committee. The committee reviews, assesses, and presents the law, with the amendments it introduces, for final approval by the parliament.
Decree laws	The parliament has empowered the council of ministers to issue decree-laws without the prior approval or supervision of the parliament. Decree laws have the same legal standing and powers as laws.
Decrees	The council of ministers issues decrees that have the power of law provided they do not contravene existing laws. The council of state should be consulted before the issuing of a decree.
Resolutions	Ministers issue resolutions without the pre-approval of the council of ministers. Resolutions have the power of law provided they do not contravene existing laws. The council of state should be consulted before the issuing of a resolution.

Table 2.2. Summary of Selected Legislation Related to Wastewater Management

Legislation	***Year***	***Brief Description***
Decree No. 7975	5/5/1931	Related to the cleanliness of residences and their extensions, and wiping out of mosquitoes and flies, and discharges of substances and wastewater.
Decree No. 2761	19/12/1933	Directions related to discharge of wastewater and dirty substances.
Law No. 216	2/4/1993	The Creation of the MoE
Decree 8735	1974	It is forbidden to allow infiltration of sewage waters from cesspools or to leave them partially exposed, or to irrigate vegetables or fruits with their waters (Article 4) It reserves places assigned by each municipality for the treatment of wastes and agricultural and industrial residues (Article 13), empty sewage waters by tankers in special locations by decision of provincial or district governor until drainage canals are built (Article 15) It is forbidden to drill wells to undefined depth with the aim of disposing of sewage water (Article 3)
Ministerial Decision No. 52/1	29/7/1996	Environmental Quality Standards & Criteria for Air, Water and Soil
Law No. 667	29/12/1997	Amendment to Law No. 216, Organization of the MoE
Draft Decree	1998	All agglomerations have to be provided with collecting systems for urban wastewater at the latest by 31 December 2010 for those with a population equivalent of more than 15,000 and 31 December 2015 for those between 2,000 and 15,000 (Article 3) All urban wastewater entering collection systems shall be subject to secondary treatment or an equivalent treatment before discharge. This deadline for achieving this goal is 31 December 2010 for all discharges from agglomerations of more than 15,000 people and 31 December 2015 for those between 2,000 and 15,000 people (Article 4) It should be ensured that urban wastewater treatment plants are designed, constructed, operated and maintained to ensure sufficient performance under all normal local climatic conditions
Ministerial Decision No. 8/1	30/1/2001	Characteristics and standards related to air pollutants and liquid waste emitted from classified establishment and wastewater treatment plants.
Project Decree	7/2000-	Environmental Impact Assessment
Law 444	29/7/2002	Law of the protection of the environment; sets the framework for environmental protection in Lebanon

Table 2.3 summarizes the two main documents that would complement the existing environmental legislation, namely the Law on the protection of the Environment (Law 444) and the draft EIA decree. Table 2.4 presents selected standards for discharge into surface waters (based on the National Standards for Environmental Quality) that this study has accounted for.

Table 2.3. Law 444 and Draft EIA Decree

Law 444 (2002)
♦ The environmental legislation will be administered by the MoE. ♦ Permitting of new facilities with potential environmental impacts will be approved by the MoE in addition to other relevant agencies depending on the type of the project. ♦ The application of environmental legislation will be supervised by the MoE; however, the modalities of the supervision exercised by the MoE are not set. ♦ Enforcement of legislation is not addressed. It is clear that the MoE will have no enforcement role. The Ministry of Interior will continue to be responsible for the legislation enforcement. ♦ A new fund, the National Environment Fund, will be created. The fund covers expenses that should be included in the budget of the MoE. It seems that the establishment of such a fund aims at collecting donations that are specifically targeted to finance environmental projects. Moreover, the fund would also be sustained by the fines and taxes established in the Code. Environmental tax incentives are mentioned for the first time in Lebanese legislation.
The Draft EIA decree (2000)
♦ The MoE decides upon the conditions to be met and information to be provided by a project to receive a permit. ♦ The MoE must supervise the projects that are undergoing an EIA. ♦ The EIA should contain at least the following sections: institutional framework, description of the project, description of the environment, impact assessment, mitigation measures, and EMP. ♦ The EIA is to be presented to the institution in charge of granting a permit to the project depending on the type of the project. A copy of the EIA is sent by this institution to the MoE for consultative and revision purposes.

Table 2.4. Selected Standards for Discharge into Surface Waters

Parameter	***Effluent Concentration*** *
PH	6 – 9
BOD_5	25
COD	125
Suspended Solids	60
Ammonia-Nitrogen	10
Nitrate	90
Total Phosphorus	10
*Concentrations in mg/L except for pH (unit less)	

2.2. INSTITUTIONAL FRAMEWORK

In addition to the MoE, other organizations play a role in environmental protection and management, in particular the Ministries of Public Health (MoPH), Interior and Municipalities (MoIM), Public Works and Transport (MoPWT), Agriculture (MoA), Industry and Petroleum (MoIP), Ministry of Energy and Water (MoEW), and South Lebanon Water and Wastewater Establishment (SLWWE). At a regional level, the Mohafaza and each local Municipality have direct responsibilities relating to the environment; and the Council for Development and Reconstruction (CDR) is leading the reconstruction and recovery program and has taken over certain responsibility from line ministries in areas with direct environmental implications. Table 2.5 summarizes the main responsibilities and authorities of key institutions in the country.

Table 2.5. Responsibilities and Authorities of Key Institutions in Lebanon

Institution	***Water Resources***	***Urban Planning / Zoning***	***Standards and Legislation***	***Enforcement***	***Biodiversity***	***Waste Water Discharge***
Council for Development and Reconstruction	√	√				√
Council for the Displaced	√					√
Ministry of Agriculture			√		√	√
Ministry of Environment	√	√	√		√	√
Ministry of Housing and Cooperatives		√				√
Ministry of Energy and Water	√		√	√	√	√
Ministry of Industry and Petroleum		√	√	√		√
Ministry of Interior and Municipalities				√		
Ministry of Public Health	√		√		√	√
Ministry of Public Works and Transport	√	√	√			√
Ministry of Tourism		√	√		√	
South Lebanon Water and Wastewater Establishment	√					√
Municipality	√	√		√	√	√

3. BACKGROUND INFORMATION

3.1. PROJECTS INITIATION

On April 22, 2003 upon the request of the Hasbaiya Municipalities, the MCI presented a Technical Proposal and an Organizational Commitment to USAID seeking funding for the implementation of various domestic wastewater and olive oil residue treatment plants in 13 villages in the specified region. Subsequently, USAID agreed to finance the implementation of (9) Wastewater Treatment Plants (WWTPs) to serve 8 of these villages and (6) Olive Oil Residue Treatment Plants (OORTP) to serve (7) of them. On that basis, MCI has commissioned Earth Link and Advanced Resources Development, s.a.r.l. (*ELARD*) to perform the EIAs for these various projects.

The thirteen villages targeted by the program include Chebaa, Kaoukaba, El Fadris, Hebbariye, Rachaiya el Foukhar, Kfar Hamam, Chouaia, Mari, Ain Qenia, Ain Jarfa, Kfeir, Khalouat and Mimes. They are located in the Caza of Hasbaya in close proximity to the Hasbani and Ouazzani Rivers. Land elevations range from less than 800 m to 1300 m above sea level. The eight WWTPs are to be located in eight of these villages, namely, Chebaa, Kaoukaba, El Fadris, Hebbariye, Rachaiya el Foukhar, Kfar Hamam, Chouaia, and Mari. It is to be noted that while the original plan was to have two plants at Chebaa, the consultants recommended that only one plant would be sufficient and accordingly, the total number of treatment plants was reduced to eight. The plants would serve total design populations of approximately 22,150 that might reach 27,540 by the year 2015 and 37,066 by the year 2030 (Table 3.1).

Table 3.1 Design Populations of Hasbaiya Villages

Village	*Year 2004*	*Year 2015**	*Year 2030**
Chebaa	9000	11,190	15,061
Chouaia	700	870	1,171
El-Fadris	700	870	1,171
Hebbariye	5,500	6,839	9,204
Kaoukaba	2,000	2,487	3,347
Kfar Hamam	1,700	2,114	2,845
Mari	1,300	1,616	2,175
Rachaya El-Foukhar	1,250	1,554	2,092
Total	*22150*	*27540*	*37066*

* Considering approximate average population growth is 2 % (design assumption)

3.2. IMPORTANCE OF THE PROJECT

Currently, untreated sewage generated within the Hasbaiya villages is directly disposed off in the environment either through direct discharge into streams and rivers or through septic tanks that can easily leak into ground water aquifers. This situation is exposing the public directly to the associated negative health impacts. Additionally, the direct disposal into the environment is leading to deterioration of water quality in the area. Proper conveyance and treatment of sewage is of utmost importance to avoid such impacts, and will be addressed by the construction of eight WWTPs to serve the population of the area.

It is essential to note that in all eight villages, potable water is being conveyed from Chebaa River through the potable water distribution network of the village. Two public wells and several seasonal springs are present in the region and are used during water shortages for irrigation and domestic purposes. Rumors spread over the villages that various springs in the area were polluted, however a survey of regional springs found low levels of contamination. There are three main factors leading to contamination of springs: 1) the absence of a proper wastewater collection network and treatment in the villages located over the recharge zone of these springs and wells; 2) the karstic constitution of the recharge zone posing no filtration and direct recharge of aquifers; and 3) the abundance of seeping septic tanks in the overlaying area. This third factor leads to the mixing of wastewater and springs water within the various Karstic aquifers. Appendix B includes reports of laboratory analysis on spring water samples confirming the presence of sewerage related contamination within some investigated springs in the Hasbaiya area. Therefore, it is imperative to treat all the generated sewage in the villages to eliminate the threats of uncontrolled disposal of raw sewage in the environment.

Additionally, wastewater is being discharged directly from residences into run-off ditches and stormwater gullies, which in turn convey the wastewater into open land, agricultural fields, and surface water bodies. This situation is evident in most of the villages in the Hasbaiya area where raw sewage is discharged into winter channels subjecting the neighboring orchards and agricultural fields to potential hazards; diseases to farmers and the consumers as well. Moreover, the geological nature of these winter channels, most being tributaries to nearby rivers, allows wastewater to infiltrate easily without any sort of natural filtration to the karstic springs underneath.

3.3. OBJECTIVES OF THE PROJECT

The main objective of the project is to provide the necessary means to treat sewage generated at the villages of Hasbaiya, and halt the current practices of uncontrolled disposal of raw sewage in the environment. These practices are posing risk to the public health and the environment, mainly through the contamination of potable water, the groundwater, and associated springs as well as affecting agricultural production. An additional objective is to reduce disease vectors and halt the nuisance associated with open disposal of raw sewage onto roadways and open trenches resulting in the generation of odors, mosquitoes and other insect populations. The concern of the municipality for the health of the public, the protection of the environment and their drive for developing local tourism is the driving force behind this project.

3.4. THE EXECUTING OFFICE

The eight concerned municipalities all along with MCI are the responsible authorities with respect to the proper construction and operation of the WWTPs. They will oversee the works and ensure its execution and operation according to specifications.

4. DESCRIPTION OF THE PROJECT

4.1. GENERAL DESCRIPTION OF THE EIGHT WASTEWATER TREATMENT PLANTS

In general, the proposed WWTPs in the Hasbaiya Area employ typical secondary biological wastewater treatment schemes. However, out of the eight villages under study, five WWTPs (Chebaa, Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar) had special considerations in the design characteristics. Those villages are located on a hydrological recharge zone of down gradient springs. This important fact subjected the forecasted treatment plants to strict effluent quality and operation measures in order to reach a tertiary biological wastewater treatment scheme. As for the remaining WWTPs (El Fardis, Kaoukaba and Mari), no need for tertiary treatment was assessed since the plants' locations are nearby the Hasbani River, thus the secondary treated effluent can be discharged directly to the perennial river.

For domestic wastewater, the major objective of biological treatment is to reduce the carbonaceous BOD (Biochemical Oxygen Demand), coagulate "non-settleable" colloidal solids, and stabilize organic matter. The WWTPs in all eight villages employ an aerobic suspended growth treatment system consisting of an Extended Aeration Activated Sludge (EAAS) system. In the WWTPs of the villages of Chebaa, Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar, tertiary treatment, in the form of filtration and additional disinfection, follows the EAAS to further reduce the BOD load, nutrient levels and bacteriological loads.

Each WWTP is usually located at the outskirts of the corresponding village, also at close proximity to any intermittent river (Hasbani River tributary) if present. Design population for each village is specified in Table 4.1 , whereas the contribution to the total inflow of raw sewage to the treatment plant for each case is summarized in Table 4.2.

Table 4.1. Present and Projected Populations of the Eight Hasbaiya Villages Served by the Wastewater Treatment Plants

Municipality	*Present (2004)*	*Year 2015**	*Year 2030***
Chebaa	9,000	11,190	15,061
Chouaia	700	870	1,171
El Fardis	700	870	1,171
Hebbariye	5,500	6,839	9,204
Kaoukaba	2000	2,487	3,347
Kfar Hamam	1,700	2,114	2,845
Mari	1,300	1,616	2,175
Rachaiya el Foukhar	1250	1,554	2,092

* Considering the 2% average population growth per year (design assumption)

**Considering that the plant will serve for 26 years (design population).

Table 4.2. Contribution from Each Village to the Total Inflow of Raw Sewage to the Corresponding Treatment Plant

Municipality	***Present Raw sewage (m^3/Day)****	***Raw sewage(m^3/Day) in 2015***	***Raw sewage(m^3/Day) in 2030***
Chebaa	900	1,119	1,506
Chouaia	70	87	117
El Fardis	70	87	117.1
Hebbariye	550	684	920
Kaoukaba	200	249	335
Kfar Hamam	170	211	284
Mari	130	165	220
Rachaiya el Foukhar	125	155	209

*Assuming water consumption per capita is 100 Liters/day

4.2. PROCESS THEORY

The treatment of municipal wastewater depends on natural processes such as gravity to clarify an effluent or microorganisms to digest the biodegradable organic content. Pathogens are removed through natural die-off and competition, through providing adequate detention time and temperature, or through disinfection. Basic wastewater treatment mechanisms include preliminary and primary treatment through screening, sedimentation and filtration. Secondary treatment relies on the digestion of the biodegradable organic content of wastewater (80% of BOD_5) by aerobic and anaerobic microorganisms. Advanced tertiary treatment includes further treatment of the effluent in the case of sensitive receiving waters and high-risk environmental damage. It includes processes such as disinfection, nitrogen removal, phosphorus removal, activated carbon adsorption, media filtration, reverse osmosis, distillation, and UV. Table 4.5 summarizes the uses and characteristics of the stages of wastewater treatment. The level of treatment of wastewater also depends on the nature of the influent. Table 4.3 characterizes wastewater as weak, medium or strong according to contaminant loads.

Table 4.3. Characterization of Raw Wastewater

Parameter	***Weak***	***Medium***	***Strong***
BOD5 (mg/l)	110	220	400
TSS (mg/l)	100	200	350
Ntotal (mg/l)	20	40	85
P (mg/l)	4	8	15

Source: Journey, W.K

Table 4.4 shows the both the total amount of wastewater to be treated for each village and its characteristics (BOD_5 and SS) based on actual wastewater samples taken in the area.

Table 4.4. Total Wastewater Inflow and Characteristics for Each WWTP in Hasbaiya

0 XQLFLSDOLW	***Total Inflow of Wastewater (m3/day)***	***BOD_5 (mg/l)***	***Suspended Solids (mg/l)***
Chebaa			
Chouaia			
El Fardis			
Hebbariye			
Kaoukaba			
Kfar Hamam			
Mari			
Rachaiya el Foukhar			

Referring to Table 4.3, the wastewater collected from all villages under study in Hasbaiya can be classified as strong.

Table 4.5. Description of Wastewater Treatment Stages

	Preliminary Treatment	***Primary Treatment***	***Secondary Treatment: Aerobic / Anaerobic***	***Tertiary Treatment***
Unit operations & processes involved	Screening / comminutor Grit removal	Primary clarifier	Anaerobic or aerobic biological reactors: Final clarifier	Secondary Treatment + Filter media + Additional Disinfection
Principal application	Removal of large objects Removal of heavy objects: sand, gravel, cinder, etc.	Removal of settleable solids and BOD	Removal of fine non-settleable solids, considerable BOD, some NH_3 & total phosphorus	Further removal of suspended solids when necessary
Land requirements	Minimum	Moderate	Moderate	Moderate
Adverse climatic conditions	-	-	Decreased microbial activity (esp. for anaerobic treatment) Freezing of piping and valves	-
Ability to handle flow variations	Good	Fair	Good	Good
Ability to handle influent quality variation	Good	Good	Good (fair for anaerobic)	Poor
Industrial pollutants affecting process	Minimum	Minimum	Moderate	Moderate
Ease of O&M	Fair	Good	Moderate / Good	Fair
Reliability of the process	Good	Good	Good / Moderate	Fair

4.2.1 Anaerobic Biological Treatment Processes

Anaerobic treatment is the use of biological organisms to degrade or stabilize organic (carbonaceous) material in the absence of oxygen into methane gas (CH_4) and inorganic products such as carbon dioxide (CO_2), orthophosphate (ortho-PO_4^{-3}), hydrogen sulfide gas (H_2S), nitrogen gas (N_2), and ammonia (NH_3). Anaerobic biomass is also produce by this process as is demonstrated by sludge formation.

Initially, anaerobic treatment was used for the treatment of sludge produced by aerobic treatment as well as meatpacking wastes. Today however, it is being used by high strength organic wastes because of its potential for producing energy (methane gas) and lower sludge growth rate.

Anaerobic treatment tends to remove a major portion of the BOD from wastewater, but considerable nitrogenous oxygen demand remains. Although some anaerobic processes may require mechanical mixing, relatively simple technologies exist making them suitable for regions with limited resources. Depending on the characteristics of the wastewater, anaerobic secondary treatment can achieve 65-85% removal of BOD_5 at 20ºC, and 60-80% removal of SS (Journey, W.K.). With anaerobic treatment of wastewater, the reduction of BOD is relatively lower, but energy input and sludge production is considerably lower. Hence, anaerobic treatment is preferred in developing countries with limited resources when the conditions suitable for anaerobic activity are present.

Optimum anaerobic activity takes place at a pH range of 7-8 (Corbit, 1998). While the optimum nutrient ratio for anaerobic activity is a COD:P:N of 100:1:0.2. This ratio demonstrates the lower requirement of anaerobic microorganisms of nitrogen. Anaerobic digestion also required the presence of other nutrients such as sulfur, iron, calcium, magnesium, sodium, potassium. Higher levels of these nutrients however may lead to toxicity and therefore hinder the treatment process (Table 4.6). As for temperature requirements, generally, the higher the reactor temperature, the higher the rate of substrate removal and cell decay. Usually, anaerobic reactors should be operated at a mesophyllic range: 25 – 40?C or thermophyllic range: 50-70 C.

Table 4.6. Inhibition Concentrations of Various Ions

Species	*Stimulatory mg/L*	*Moderate mg/L*	*Strongly Inhibitory mg/L*
Sodium	100 – 200	3500 - 5500	8000
Potassium	200 – 400	2500 – 4500	12000
Calcium	100 – 200	2500 – 4500	8000
Magnesium	75 – 150	1000 – 1500	3000
Ammonia	-	1500 – 3000	3000
Hydrogen Sulfide	-	-	200 - 300

Source: Corbitt, 1998

4.2.2 Anaerobic Reactor Types

Anaerobic reactors may be classified as “suspended growth” when the bacteria are suspended in the reactor, or “attached film” when the bacteria are attached as dense films to solid media inside the reactor. Both types may also be categorized according to the rate of anaerobic activity into high rate or low rate reactors (Table 4.7). *Low rate* reactors, such as septic tanks, are used for single households or small groups of houses where no wastewater collection system exists. *High rate suspended growth* reactors are used to treat industrial (food industries) wastewater or mixtures of industrial wastewater and domestic. Examples include the Anaerobic Contact Reactor (ACR) and the Upflow Anaerobic Sludge Blanket (UASB). *High rate attached film* reactors use a granular solid medium as a carrier. Though this type of reactor has more efficient COD removal rates, it has not been proven that its use with municipal wastes is as effective as the high rate suspended growth reactor type. As Table 4.7 indicates, the high rate suspended growth anaerobic treatment reactor would be the most appropriate to use in the given situation.

Table 4.7. Summary of Anaerobic Reactor Types

Anaerobic Reactor Type	*Description*	*Removal Efficiency*	*Operation & Maintenance Requirements*	*Usage*	*Ex.*
Low Rate Reactor	Low rate of anaerobic digestion	High SS: 90 – 98 % Low BOD: 40 – 60 % Retention Time: few days	Low	- In the absence of wastewater collection network used with single households or a Group of few houses.	Septic Tank
High Rate Suspended Growth	High rate of anaerobic digestion Microorganisms are suspended in reactor fluid	High SS (>90%) High BOD_5 removal	Moderate	- Food Processing Industry - Combined food processing industry wastewater with municipal sewage - Sustainable - Appropriate for areas with limited resources	UASB ACR
High Rate Attached Growth	High rate of anaerobic digestion Microorganisms grow attached to a solid media in reactor	High SS Highest BOD_5 removal	High: Requires sophisticated feed inlets, high rates of effluent recycle,	- Not appropriate to treat municipal sewage of areas with limited resources	Expanded Fluidized

4.2.2.1 High Rate Suspended Growth Anaerobic Reactors

This section will describe the two types of high rate suspended anaerobic reactors: the upflow anaerobic sludge blanket (UASB) and the Anaerobic Contact Reactor (ACR).

The UASB process is a high-rate anaerobic suspended growth biological treatment process. Since this treatment process is biological, it is based on the metabolic reactions of microorganisms that in the absence of oxygen, convert the suspended and dissolved organic load into methane gas and carbon dioxide. The organic matter in the wastewater remains in suspension due to the upward flow of influent into the reactor. However, these “flocs” of suspended organisms tend to settle the moderate upflow velocities forming the sludge. The organic load is trapped under a “sludge blanket” where it is slowly digested. The liquid fraction of the influent passes through the suspended “sludge blanket” at a higher rate and is collected in gutters at the tope of the reactor (Figure 4.1).

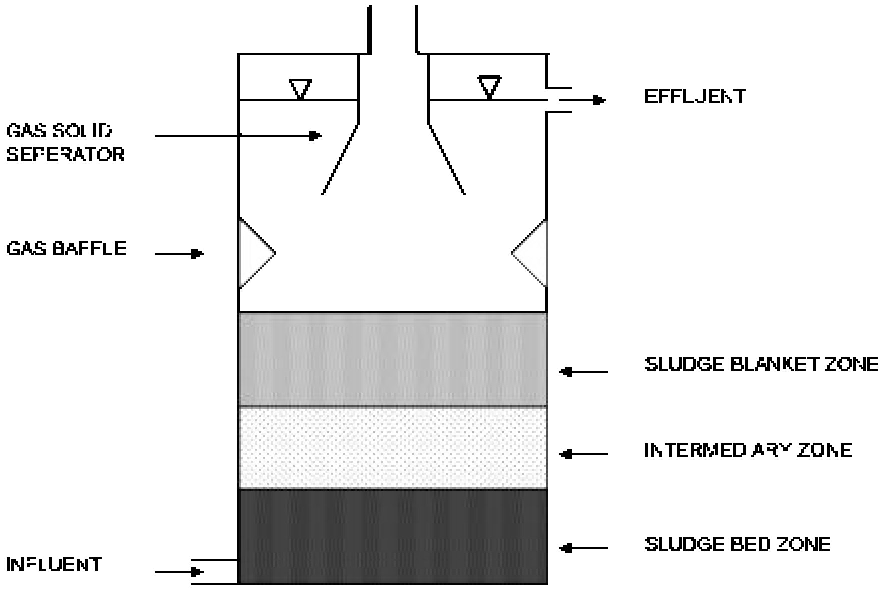


Figure 4.1. Schematic Diagram of a UASB Reactor

The ACR is the anaerobic analogue of the aerobic activated sludge process. It is widely used with industrial wastewater especially that of the food processing industry with high suspended solids load. ACRs are not used with municipal wastewater due to the relatively low organic content of such wastewater. Lower BODs necessitate a larger volume for the reactor to satisfy the necessary solids retention time. Similar to the conventional activated sludge process, the reactor utilizes mechanical mixing of the substrate to maintain the microorganisms' suspended state as well as recycling of the recovered sludge into the reactor (Figure 4.2). Therefore, ACRs have higher requirements for energy input.

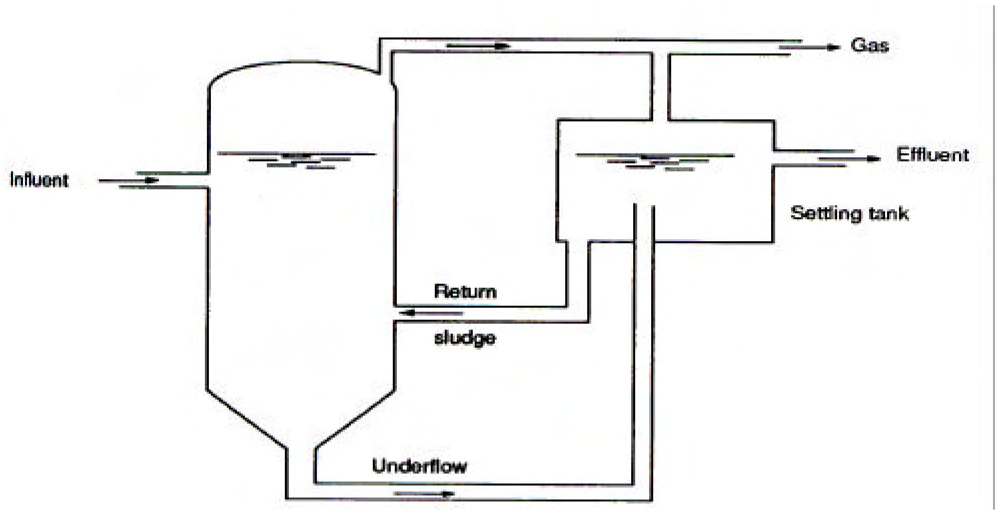


Figure 4.2. Schematic Diagram of an ACR

To compare, UASB reactors can be used with high strength and medium/low strength wastewater from industries such as distilleries, food processing units, tanneries, as well as municipal sewage. On the other hand, ACRs are more commonly used with food industry wastewater rather than domestic wastes. Additionally, using UASB reactors reduces the electric power consumption of a plant when compared to ACRs. UASB reactors are also easier to operate and maintain. Therefore, in regions with limited economic resources, UASB reactors constitute an ideal option when the optimal temperature conditions are permit.

4.2.3 Aerobic Biological Treatment Processes

The aerobic biological treatment process relies on the activity of microorganisms to digest the biodegradable organic content of wastewater in the presence of oxygen to release carbon monoxide and gas. Similar to anaerobic treatment aerobic treatment may be classified as *suspended growth* type (such as activated sludge and aerobic ponds,) or as *fixed growth* type (such as trickling filters and rotating biologic contractors).

Unlike anaerobic treatment, aerobic treatment of wastewater typically requires energy for aeration and produces a higher sludge growth rate. However, aerobic digestion reduces the COD content of the effluent by a larger extent (Figure 4.3).

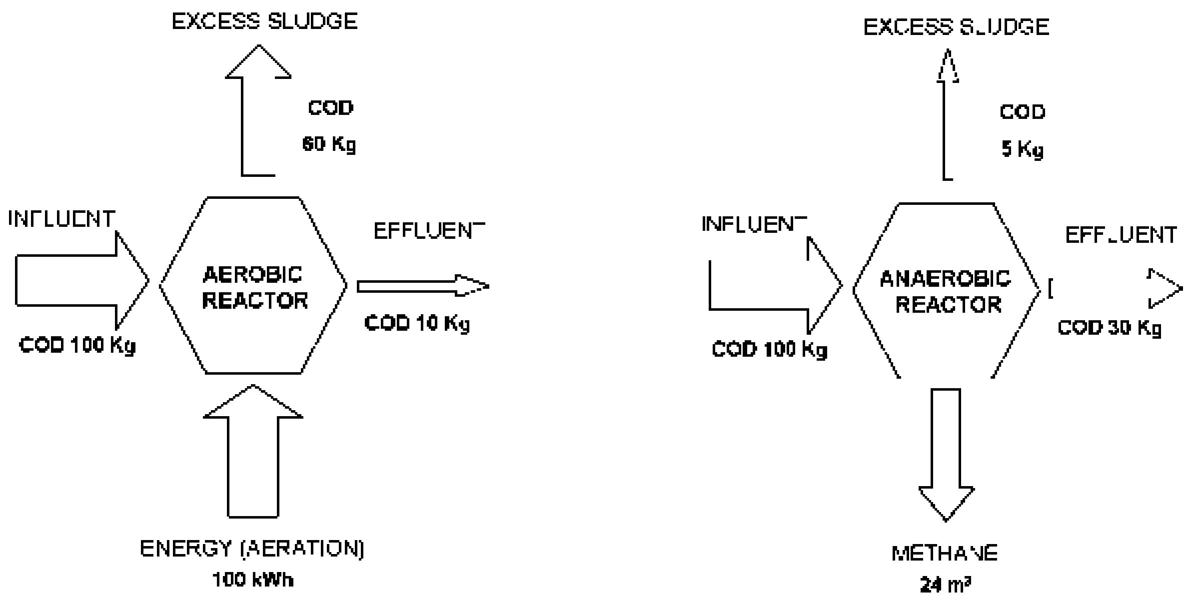


Figure 4.3. Comparison Between Aerobic and Anaerobic Biological Treatment(Journey, W.K.)

4.2.1.1. *Aerobic Reactor Types*

Similar to anaerobic treatment, the secondary treatment of wastewater by aerobic processes may be classified according to the type of reactor used: suspended growth reactors or attached growth reactors. Table 4.8 and Table 4.9 give a detailed comparison of both types of aerobic reactors.

Table 4.8. Comparison of Aerobic Suspended Growth and Attached Growth Reactors

	Aerobic Suspended Growth	***Aerobic Attached Growth***
Unit operations & processes involved	Suspended growth aerobic biological reactor: Conventional or EAAS system	Attached growth aerobic biological reactor: high-rate trickling filters
Principal application	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus
Land requirements	Moderate	High
Adverse climatic conditions	Decreased microbial activity Freezing of piping and valves	Decreased microbial activity Freezing of piping and valves
Ability to handle flow variations	Good	Good
Ability to handle influent quality variation	Good	Fair
Industrial pollutants affecting process	Moderate	Moderate
Ease of O&M	Good	Good
Reliability of the process	Good	Good

Table 4.9. Comparison of the Waste Products of Aerobic Reactors

		Aerobic Suspended Growth	***Aerobic Attached Growth***
Waste products		Sludge (biomass) for conventional; Stabilized and reduced sludge (biomass) for EAAS	Sludge (biomass)
Typical Removal Efficiencies (%)	**BOD_5**	80-85 (conventional); 80-95 (EAAS)	60-80
	COD	80-85 (conventional); 80-90 (EAAS)	60-80
	TSS	80-90 (conventional); 70-90 (EAAS)	60-85
	TP	10-25 (conventional); 10-15 (EAAS)	8-12
	ON	60-85 (conventional); 75-85 (EAAS)	60-80

4.2.1.2. Activated Sludge (Suspended Growth) Aerobic Reactors

The activated sludge process is an aerobic, suspended growth, biological treatment method. Suspended growth processes aim at maintaining an adequate biological mass in suspension within a reactor, by employing either natural or mechanical mixing. The process is based on the metabolic reactions of microorganisms to produce a high quality effluent by converting and removing soluble organic matter that exerts an oxygen demand. A clear effluent, low in suspended solids, is produced due to the flocculent nature of the biomass. A critical requirement in activated sludge systems is the need of oxygen to stabilize the waste. Four factors are common to all activated sludge systems: (1) a flocculent slurry of microorganisms, also termed Mixed Liquor Suspended Solids (MLSS), in the bioreactor; (2) quiescent settling in the clarifier; (3) activated sludge recycling from the clarifier back to the bioreactor; and (4) excess sludge wasting to control the Solids Retention Time (SRT). The activated sludge process is by far the most widely used biological wastewater treatment process for reducing the concentration of dissolved and colloidal carbonaceous organic matter in wastewater.

The extended aeration activated sludge (EAAS) process is a variation of the conventional activated sludge process. It is a completely mixed process operating at a long hydraulic detention time (18-36 hrs) and a long SRT (20-30 days). Long SRT offers two benefits: remarkably reduced production of stabilized sludge, and greater process stability.

However, oxygen requirements are higher for combined UASB and EAAS systems. The system is very robust, stable, and simple to operate, thus rendering it extremely suitable for smaller communities. Moreover, in this case advanced levels of filtration and chlorination are imperative in order to reach complete disinfection of the final effluent to be discharged in the existing winter channel. Figure 4.4 depicts a flow diagram for the complete-mix modification of the activated sludge process.

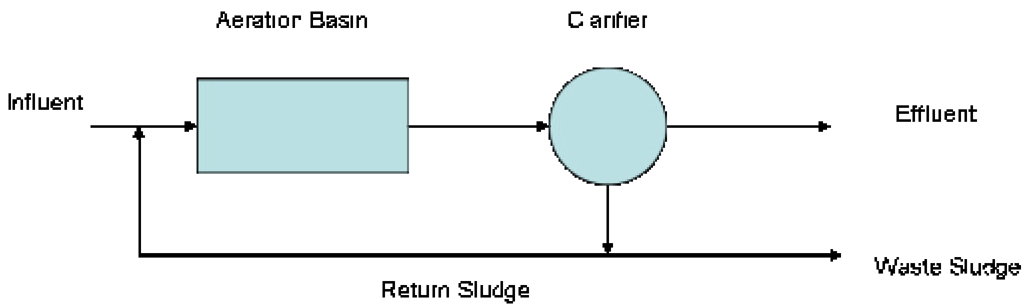


Figure 4.4. Flow Diagram for the Complete-Mix Activated Sludge Process

4.2.1.3. Trickling Filter (Attached Growth) Aerobic Reactor

The trickling filter (TF) process is an aerobic, attached growth, biological treatment method. TFs enable organic material in the wastewater to be adsorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria; fungi; algae; and protozoa) attached to the medium as a biological film or slime layer (approximately 0.1 to 0.2 mm thick). As the wastewater flows over the medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film. The organic material is then degraded by the aerobic microorganisms in the outer part of the slime layer.

As the layer thickens through microbial growth, oxygen cannot penetrate the medium face, and anaerobic organisms develop. As the biological film continues to grow, the microorganisms near the surface lose their ability to cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing. The sloughed solids are picked up by the under-drain system and transported to a clarifier for removal from the wastewater (Figure 4.5).

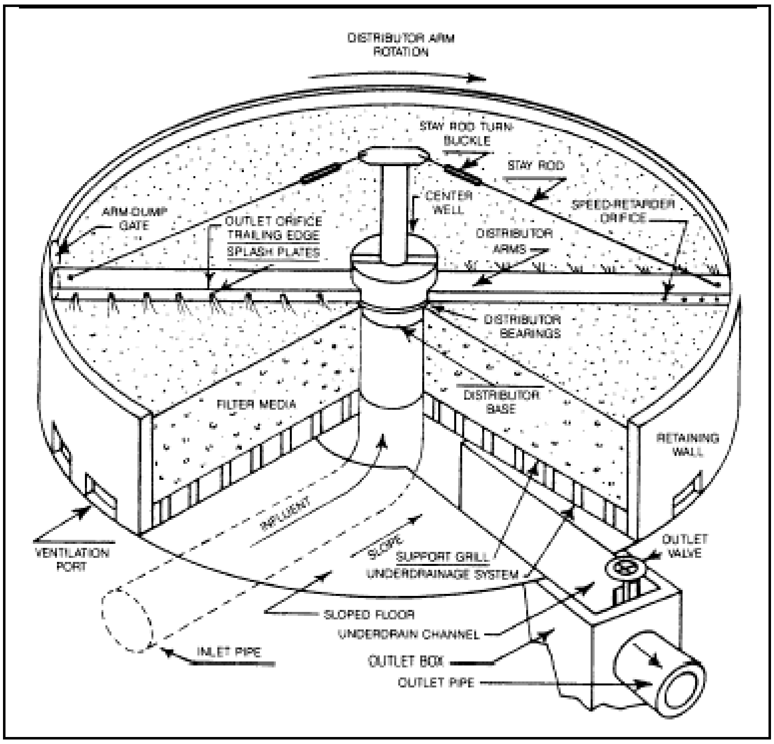


Figure 4.5. Diagram of Trickling Filters

Recent efforts have been made to combine fixed film reactors with suspended growth processes to efficiently remove organic materials from wastewater. For example, the combination of a trickling filter with an activated-sludge process has allowed for the elimination of shock loads to the more sensitive activated sludge while providing a highly polished effluent that could not be achieved by a trickling filter alone. Although the TF process is generally reliable, there is still potential for operational problems. Some of the common problems are attributed to increased growth of biofilm, improper design, relatively high land requirements, changing wastewater characteristics, or equipment failure. Some of the most prominent advantages and shortcomings of this method are listed in Table 4.10.

Table 4.10. Advantages and Disadvantages of Trickling Filters

Advantages	*Disadvantages*
Simple, reliable process with high degree of performance reliability at low or stable loadings	Additional treatment may be needed to meet more stringent discharge standards
Suitable in areas where large tracts of land are not available for a treatment system	Regular operator attention needed
Effective in treating high concentrations of organics depending on the type of media used, and flow configuration	Relatively high incidence of clogging
Appropriate for small- to medium-sized communities	Relatively low organic loadings required depending on the media
Reduction of ammonia-nitrogen concentrations in the wastewater	Limited flexibility and control in comparison with activated-sludge processes
Durability of process elements	Potential for vector and odor problems
Low power requirements	Savings in energy costs may not always justify increased capital cost
Requires only a moderate level of skill and technical expertise to manage and operate the system	Predation (i.e. fly larvae, worms, snails) decreases the nitrifying capacity of the system

4.2.4 Disinfection

In response to the high pathogenic content of domestic wastewater, disinfection has become one of the primary mechanisms for the inactivation and destruction of microorganisms such as enteric bacteria, protozoan cysts and viruses. Table 4.11 identifies the infectious agents typically found in municipal sewage and the diseases cause by these agents.

Table 4.11. Infectious Agents Potentially Present in Untreated Domestic Sewage

Organism	***Disease***
	BACTERIA
Escherichia Coli	*Gastroenteritis*
Leptospira (spp.)	*Leptospirosis*
Salmonella typhi	*Typhoid fever*
Salmonella (2100 serotypes)	*Salmonellosis*
Shigella (4 spp.)	*Shigellosis (bacillary dysentery)*
Vibrio cholerae	*Cholera*
	PROTOZOA
Balantidium coli	*Balantidiasis*
Cryptosporidium parvum	*Cryptosporidiosis*
Entamoeba histolytica	*Amebiasis (amoebic dysentery)*
Giardia histolytica	*Giardiasis*
	HELMINTHS
Ascaris lumbricoides	*Ascariasis*
T. solium	*Taeniasis*
Trichuris truchuria	*Trichuriasis*
	VIRUSES
Enteroviruses	*Gastroenteritis, heart anomalies, meningitis*
Hepatitis A virus	*Infectious hepatitis*
Norwalk agent	*Gastroenteritis*
Rotavirus	*Gastroenteritis*

Crites and Tchobanoglous (1998)

Chlorination is the most widely used disinfection process for municipal wastewater because it destroys target organisms by oxidizing cellular material. Chlorine may be supplied in many forms that include chlorine gas, hypochlorite solution, or other chlorine compounds in solid or liquid form. Some alternative disinfection processes include ozonation and ultraviolet irradiation. The choice of disinfection method depends on the following factors:

- Ability to penetrate and destroy infectious agents under normal operating conditions
- Safe and easy handling, storage, and shipping
- Absence of toxic residuals and mutagenic or carcinogenic compounds after disinfection

- Affordable capital and operation and maintenance (O&M) costs

In Lebanon, the most popular form of disinfection is chlorination due to its cost effectiveness, when compared with either UV disinfection or ozonation. Chlorine is a disinfectant that has certain health and safety limitations, but at the same time, has a long history of being an effective disinfectant. Table 4.12 lists the advantages and disadvantages of using chlorine as a disinfection process.

Table 4.12. Advantages and Disadvantages of Chlorination

Advantages	***Disadvantages***
Well-established technology	Residue is toxic, at low concentration to aquatic life
Most cost effective disinfection process	Highly corrosive and toxic (for shipping, handling, and storage)
Residuals can prolong disinfection even after initial treatment, and can be measures to evaluate effectiveness	Oxidation of some organic mater may generate more hazardous compounds such as trihalomethanes (THMs)
Reliable and effective against a wide spectrum of pathogenic organisms	Chloride content increases
Effective in oxidizing certain organic and inorganic compounds	Higher doses are required in high concentrations of oxidizable substances
Flexible dozing control	Some parasites are resistant in low doses
Can eliminate noxious odors	Level of Total dissolved solids is increased in the treated effluent
	Long-term effect of discharge into the environment is unknown

4.3. ANALYSIS OF ALTERNATIVES

4.3.1. Process Selection

Selection of the most appropriate solution to meet a certain long-term objective is not a simple and straightforward task. Several factors must be taken into consideration, including technical criteria, environmental considerations, and economic observations. The aim of this section is to weigh the potential of all relevant alternatives concerning the treatment process, the system selection and the site location for each WWTP.

In Section 4.2 (Process Theory), alternative processes were evaluated in terms of purpose, usage and efficacy. Given that anaerobic activities require high temperatures (25 - 30 ºC) to be effective *ELARD* has recommended against the use of anaerobic processes in all Hasbaiya villages under study, all having an average annual temperature of approximately 15 ºC, despite the benefits of anaerobic secondary treatment. Therefore, anaerobic treatment options were not considered amongst the alternatives in this section. Additionally, since the current situation in the Hasbaiya area is not desirable, the "Do Nothing" scenario is also not considered a legitimate option.

In the context of analysis of alternatives, six alternative wastewater treatment schemes were screened. Table 4.13 provides a comparison of the different scenarios. The alternatives are:

Alternative 1: Pretreatment alone

Alternative 2: Primary Treatment alone

Alternative 3: Secondary Biological Treatment (Aerobic) through Suspended Growth Process (Activated Sludge)

Alternative 4: Secondary Biological Treatment (Aerobic) through Attached Growth Process (Tricking Filter)

Alternative 5: Combined Secondary Biological Treatment: Attached Growth (TF) Followed by Suspended Growth (Activated Sludge) Processes

Alternative 6: Secondary Biological Treatment (Aerobic) through Suspended Growth Process (Activated Sludge) with additional Disinfection and Media Filtration

Table 4.13. Analysis of Different Scenarios of Wastewater Treatment Schemes

	Preliminary Treatment (1)	*Primary Treatment (2)*	*Secondary Treatment: biological (suspended) (3)*	*Secondary Treatment: biological (attached) (4)*	*Combined Secondary biological (Attached + Suspended) (5)*	*Tertiary Treatment (EAAS + Disinfection + Filtration) (6)*
Unit operations & processes involved	Grit removal Grease Trap	Primary Clarifier	Activated Sludge System (EAAS)	High-Rate Trickling Filters	Trickling Filter + Activated sludge system (EAAS) + Final Clarifier	Activated sludge system (EAAS) + Contact Tanks + Filter Media
Principal application	- Removal of large objects - Removal of heavy objects: sand, gravel, cinder, etc. - Removal of grease and oils	Removal of settleable solids and BOD	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus	Removal of fine non-settleable solids, BOD, some NH_3 & total phosphorus Further removal of suspended solids	Further removal of suspended solids
Land requirements	Minimum	Moderate	Moderate	High	High	Moderate
Adverse climatic conditions			Decreased microbial activity Freezing of piping and valves	Decreased microbial activity Freezing of piping and valves	Decreased microbial activity in aeration tank Freezing of piping and valves	Decreased microbial activity in aeration tank Freezing of piping and valves
Ability to handle flow variations	Good	Fair	Good	Good	Good	Good
Ability to handle influent quality variation	Good	Good	Good	Fair	Fair	Good
Industrial pollutants affecting process	Minimum	Minimum	Moderate	Moderate	Moderate	Moderate
Ease of O&M	Fair	Good	Good	Good	Good	Good
Reliability of the process	Good	Good	Good	High	Good	Moderate

Table 4.14 Analysis of the Waste Products of Different Wastewater Treatment Schemes

		Alternative 1	*Alternative 2*	*Alternative 3*	*Alternative 4*	*Alternative 5*	*Alternative 6*
Waste Products		Screenings, floatables, grit, grease	Sludge (organic & inorganic)	Stabilized and reduced sludge (biomass) for EAAS	Sludge (biomass)	Stabilized and reduced sludge (biomass)	Stabilized and reduced sludge (biomass) Backwash Waste (Filter)
Typical Removal Efficiencies (%)	**BOD_5**	Small	30-40	80-95 (EAAS)	60-80	60-80 (TF) 80-95 (EAAS)	80-95 (EAAS) 20-60 (Tertiary)
	COD	Small	30-40	80-90 (EAAS)	60-80	60-80 (TF) 80-90 (EAAS)	80-90 (EAAS) 0-50 (Tertiary)
	TSS	Small	50-65	70-90 (EAAS)	60-85	60-85 (TF) 70-90 (EAAS)	70-90 (EAAS) 60-80 (Tertiary)
	TP	Small	10-20	10-15 (EAAS)	8-12	8-12 (TF) 10-15 (EAAS)	10-15 (EAAS) 20-50 (Tertiary)
	ON	Small	20-40	75-85 (EAAS)	60-80	60-80 (TF) 75-85 (EAAS)	75-85 (EAAS) 50-70 (Tertiary)
	NH_3-N	Small	0	85-95 (EAAS)	8-15	8-15 (TF) 85-95 (EAAS)	85-95 (EAAS) No additional removal by filtration

The disadvantage of a system with only preliminary and/or primary treatment options is that contaminant removal, in particular organic, is relatively limited. When environmental protection is an issue, a treatment system should include secondary treatment, at a minimum. Therefore, both alternatives 1 and 2 would not be sufficient to treat the wastewater of the Hasbaiya area to acceptable water quality levels.

In general, as long as effluents are properly managed, a secondary treatment based on suspended growth activated sludge is a reliable process that produces acceptable levels of sewage treatment. Alternative 3 consists of utilizing secondary aerobic suspended growth treatment. Although both conventional and extended activated sludge processes could be used, the extended aeration activate sludge (EAAS) treatment was selected for the reasons listed in Table 4.15.

Table 4.15. Advantages of EAAS over Conventional Activated Sludge Treatment

Advantages of Extended Aeration Activate Sludge (EAAS)
Simpler design and operation
Provision of equalization to absorb sudden/temporary shock loads (hydraulic and biological)
High quality and well nitrified effluent meeting secondary effluent guidelines;
Lower production of organically stable waste sludge
Reliable with little need for operator attention
Relatively minimal land requirements and low initial costs;
Nitrification likely at wastewater temperatures of more than 15°C with addition of chemicals
Exists in flexible pre-engineered package plants for small communities

When comparing Alternative 3 (EAAS) and Alternative 4 (TF), Alternative 3 would generate secondary treated effluent of sufficient quality. Yet the costs of operating and maintaining such a plant are higher than one relying on a TF for treatment (Alternative 4). On the other hand, a TF alone (Alternative 4) would not achieve sufficient levels of treatment performance and has high land requirements despite its low lifecycle cost, resistance to shock loading, and ease of operation. Therefore, Alternative 3 is acceptable while Alternative 4 is not.

Alternative 5 capitalizes on the benefits of TF and EAAS systems by both deploying a TF as a pretreatment to the EAAS. Therefore, it allows for: lower power consumption of the EAAS, lower land requirement of the TF, higher treatment efficiency than that of the TF and EAAS individually. This alternative is preferred for all WWTPs in Hasbaiya due to the ease of maintenance and operation of both the TF and EAAS components. However, during the design phase of the WWTP, it was determined that installing a TF is not possible due to the considerably high volume requirement of the TF taking into consideration the particular hydraulic and organic loading of the Hasbaiya villages sewage. Therefore, although preferred, alternative 5 can not be applied in the villages of Hasbaiya due to design limitations.

Tertiary treatment (Alternative 6) consisting of the EAAS followed by media filtration and additional disinfection (chlorination)) generates the highest removal efficiency of BOD_5, COD, DO, SS, ON, Fecal Coliform and Total Coliform. Though such a treatment process is ideal, its associated maintenance, capital and operational costs could be excessive.

For the purpose of this report, the eight villages under study have been divided into two groups, according to the most appropriate alternative (treatment level) selected for each site. Groups are shown in Table 4.16.

Table 4.16. Grouping of the Hasbaiya Villages WWTPs According to Required Treatment Level

Group I ***(Secondary Treatment Level)***	***Group II*** ***(Tertiary Treatment Level)***
El Fardis	Chebaa
Kaoukaba	Chouaia
Mari	Hebbariye
	Kfar Hamam
	Rachaiya el Foukhar

Group I comprises three villages, namely: El Fardis, Kaoukaba and Mari. Those villages are located downstream, at close proximity to the Hasbani River. The presence of a perennial flowing body of water allows for secondary treatment processes, therefore, the EAAS of Alternative 3 would satisfy the discharge limitations of the sites and alternative 6 for group I villages is not cost effective. Table 4.17 summarizes the process selection for the villages in group I.

Table 4.17. Summary of Process Selection Alternatives for Group I Villages

Alternative	***Concerns***	***Outcome***
1) Preliminary Treatment	Effluent will not meet ELVs	Not Acceptable
2) Primary Treatment	Effluent will not meet ELVs	Not Acceptable
3) Secondary Aerobic Treatment: Activated Sludge (EAAS)	High Electric Input Will meet ELVs Need for further treatment due to sensitive discharge site	Preferred
4) Secondary Aerobic Treatment: Trickling Filter	Will not meet ELVs Can not be implemented due to size	Not acceptable
5) Combined Secondary Aerobic Treatment: Trickling Filter + Activated Sludge (EAAS)	Effluent will meet ELVs Requires safe discharge site Can not be implemented due to size of TF	Not applicable
6) Secondary Aerobic Treatment with Additional Tertiary Treatment: EAAS + Disinfection (Contact Tanks) + Filter Media	Highest quality effluent with highest capital, operation and maintenance costs and requirements	Not needed

Group II includes the villages of Chebaa, Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar. For the case of group II villages, the absence of a perennial flowing body of water nearby each site limits the level of treatment to tertiary levels. Therefore, the EAAS of Alternative 3 would not satisfy the discharge limitations of each site and alternative 6 is the preferred alternative for those villages. Table 4.18 summarizes the process selection for the case of the group II villagesWWTPs.

Table 4.18. Analysis of Process Selection Alternatives for Group II Villages

Alternative	***Concerns***	***Outcome***
1) Preliminary Treatment	Effluent will not meet ELVs	Not Acceptable
2) Primary Treatment	Effluent will not meet ELVs	Not Acceptable
3) Secondary Aerobic Treatment: Activated Sludge (EAAS)	High Electric Input Will meet ELVs Need for further treatment due to sensitive discharge site	Acceptable with further treatment
4) Secondary Aerobic Treatment: Trickling Filter	Will not meet ELVs Can not be implemented due to size	Not acceptable
5) Combined Secondary Aerobic Treatment: Trickling Filter + Activated Sludge (EAAS)	Effluent will meet ELVs Requires safe discharge site Can not be implemented due to size of TF	Not applicable
6) Secondary Aerobic Treatment with Additional Tertiary Treatment: EAAS + Disinfection (Contact Tanks) + Filter Media	Highest quality effluent with highest capital, operation and maintenance costs and requirements	Preferred

4.3.2. Site Selection

In general, the most practical and economical location of each plant would be down gradient with respect to the areas being served in the corresponding village. As such, the sewage is conveyed to the plant by gravity, avoiding the need for pumping stations along the sewage collection lines, therefore minimizing operational costs and reducing the potential for a second point source of contamination. Other significant criteria in the selection of a location are the hydrological and geological settings. The distances of the locations from sensitive receptors such as residences and institutions are also considered. The potential proximity of the proposed sites to nearby springs or the potential presence of direct hydrological connections with the ground water is also highly investigated. Appendix B presents the Topography map showing the location on which the plant will be built.

Exact site selection for the different WWTPs is strictly case-specific. Some villages present limited alternative sites that were not investigated, others present two or three available scenarios for site selection. The process for each case site selection is described in detail in the following paragraphs, whereas a summary of only *preferred* scenarios for site selection is presented in Table 4.19.

In the case of Chebaa, note that initially the client was planning to install two (2) plants to serve the village. As a result of the EIA conducted for this plant, the client was convinced that only one plant would be necessary to serve the village. The wastewater plant is located on the northern banks of Chebaa Valley on the Kesrouane formation, which is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels - a typical occurrence in karstic aquifers. As indicated in the geologic setting presented in Appendix A and in section 0 the plant site is located in an area proximal to the intermittent Chebaa River that does not maintain a flow > $0.1m^3/s$, and therefore effluent treated to secondary level cannot be discharged into this river. Hence, the need for stricter ELV and the deploy of tertiary treatment is necessary if the effluent is to be discharged of in the Chebaa River.

In Chouaia, the wastewater plant is located on permeable sandstone overlying the Aquiferous Bikfaya-Kesrouane Formation. The overlying Chouf Sandstone Formation is characterized by its permeability and capacity for simultaneous natural filtration. As indicated in section 5.5, the plant site is located adjacent to an intermittent Bou Aamte Valley waterway and therefore secondary treated effluent cannot be discharged into this stream. The effluent must be further treated to tertiary levels before it can be discharged in the valley on the Chouf sandstone allowing natural attenuation. Since the major wind direction in the region is W and WNW, and the site is NW of the village, then residential areas in the village of Chouaia are generally not downwind of the WWTP. Moreover, the proposed site is located approximately 600m downhill of the Chouaia village and the nearest household. The Chouaia village primary sewage collection line is located close to the proposed site and would only have to be extended approximately 100m by the Chouaia Municipality. The Chouaia Municipality would also be responsible for minor rehabilitation of the remaining collection network. Since the proposed site location is owned by the Chouaia Municipality, then no additional cost will be incurred by land purchase.

In El Fardis, the wastewater plant is located on the southern banks of Chebaa Valley on the Quaternary deposits overlying the Sannine Formation, which is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels - a typical occurrence in karstic aquifers. As indicated in the geologic setting presented in Appendix A and in section 5.5 the plant site is located in an area adjacent to the Chebaa River and therefore the treated effluent can not be discharged into this river knowing that it is intermittent and does not maintain a flow greater than $0.1m^3/s$. Moreover, the proposed site is located 500m from the Hasbani River, which is perennial and maintains a flow greater than 0.1 m^3/s. El Fardis village is approximately 1Km away from the nearest WWTP. Therefore, although located downgradient of the village, the site carries the risk of groundwater contamination through accidental leakages. In addition, the site may be subjected to flooding in the case of high river flow during the snowmelt seasons or high intensity precipitation.

In Hebbariye, the wastewater plant is located on the southern banks of Chebaa Valley on the Bikfaya- Kesrouane formation (J_7- J_4) (Appendix A), which is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels - a typical occurrence in karstic aquifers. As indicated in the geologic setting presented in Appendix A and in section 5.5 the plant site is located in an area adjacent to the intermittent Chebaa waterway and therefore secondary treated effluent can not be discharged into this river knowing that it does not maintains a flow > $0.1m^3/s$. Moreover, the proposed site is located 1.2 Km from the Hebbariye village. Therefore, although located downgradient of the village, the site carries the risk of groundwater contamination through accidental leakages. Thus, the effluent must be tertiary treated before it is discharged into the intermittent river (the Chebaa waterway) leading downstream to the Hasbani River. Another preferred site for Hebbariye has been suggested and is presented in Table 4.19.

In the case of Kaoukaba, the proposed location for the plant does permit the discharge of treated effluents into a perennial River, given that, the River is at proximity and the quality of effluent should meet the Environmental Limit Values (ELV) for wastewater discharged into surface water that is in turn defined as having a minimum *flow of 0.1* m^3/s providing proper dilution factor. That does apply here since the perennial river nearby does meet the minimum requirements of flow. As indicated on the geologic setting presented in Appendix A and in section 5.5 the plant site is located in an area identified as impermeable marly limestone adjacent to the Hasbani River. The site proposed by the municipality is suitable for the construction of the plant, and alternative sites were not investigated.

In Kfar Hamam, the wastewater plant is located on volcanic basalts overlying the Aquiferous Bikfaya-Kesrouane Formation (Appendix A). The basaltic Bhannes Formation is characterized by its low permeability hindering the flow of contaminated wastewater mainly into the underlying karstic aquifers. As indicated in the geologic setting presented in Appendix A and in section 5.5, the plant site is located adjacent to the intermittent Ras-en-Nimer Valley River and therefore the secondary treated effluent cannot be discharged into this River. The effluent must be tertiary treated before it can be transported 300 – 400 m into the valley and discharged on the Chouf sandstone, allowing for natural attenuation. Since the major wind direction in the region is W and WNW, and the site is NW of the village, then residential areas in the village of Kfar Hamam are not downwind of the WWTP. Moreover, the proposed site is located 1 Km down hill the Kfar Hamam village and the nearest household. The village sewage collection main reaches the proposed site. No additional cost would be incurred by the Kfar Hamam Municipality from setting new network infrastructure (500 m of the existing sewage network has to be rehabilitated).

In Mari, the proposed WWTP is located on Quaternary deposits overlying the Sannine Formation. However, this formation is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels - a typical occurrence in karstic aquifers. Since the major wind direction in the region is W and WNW, then residential areas in the village of Mari are upwind of the site. Moreover, the proposed site is located 1 Km from the Mari village and approximately 0.6 Km away from the nearest household. Therefore, although located down gradient of the village, at a distance from the site carries the risk of groundwater contamination through accidental leakages. In addition, the site may be subjected to flooding in the case of high river flow during the snowmelt seasons or high intensity precipitation. The proposed location for the plant in Mari does permit the discharge of treated effluents into the perennial Hasbani River especially since the River is at a close proximity and is of continuous yearly flow. With the appropriate treatment system in place, the quality of effluent from the Mari WWTP would meet the Environmental Limit Values (ELV) for wastewater discharge into surface water (defined as having a minimum *flow of 0.1* m^3/s providing proper dilution factor). Therefore, the Mari plant should be able to discharge treated effluent in the Hasbani river without causing any potential threats from infiltration into down gradient springs. No additional tertiary treatment level would be required.

In Rachaiya el Foukhar, as indicated on the geologic setting presented in Appendix A and in section 5.5 the plant site is located in an area identified as a recharge zone for down gradient surface water, and, therefore, the effluent from the plant will contribute to the perennial Hasbani River that maintains a flow of more than 0.1 m^3/s. Note that limited options for site selection were made available to the consultants. Tertiary treatment was deemed necessary given the characteristics of the available site.

Table 4.19. Summary of Preferred Scenarios for Site Selection

WWTP	*Site Location*	*Property*	*Treatment Level*	*Discharge Site*	*Geological/Hydrogeological Constrains*	*Distance from Residential Areas*	*Collection Network Infrastructure*	*Capital Costs*	*Operational/Maintenance Costs*
Chebaa	Shifted from original location proposed by municipality	Purchased by municipality	Tertiary	Chebaa River adjacent to site	Kesrouane Fm.	~ 1 km from village	Has to be extended 1km to WWTP	- Increased due to tertiary infrastructure - Increase due to expanded collection network - Slight increase due to the protective seal beneath the site - Increased capital cost for purchase of new land parcel	- Increased due to stringent environmental management plans and monitoring of the plant - Slightly increased due to increase in operation and maintenance cost
Chouaia	Proposed Location by municipality	Municipal property	Tertiary	Shouf Sandstone	Located on permeable sandstone	~ 0.6 km from village (residences upwind)	Close to site, little need for extention	- Increased due to tertiary infrastructure - Slight increase due to expansion of primary collection infrastructure	- Increased due to stringent environmental management plans and monitoring of the pant - Slightly increased due to increase in operation and maintenance cost.
El Fardis	Proposed Location by municipality	Purchased by municipality	Secondary	Hasbani River 500 meters from site	Located on quaternary formations, ➔ acceptable location	~ 1 km from village	Has to be extended approx. 1km	- Increased due to extending the discharge pipeline. - Slight increase due to the construction of the retaining wall and	Moderate

WWTP	Site Location	Property	Treatment Level	Discharge Site	Geological/Hydrogeological Constrains	Distance from Residential Areas	Collection Network Infrastructure	Capital Costs	Operational/Maintenance Costs
Hebbariye	Shifted from proposed alternative	Unknown	Tertiary	Hasbani River	Located on non-permeable Chouf Sandstone formation	Approx. 2 km from village	Has to be extended at least 0.8 km.	- Increased due to tertiary infrastructure Increase due to expanded collection network - May include cost of land parcel	- Increased due to stringent environmental management plans and monitoring of the plant - Slightly increased due to increase in operation and maintenance cost
Kaoukaba	Proposed Location by municipality	Municipal property	Secondary	Hasbani River adjacent to site	Located within the marl, marly limestone ➔ acceptable location	Approx. km from village and 600 m from nearest household	Has to be extended approx. 700m	- Slight increase due to the construction of the retaining wall and protective seal beneath the site	Moderate
Kfar Hamam	Proposed Location by municipality	Municipal property	Tertiary	Sandstone 400 m into the Ras-en-Nimer Valley	Located on impermeable Bhannes Formation (Basalts)	Approx. 1km from village and nearest household	Reaches the site, No need for extension	- Increased due to tertiary infrastructure - Increase due to construction of 400 m of discharge infrastructure	- Increased due to stringent environmental management plans and monitoring of the pant - Slightly increased due to increase in operation and maintenance cost.

WWTP	***Site Location***	***Property***	***Treatment Level***	***Discharge Site***	***Geological/Hydrogeological Constrains***	***Distance from Residential Areas***	***Collection Network Infrastructure***	***Capital Costs***	***Operational/Maintenance Costs***
Mari	Proposed Location by municipality	Municipal property	Secondary	Hasbani River adjacent to site	Located between the Karstic Sannine Formation and the Hammana Formation ➔ acceptable	Approx. 1km from village and 600 m from nearest household	Has to be extended approx. 700 meters	- Slight increase due to the construction of the retaining wall and protective seal beneath the site	Moderate
Rachaiya el Foukhar	Proposed Location by municipality	Municipal property	Tertiary	Hasbani River	Located within the Karstic Sannine ➔ acceptable	Approx. 2km from village and from nearest household	Has to be extended approx. 700 meters	- Increased due to tertiary infrastructure - Slight increase due to the construction of the retaining wall	- Increased due to stringent environmental management plans and monitoring of the pant - Slightly increased due to increase in operation and maintenance cost.

4.4. DETAILED PROCESS DESCRIPTION

The WWTPs in Group I (El Fardis, Kaoukaba and Mari) requiring only secondary treatment levels shall consist of the following unit operations(indicated in blue in Figure 4.6):

- Grit trap
- Grease Trap
- Aeration reactor with air blowers
- Clarifier with sludge re-circulation pumps
- Chlorine feed system
- Chlorine contact zone
- Sludge drying beds with sludge filtrate pump
- Control panel
- Electric generator

The WWTPs in Group II (Chebaa, Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar) requiring advanced treatment levels shall consist of the following unit operations:

- Grit trap
- Grease Trap
- Aeration reactor with air blowers
- Clarifier with sludge re-circulation pumps
- Chlorine feed system
- Chlorine contact zone
- Filters' feed pumps*
- Dual media filter*
- Granular activated carbon filter*
- Sludge drying beds with sludge filtrate pump
- Control panel
- Electric generator

* Note that additional units specific to advanced treatment levels are indicated in red in Figure 4.6.

In both groups, as a first step, raw wastewater flows in to a grit trap where grit, consisting of sand, gravel, cinders and other heavy solid materials having subsiding velocities of relatively high specific gravities, is removed. Settled grit is pumped by the sludge pumping station to the sludge holding tanks for storage and dewatering. The grit trap liquid effluent then flows into a grease trap where the low-density grease component is skimmed and transported to the sludge-handling unit.

The wastewater then flows into the aeration basin of the EAAS system. In the reactor, the organic matter is aerobically digested by suspended microorganisms while air is mechanically introduced in the reactor. The aerobic environment in the reactor is achieved by the use of diffused aeration in the form of aerators or blowers, which also serve to maintain the mixed liquor in a completely mixed regime. After a specific period of time, the mixture of new and old cells is passed into a settling tank, where the cells are separated from the treated wastewater. A portion of the settled sludge is recycled back into the aeration basin and the grit trap to maintain the proper food to microorganism ratio needed for the rapid breakdown of organic matter. The remainder of the waste sludge is conveyed to sludge-drying beds for proper treatment and disposal.

Effluents produced from EAAS systems are of high quality and are well nitrified. Typical removal efficiencies for BOD_5, COD, TSS, ON, and TP are 90-95 %, 80-85 %, 70-95 %, 75-85 %, and 10-15 % respectively, as reported in published literature.

The effluent from the final settlement tank flows into a chlorine contact basin for disinfection. When chlorine gas or hypochlorite salts are added to the wastewater, hydrolysis and ionization takes place to form free available chlorine. The free chlorine reacts readily with ammonia in the non-nitrified effluents destroying infectious agents. After disinfection, the chlorine residual can persist in the effluent for many hours. The effluent from group I plants can be discharged into the perennial river as a final step.

In view of the limited options for liquid effluent discharge sites in the case of Group II plants, the chlorinated wastewater is dechlorinated prior in a later stage, in an effort to reduce the organic and nutrient load.

Next, the chlorinated effluent of only groups II plants flows through a dual media filter in order to remove residual suspended solids. The filter is composed of a layer of silica sand, overlying anthracite to extend filter life, and is supported by a layer of quartz. Following the dual media filer, the treated wastewater passes through granular activated carbon (GAC) filter where organic compounds including chlorination residues and byproducts such as THMs are removed. Effluents produced from the WWTP will be of high quality.

The achievable treatment levels specific to the proposed Group II WWTPs are indicated in bold in Table 4.20.

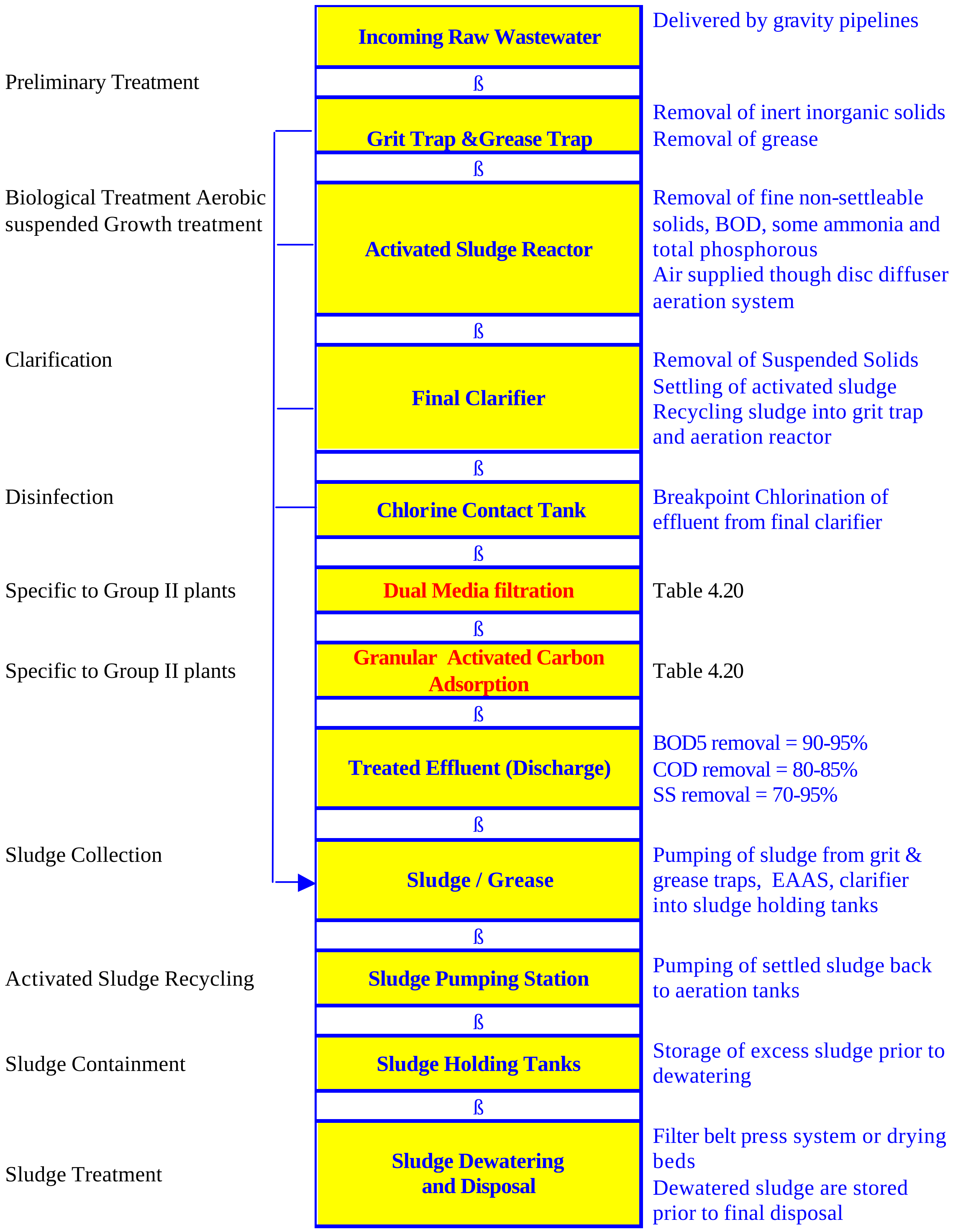


Figure 4.6. Flow Diagram of EAAS Treatment Plant

Table 4.20. Treatment Efficiencies for Various Combinations of Advanced Wastewater Treatment Processes

Treatment Process	**Typical Effluent Quality**						
	SS mg/l	***BOD_5 mg/l***	***COD mg/l***	***Total N, mg/l***	***NH_3-N, mg/l***	***PO_4 –P, mg/l***	***Turbidity, NTU***
National ELVs for discharge into surface water	60	25	125	30	10	5	N.A.
Activated Sludge + Media Filtration	4-6	<5-10	30-70	15-35	15-25	4-10	0.3-5
Activated Sludge + Media Filtration + Carbon adsorption	**<3**	**<1**	**5-15**	**15-30**	**15-25**	**4-10**	**0.3-3**
Activated Sludge / Nitrification, single stage	10-25	5-15	20-45	20-30	1-5	6-10	5-15
Activated Sludge / Nitrification-Denitrification separate stages	10-25	5-15	20-35	5-10	1-2	6-10	5-15
Metal Salt addition to activated sludge	10-20	10-20	30-70	15-30	15-25	<2	5-10
Metal Salt addition to activated sludge + Nitrification / denitrification + Filtration	<5-10	<5-10	20-30	3-5	1-2	<1	0.3-3
Mainstream Biological Phosphorus removal	10-20	5-15	20-35	15-25	5-10	<2	5-10
Activated Sludge Mainstream Biological P & N Removal + Media Filtration + Carbon Adsorption	<10	<5	20-30	<5	<2	<1	0.3-3

Source: Metcaff & Eddy, 1991

4.5. EFFLUENTS CHARACTERIZATION AND MANAGEMENT

The EAAS treatment plants typically generate two main types of by-products: treated liquid effluent, and waste sludge. Other miscellaneous effluents will include biogases and "bulk" solids removed during the preliminary treatment, namely, grit and grease traps, in addition to saturated media and activated carbon materials.

4.5.1. Liquid Effluent

4.5.1.1. Liquid Effluent Characteristics

The quantity of liquid effluent that will be generated daily is equivalent to the quantity of sewage received by each plant. The average daily volume of generated treated effluent from the wastewater treatment plant by year 2015 and 2030 can be calculated from the projected design population in each corresponding village (Table 4.21). In the calculations, an average daily per capita sewage generation of 100L is assumed. It should be noted that quantities of generated liquid effluents would be much less during the first years of operation.

Table 4.21. Average Daily Volumes of Treated Liquid Effluent

Municipality	*Present Efluent Flow (m^3/Day)**	*Effluent Flow by Year 2015 (m^3/Day)*	*Effluent flow by year 2030 (m^3/day)**
Chebaa	900	1,119	1,506
Chouaia	70	87	117
El Fardis	70	87	117.1
Hebbariye	550	684	920
Kaoukaba	200	249	335
Kfar Hamam	170	211	284
Mari	130	165	220
Rachaiya el Foukhar	125	155	209

* Considering the 2% average population growth per year (design assumption)

The expected quality of the liquid effluents varies with the type of adopted treatment technology. However, in the case of imposed tertiary treatment levels, this will lead to advanced levels of water quality (Table 4.20).

4.5.1.2. Liquid Effluent Management

The treated effluent should meet very stringent quality standards and thus its disposal into the environment should not cause adverse impacts. However, to avoid any risk of contaminating nearby springs or underground waters, the hydrological as well as geological settings have been evaluated for all sites in Section 5.5 and are being accounted for.

All Group I plants will have their secondary treated liquid effluent discharged into the Hasbani River, given that the perennial river flow is considered more than 0.1 m^3/sec, thus above the standard dilution factor for effluent disposal in surface water. However, some WWTPs in this group will require additional network downstream of the WWTP site.

As for Group II plants, given that the quality of tertiary treated liquid effluent will have lower values than the Environmental Limit Values (ELV) for wastewater discharged into surface water and will actually meet stringent levels of water treatment, the liquid effluent may be discharged into the intermittent river adjacent to the WWTP site. It is noteworthy to mention that all Group II WWTP sites have been located nearby an intermittent river, which is usually a tributary to the Hasbani River. Table 4.22 summarizes the effluent management practices for each OORTP in Hasbaya.

Additionally, the tertiary treated effluent could be used for irrigation purposes for olive orchards present in the area only after dechlorination has take place. Appendices E and F provides EPA guidelines for wastewater re-use in the biological environment. However, at the present time, this alternative is not acceptable to the villagers of Hasbaiya in general and the treated effluent will be discharged in the corresponding intermittent spring.

Table 4.22. Summary of the Liquid Effluent Management Practices for the Eight WWTPs in Hasbaya

	WWTP Location	***Surface Cover***	***Geological Formation***	***Liquid Effluent Management***			
				Effluent Treatment Level	***Location of Effluent Discharge***	***Down Gradient Receptors***	***Remarks***
GROUP I WWTP	El Fardis	Approx. 2m of alluvial (conglomerate-reddish-brown clay)	Sannine Fm.	Secondary treatment	Hasbani River (500 meters from site)	- Groundwater - Vegetation - Hasbani River	Protective seal is required underneath the site because of the high secondary porosity of the karstic fm.
	Kaoukaba	Few meters of white soil	Chekka Fm. (Marly limestone)	Secondary treatment	Hasbani River adjacent to site	- Vegetation - Hasbani River	Effluent should be transported approx. 300m to the Hasbani River
	Mari	>2m of alluvial (conglomerate-reddish brown clay)	Sannine Fm..(dolomitic limestone, marly limestone and marl)	Secondary treatment	Hasbani River	- Groundwater - Vegetation - Hasbani River	Protective seal is required underneath the site because of the high secondary porosity of the karstic fm
GROUP II WWTP	Chebaa	Less than 2 meters of red/brown clay soil	Kesrouane Fm.	Tertiary treatment	Chebaa Valley seasonal flow adjacent to site	- Groundwater - Vegetation - Important spring for domestic drinking water	- Groundwater will be encountered in the karstic limestone of the Kesrouane Fm.
	Chouaia	Less than 2 meters of red/brown clay soil	Shouf Sandstone Fm.	Tertiary treatment	Abou Aamte Valley seasonal flow	- Groundwater - Vegetation - Spring < 100m away, downgradient northwards	- Groundwater will be encountered in the karstic limestone of the Kesrouane fm. under the Shouf Sandstone fm. - Plant relocated downgradient of spring
	Hebbariye	Approx. 2m of alluvial (conglomerate-reddish-brown clay)	Kesrouane Fm.	Tertiary treatment	Chebaa Valley seasonal flow	- Groundwater - Vegetation	- Site is located on karst - Protective seal is required underneath the site

	WWTP Location	Surface Cover	Geological Formation	Liquid Effluent Management			
				Effluent Treatment Level	Location of Effluent Discharge	Down Gradient Receptors	Remarks
GROUP II WWTP	Kfar Hamam	None	Bhannes Fm. (volcanic basalts)	Tertiary treatment	Ras-en-Nimer Valley seasonal flow adjacent to site	- Groundwater - Vegetation	- Formation acts as a protective seal - All construction should be located on volcanic rocks - Effluent should be transported approx. 300m into the valley to discharge into the Shouf Sandstone
	Rachaiya el Foukhar	Less than 1 meter of reddish brown soil, patchy	Hammana Fm.	Tertiary treatment	Fardis Valley Seasonal flow	- Small seepage zone 200 m from site - Vegetation	Site located on a hydrological recharge zone

4.5.3. Sludge Effluent

4.5.3.1. Sludge Characteristics

The estimated volume of generated sludge varies with the type of adopted treatment technology. Typical sludge generation rate for an EAAS system is published to be 6.4-9.1 Lit/m^3 of wastewater treated or 748-1069 Lit of sludge daily. Typical quality of sludge generated after EAAS treatment compared to the standards set in the MoE's Compost Ordinance is depicted in Table 4.23 and Table 4.24.

Table 4.23. Typical Ranges for Chemical Composition of Activated Sludge

Parameter	*Typical Range*
Total dry solids (%)	0.83-1.16
Nitrogen (N, % of TS)	2.4-5.0
Phosphorus (P_2O_5, % of TS)	2.8-11.0
PH	6.5-8.0
Organic acids (mg/L or ppm as acetic acid)	1,100-1,700

Table 4.24. Typical Metal Content in Wastewater Sludge

Metal	*Dry Sludge (mg/Kg or ppm)*		
	Range	*Median*	*MoE's Ordinance (grade A)*
As*	1.1-230	10	-
Cd*	1-3,410	10	<1.5
Cr	10-99,000	500	<100**
Co	11.3-2,490	30	-
Cu*	84-17,000	800	<100**
Fe	1,000-154,000	17,000	-
Pb*	13-26,000	500	<150**
Mn	32-9,870	260	-
Hg*	0.6-56	6	-
Mo	0.1-214	4	-
Ni*	2-5,300	80	-
Se*	1.7-17.2	5	-
Sn	2.6-329	14	-
Zn*	101-49,000	1,700	<400**

* Metals that are regulated for land application of wastewater sludge
**Values exceeded

4.5.3.2. Sludge Management

Once the plants are operational, *detailed sludge characterization and monitoring will be necessary to assess the best disposal option for it*. The sludge residue of the WWTPs can be managed through three options:

Option#1: Stabilized sludge used as a fertilizer or soil cover for land application (landscaping activities, reforestation, silviculture, quarry rehabilitation)

Option#2: Integration in the regional composting process or Co-composting

Option#3: Stabilization and Landfilling

Table 4.25 shows the selection process of the best management option or solution for sludge disposal. The sludge should only be used for agricultural purposes (option 1) if trace levels of heavy metals prevail as indicated in Appendix E Option 1 is also highly dependent on the demand of such a product in the market and the level of acceptance from the farmers, which is mediocre in the region. In addition, since no Solid Waste Treatment Plant (SWTP) is located in the region, the sludge produced can not be integrated in a regional composting process, therefore option 2 is not applicable at the moment unless the sludge is treated onsite through windrow composting or if a plant becomes available at a reasonable distance from the site. Option 3, which consists of land filling, is recommended, as long as there is an authorized landfill MoE where the stabilized sludge could be sent.

Table 4.25. Selection of Best Management Practice for Generated WWTPs Sludge

Sludge Management	***Option#1 Land Application***	***Option#2 Composting***	***Option#3 Landfilling***
Monitoring	Frequent & Regular	Frequent & Regular	Frequent & Regular
Impact / Mitigation Measures	High/ requires surface area	High	High / Decrease landfill life
Sustainability of Solution	Sustainable	Highly Sustainable	Less sustainable
Technical & Financial Applicability	Highly Applicable	No SWTP – needs to be onsite composting	Applicable as long as an authorized landfill is available

4.5.4. Miscellaneous Wastes

Other debris and solid wastes produced from the different plants will be managed similarly to the management of the municipal solid waste in the area. However, since at the moment, no such program is being implemented, plant debris should be disposed of in a landfill approved by the MoE. Wastes generated by WWTPs that include tertiary treatment are saturated media filter and activated carbon that will be returned to the supplier.

4.6. PLANT CONSTRUCTION

The size of a WWTP varies according to the location and the population that it serves as well as the technology implemented. Table 4.26 provides information on the resources needed to build the EAAS WWTP in all eight Hasbaiya villages; it includes the surface area of land required, the population served, the volume of reinforced concrete to be used, and the wastewater hydraulic loading as well as BOD and Suspended Solids loads the plant is designed to treat for.

It should be noted that for all plants the cost of excavation is $3/m^3. The excavated material will be either sent to quarries where it can be re-utilized (preferred option) or to the nearest landfill for final disposal.

Moreover, construction work will be phased over 6-8 months, which account for the time necessary to procure electro-mechanical equipment. After completion of concrete works and installation of all electro-mechanical equipment, piping, and fixtures, a testing and start-up period of 2 - 3 months will be provided to ensure that plant is working according to specifications.

Table 4.26. Hasbaiya WWTPs Construction Characteristics

WWTP	*Population Served*	*Area Utilized* m^2	*Total Volume of Excavation* m^3	*Total Volume of Reinforced Concrete* m^3	*Amount of Reinforced Steel (Tons)*	*Hydraulic Loading* m^3*/day*	*BOD mg/L*	*Suspended Solids mg/L*
Chebaa	15,061	1000	1,500 – 3,000	200	250	1,500	825	750
Chouaia	1,170	1000 - 1500	1,500 – 3,000	200	20	120	825	750
El Fardis	2,175	1000 - 1500	Minimal	200	20	220	825	750
Hebbariye	1,171	1000	450 (10 truck trips/day during 6 days)	1,500	150	120	825	750
Kaoukaba	2,175	1000 - 1500	Minimal	200	20	435	825	750
Kfar Hamam	2,175	1000 - 1500	1,500 – 3,000	200	20	220	825	750
Mari	2,175	1000 - 1500	Minimal	200	20	220	825	750
Rachaiya el Foukhar	1,250	1000 - 1500	1,500 – 3,000	200	20	209	1,100	950

5. DESCRIPTION OF THE ENVIRONMENT

5.1. GENERAL SETTING

Two parallel mountainous ranges, Mount Lebanon and Anti Lebanon, separated by the Bekaa plain are the dominating topographic features of Lebanon (Figure 5.1). These topographic features extend in a NNE-SSW direction. The study area is located on the Eastern slopes of the South Lebanon, where the lowest elevations coincide with the Hasbani River. Land elevations in the Hasbaiya area range on average between 800 m and 1300 m above sea level.

The eight villages under study (Chebaa, Chouaia, El Fardis, Hebbariye, Kaoukaba, Kfar Hamam, Mari, Rachayia el Foukhar) are located in the region of the Caza of Hasbaiya to the Eastern side of the Hasbani River (Figure 5.2). A generally good road network exists in the region (Figure 5.3) connecting the villages to each other. However, in the case of most villages the road that connects the main road to the proposed site of the wastewater plant needs rehabilitation and/or lengthening. The road is essential to connect the site to the main road in order to perform the excavation and building machinery to reach the site easily during plant construction phases.

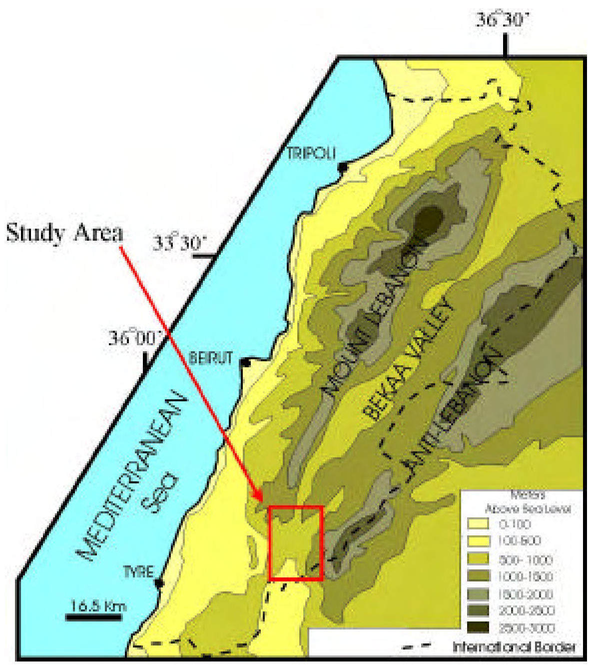


Figure 5.1. Topographic Map of Lebanon

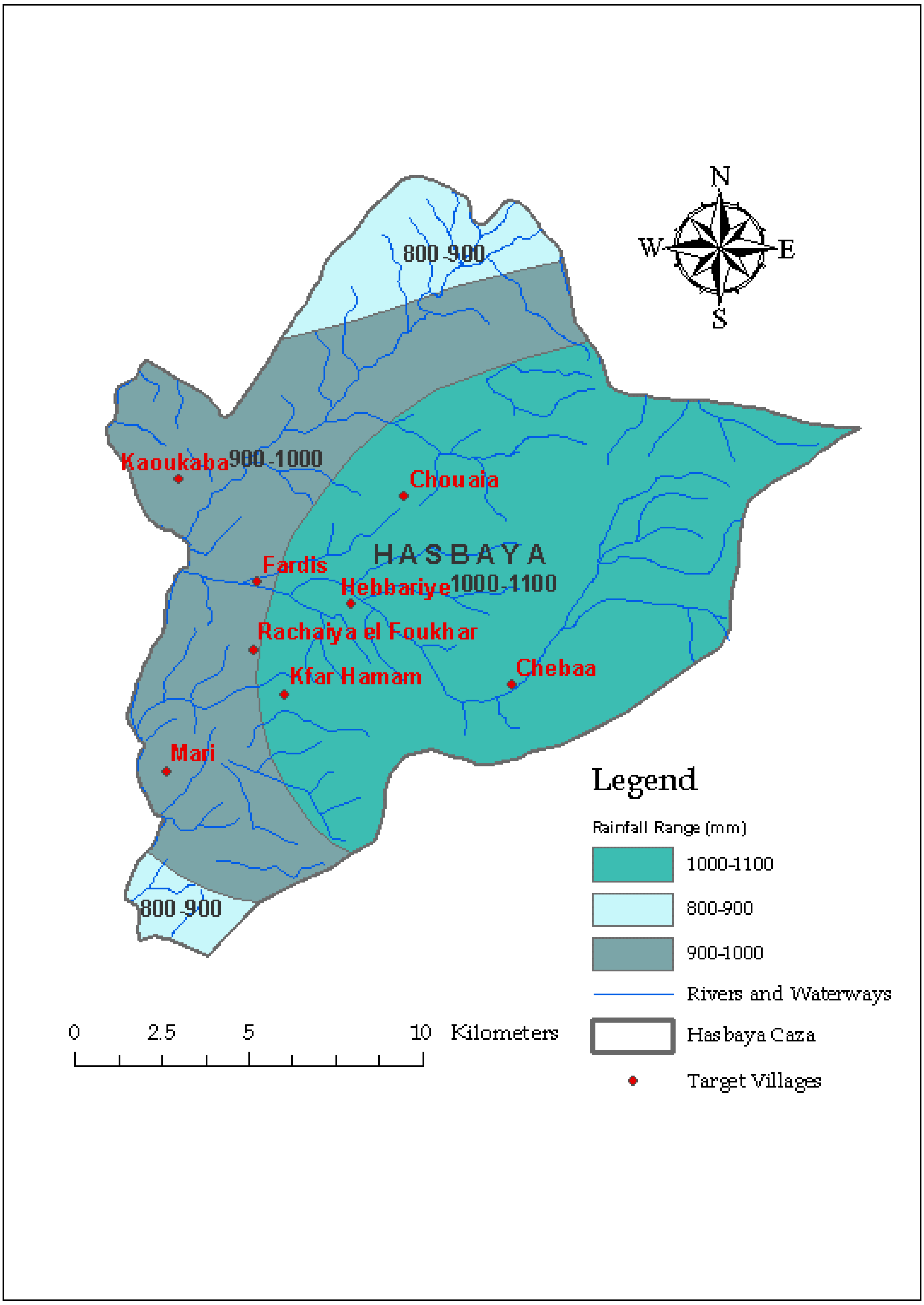


Figure 5.2. Villages to be Served by Wastewater Treatment Plants in Caza of Hasbaiya

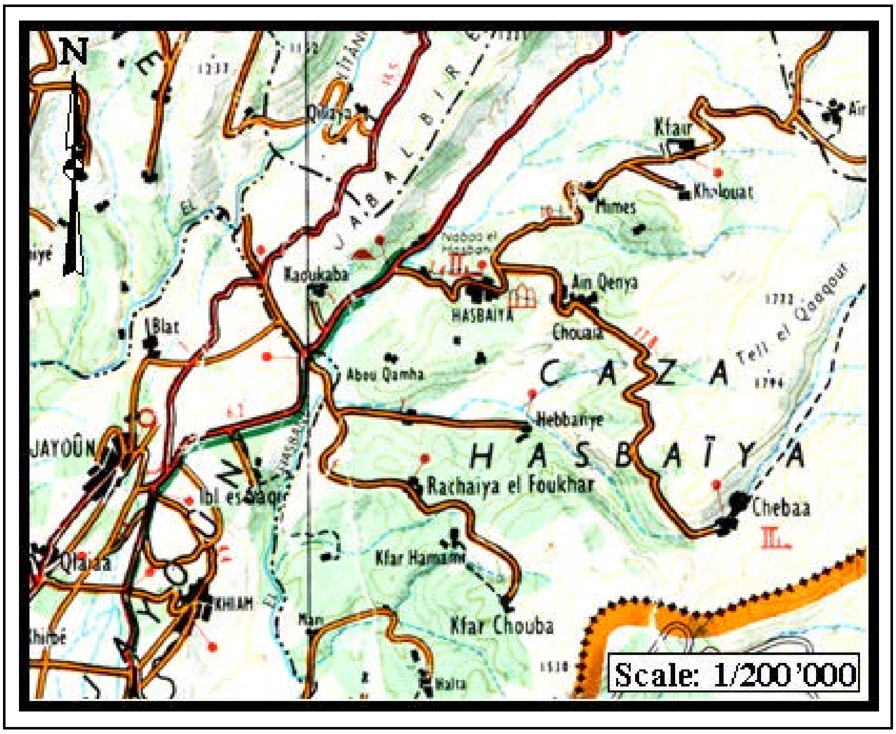


Figure 5.3. Detailed topographic map showing the road network connecting the different villages of the area

The general land use map of the Hasbaiya Region (not to scale) indicates that all WWTPs would be located in a region (Figure 5.4) that predominantly consists of scrubland, permanent crops, annual crops and broad leaved forests.

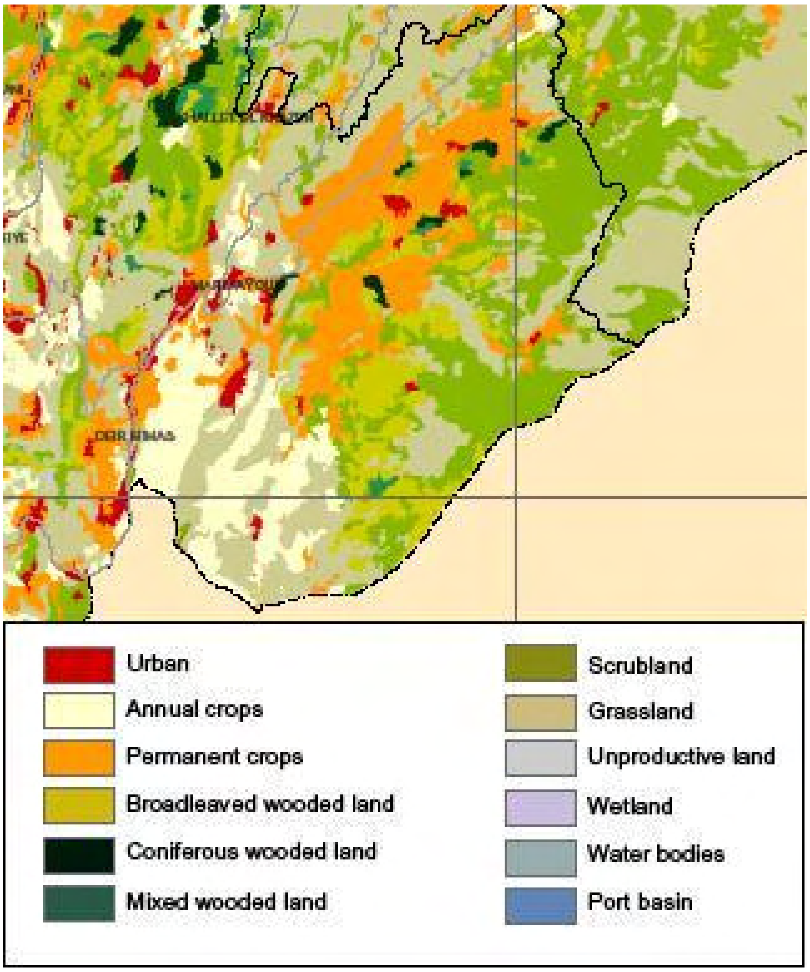


Figure 5.4. Land Use Map of Hasbaiya Region (MoE, January 2004)

5.2. METEOROLOGICAL SETTING

The topographic features of Lebanon, in general, influence largely the climate of the country. The climate of the Lebanese coast is of Mediterranean subtropical type, where summers are hot and dry; and winters are mild and wet. On the other hand, snow covers the mountains of the two ranges at times for several months per year. The two mountain ranges tend to have a cool and wet climate in contrast to that of the coastal zone.

Meteorological information including primarily precipitation, ambient temperature, as well as wind direction and speed, are essential data for adequately assessing environmental impacts. Unfortunately, meteorological records are seldom available, except for few locations in the country where stations were operating, in particular the Hasbaiya, Marjayoun and Rachaya stations of the Service Meteorologique and the American University of Beirut (AUB) stations. Recently, new stations have been installed across different regions of the country, providing a better coverage of meteorological parameters. Precipitation

The two mountain ranges of Lebanon are perpendicular to the path of atmospheric circulation. They intercept humidity and receive high rainfall compared to areas with similar locations (Figure 5.5). Figure 5.6 depicts monthly rainfall distribution from data collected at the AUB station (1996 - 1998 and 1877 - 1970), at the Hasbaiya station (1931 - 1960) and Marjayoun (1931 - 1960). Precipitation data was obtained from BIA records, Service Météorologique du Liban (1977) and from AUB records. The following observations can be made:

- The total annual precipitation is 985, 890, 660.3, and 887 mm at Hasbaiya (1931-1960), Marjayoun (1931-1960), AUB (1996-1998), and AUB (1944-1977), respectively.
- Precipitation patterns show large seasonal variations with more than 80 percent of the annual rainfall typically occurring between November and March.
- A marked decrease in precipitation levels is noticed at the AUB station, with approximately 25 percent decrease between the two reported periods.
- Based on the above observations, about 80 percent of precipitation that is 788 mm in Hasbaiya and 712 mm in Marjayoun are probably distributed between November and March. On the other hand, if the same pattern of precipitation levels decrease has occurred in the mountains, similarly to the decrease noticed in the coastal area precipitation in Hasbaiya and Marjayoun would be approximately 739 and 668 mm. This is however yet to be confirmed by future data.

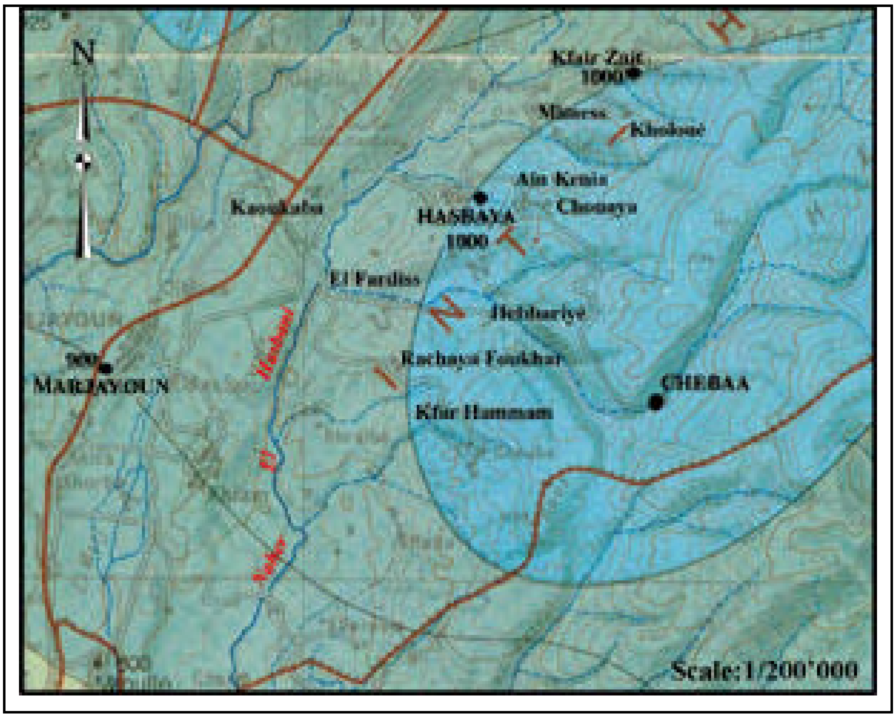


Figure 5.5. Pluviometric Map of the Hasbaiya Area and Surroundings (scale 1: 200 000) (Service Météorologique du Liban, 1977)

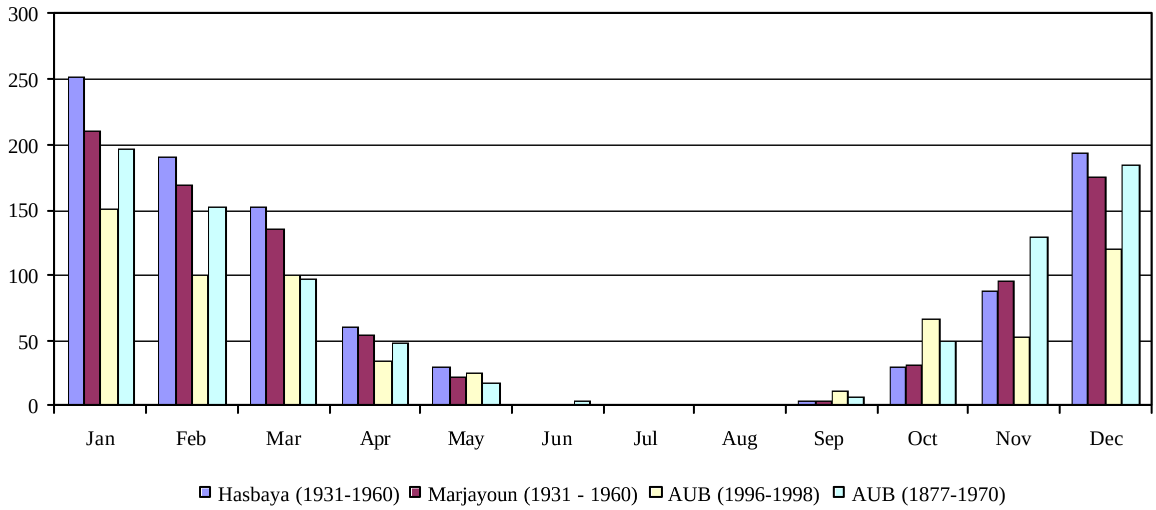


Figure 5.6 Precipitation Data from AUB (34 m), Hasbaiya (770 m) and Marjayoun (760 m) Stations (Elevations are from mean sea level)

The mean temperature along the coastal plains is 26.7° C in summer and 10° C in winter. The temperature gradient is around 0.57 °C per 100-m altitude (Blanchet, 1976). January is typically the coldest month with daily mean temperatures falling to -4 ºC in the mountains and 7 ºC in Saida, on the west coast. The warmest months are July and August, when mean daily temperatures can rise to 28 ºC in the mountains and 33 ºC on the coast. Figure 5.7 depicts monthly temperature distribution from data collected at AUB station (between 1996 and 1998, and between 1931 and 1970), at Marjayoun station (between 1947 and 1963) and at Rachaya (1965-1970). The following observations can be made:

- Average monthly temperatures in Marjayoun vary between 8.4 ºC in January and 23.3 ºC in August.
- Average monthly temperatures in Rachaya vary between 4.0 ºC in January and 22.2 ºC in July.
- Temperature records did not change significantly at the AUB station between the two-recorded periods.

The average annual temperature is 16.4 and 13.6 in Marjayoun and Rachaya respectively. Temperature in the study area does not vary much (Figure 5.7); variation is probably in the order of 1 ºC as documented between Rachaya and Marjayoun. However, since temperature records did not change much between the two-recorded periods in the AUB station the average yearly temperature in the study area would be approximately 13.6ºC.Winds

Dominant wind directions are southwesterly; continental east and southeasterly winds are also frequent. The two mountain ranges have a major impact on wind direction, and contribute to reducing the incidence and strength of the southeasterly and northwesterly winds on the mountain-backed shoreline and in the Bekaa valley. Strongest winds are generally observed during the fall season. Wind data is available at AUB and BIA stations, in Tyr, Tripoli, Cedars, Rayak, Ksara and Marjayoun. Wind data close to the study area is available at the Marjayoun station. Dominant wind direction is oriented in the W and NW (Figure 5.9) (Service Météorologique du Liban, 1969). Nevertheless, since the study area covers a wide range of settings from valleys to highs, locals were consulted regarding the general wind directions in the proposed location. Stronger winds (6-10 m/s and 11-15 m/s) are more frequent in the summer months. On the other hand, relatively weaker winds are prevalent in the winter season (Figure 5.8).

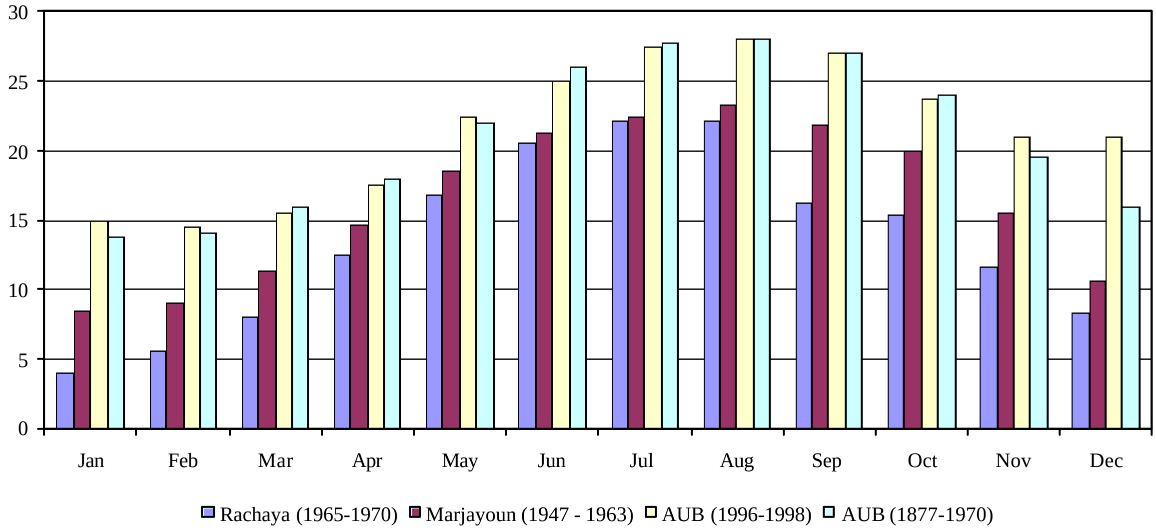


Figure 5.7. Average Monthly Temperature Data from AUB (34 m), Rachaya (1235 m) and Marjayoun (760 m) Stations (Elevations are from mean sea level).

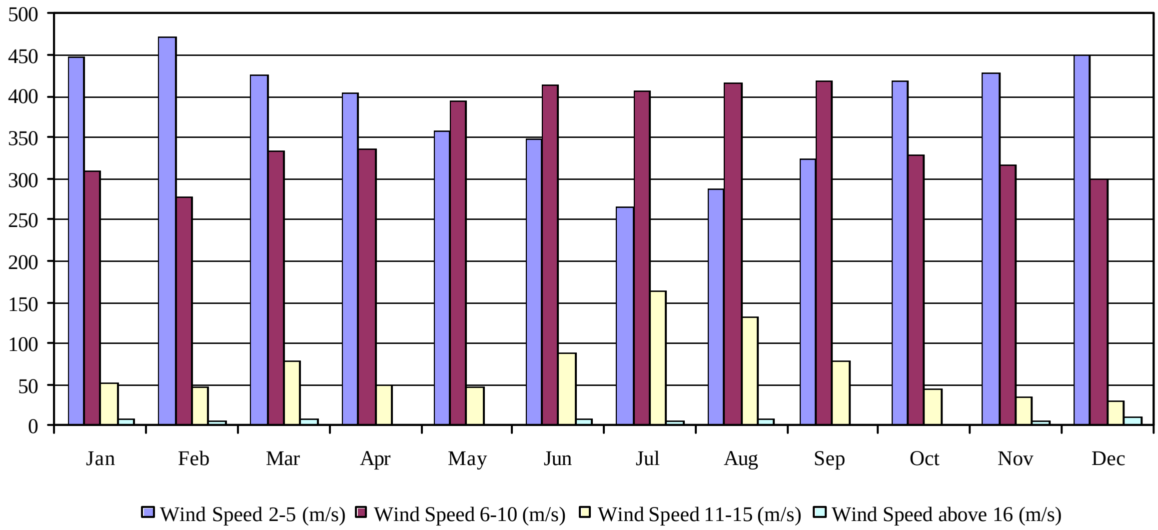


Figure 5.8. Average Monthly Frequency Data of Wind Speed Ranges 2-5, 6-10, 11-15, and above 16 m /s at Marjayoun Station (1956-1968) (Elevation from mean sea level is 760m).

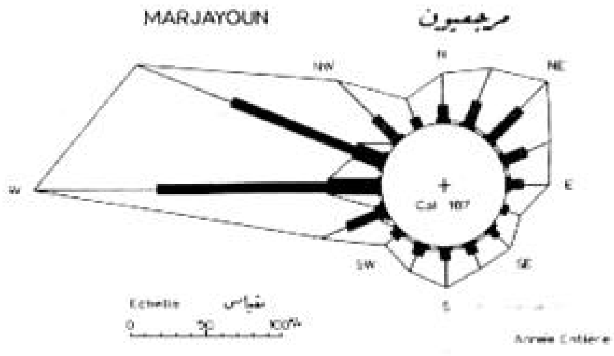


Figure 5.9. Wind Direction for Marjayoun Station (Service Météorologique du Liban, 1977)

5.3. SITE SETTING

As mentioned above, with the tight collaboration with MCI and the environmental consultants, all concerned municipality officials proposed a location for each treatment plant. The data presented in this section was either collected through field visits, location assessments, research, and/or in consultation with municipality officials or local citizens. Climate data were mainly obtained from records from Hasbaiya, Marjayoun and AUB stations. Appendix A presents the corresponding Geological Maps and Appendix B includes Topographic Maps of each WWTP location.

5.3.1. Chebaa Site

Originally, the Chebaa municipality proposed locations for two separate WWTPs. However, with the tight collaboration with MCI and the environmental consultants, Chebaa municipality agreed to construct only one WWTP and change the site location down gradient from the initially proposed sites, avoiding proximity to the Chebaa spring. The municipality of Chebaa purchased the proposed site location to build the treatment plant on. The site is located at the Western outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity (Photograph 5.1). The average land elevation is approximately 1220 m above sea level. The site is delineated by an intermittent river called Chebaa River on the southern side of the location coming from the village direction located towards the East. This intermittent river intersects downstream with the perennial Hasbani River. The proposed site is located on a reclaimed land, on agricultural terraces adjacent to the intermittent Chebaa River located south of the site, and has a road on the Southern side. The site is surrounded by a *Quercus sp*. shrub land, walnut and cherry tree orchards. Photograph 5.2 illustrates the proposed site location and its surroundings.

Precipitation in the area ranges between 660 and 985 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of W and NW (Service Meteorologique du Liban, 1969). Average annual temperature at Chebaa is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

Photograph 5.1. General View the Proposed Site for the WWTP in Chebaa

Photograph 5.2. Proposed Site Location and Surrounding Area (Young cherry trees on terraces) in Chebaa

5.3.2. Chouaia Site

A 1000 – 1500 m^2 parcel of land was selected from the Chouaia Municipality property to build the WWTP on. The site is located at the northwestern outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity. Since the dominant wind directions in the region are W and WNW, then the village remains relatively upwind of the site for a majority of the year.

The average land elevation in Chouaia is approximately 910 m above sea level. Located at the fork of two rudimentary footpaths, the site is surrounded by natural shrublands that have replaced the primary pine forest habitat. Average slope inclination of the surface topography is approximately 10%, down sloping in the westwards (Photograph 5.3). The proposed WWTP would be located at a distance of approximately 0.6 Km from the residential area in the village of Chouaia and the nearest household. Precipitation in the area ranges between 900 and 1000 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of W and WNW (Service Meteorologique du Liban, 1969). Average annual temperature at Chouaia is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

Photograph 5.3. General View of WWTP Site in Chouaia

The site is accessible by an agricultural road that gradually transforms into a sandy footpath road needing to be rehabilitated in order to allow building equipment and machinery to reach the site (Photograph 5.4). Both the sewage collection network as well as open solid waste dump are located close to the site (Photograph 5.5 and Photograph 5.6).

Photograph 5.4. Road Leading to the WWTP in Chouaia

Photograph 5.5. Sewage Collection Network in Chouaia

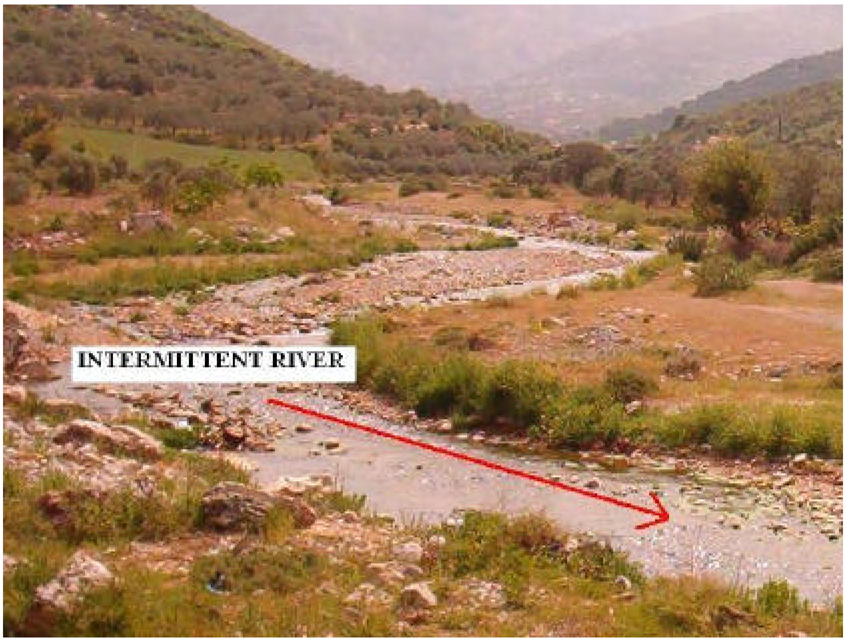
Photograph 5.6. Chouaia Solid Waste Dump

5.3.3. El Fardis Site

A land parcel of an area of 1000m² was purchased from Mr. Fares Chehade Slika by the municipality to build the treatment plant on. The site is located at the Western outskirts of the village, down gradient to most of the populated area, therefore the wastewater would be easily collected by gravity (Photograph 5.7). The average land elevation is approximately 560 m above sea level. The site is delineated by an intermittent river called Chebaa River on the northern side of the location coming from the village direction located towards the East. This intermittent river intersects downstream with the perennial Hasbani River originating upstream to the village. Average slope inclination of the surface topography is approximately 20%, down sloping in a Northwesterly direction. The proposed site is located on a plateau adjacent to the intermittent river, and has the main village road on the Northern side and surrounded by old olive orchard towards the Western side (Photograph 5.8).

Precipitation in the area ranges between 660 and 985 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of W and NW (Service Meteorologique du Liban, 1969). Average annual temperature at El Fardis is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

Photograph 5.7. General View the Proposed Site for the WWTP in El Fardis



Photograph 5.8. Intermittent river stream on the Northern edge of the site

5.3.4. Hebbariye Site

The municipality of Hebbariye purchased the proposed project location from a local citizen of the village of Hebbariye (Mr. Massoud Ghanem) to build the treatment plant on. The site is located at the Western outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity. The average land elevation is approximately 725 m above sea level. The site (Photograph 5.9) is delineated by an intermittent river called Chebaa River on the northern side of the location coming from the village direction located towards the East. This intermittent river intersects downstream with the perennial Hasbani River. Average slope inclination of the surface topography is approximately 35%, down sloping in a westerly direction. The proposed site is located on a plateau adjacent to the intermittent river located west of the site, and has the main village road on the Southern side and surrounded by old olive orchard towards the Eastern side (Photograph 5.10).

Precipitation in the area ranges between 660 and 985 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of W and NW (Service Meteorologique du Liban, 1969). Average annual temperature at Hebbariye is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

Photograph 5.9. General View the Proposed Site for the WWTP in Hebbariye

Photograph 5.10. Intermittent River stream West of the Hebbariye Site

5.3.5. Kaoukaba Site

The site is located at the Southern outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity (Photograph 5.11). The average land elevation is approximately 510 m above sea level. The site is delineated by a perennial river called Hasbani on the southern side of the location.

The land is mainly flat with no slopes to be mentioned. The proposed site then is located within a flat area close to the Hasbani River. The site is mainly covered by young olive trees and is 300 meters northern to the Hasbani River (Photograph 5.12 and Photograph 5.13). The site is accessible through an agricultural road that needs to be rehabilitated in order to allow building equipment and machinery to reach the site.

Precipitation in the area ranges between 900 and 1100 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of WNW and W (Service Meteorologique du Liban, 1969). Average annual temperature at Kaoukaba is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

Photograph 5.11. General view the proposed site for the WWTP site located towards the Southern outskirts of the village of Kaoukaba. Photograph looking towards the South.

Photograph 5.12. Perennial River stream on the Southern edge of the Kaoukaba Site

Photograph 5.13. Young olive trees on site Surrounded by *Quercus sp*. in Kaoukaba

5.3.6. Kfar Hamam Site

A 1000 – 1500 m^2 parcel of land was selected from the Kfar Hamam Municipality property to build the WWTP on. The site is located at the Northwestern outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity (Photograph 5.14). Since the dominant wind directions in the region are W and WNW, then the village remains relatively upwind of the site for a majority of the year.

Photograph 5.14. View towards Village from the Proposed WWTP Site in Kfar Hamam

Photograph 5.15. General View of Kfar Hamam Site

The average land elevation in Kfar Hamam is approximately 700 m above sea level. Both the eastern and western edges of the site are delineated by agricultural terraces of olive plantations. Average slope inclination of the surface topography is less than 5%, down sloping in the eastern direction. The proposed WWTP would be located at a distance of approximately 1 Km from the residential area in the village of Kfar Hamam and the nearest household.

Precipitation in the area ranges between 900 and 1000 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of W and WNW (Service Meteorologique du Liban, 1969). Average annual temperature at Kfar Hamam is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

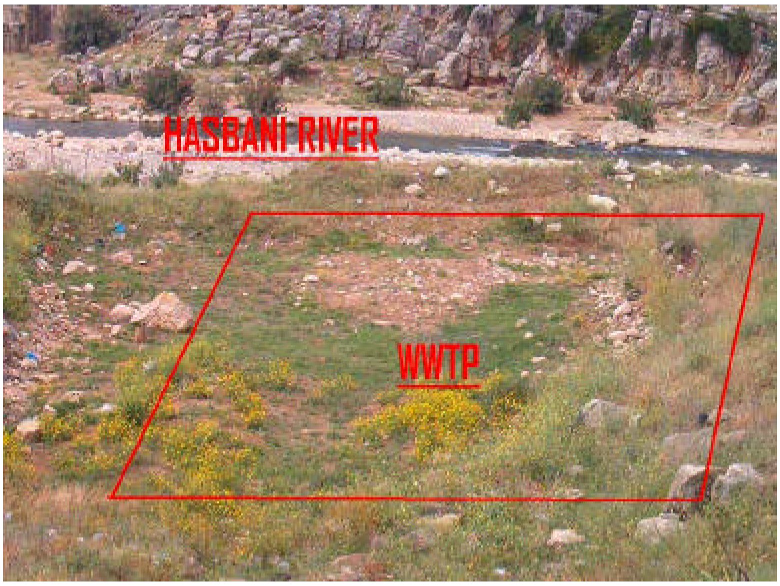
The site is accessible through an agricultural road that needs to be rehabilitated in order to allow building equipment and machinery to reach the site. The village collection network reaches the site (Photograph 5.16) and empties into an irrigation ditch that traverses the site and continues to adjacent agricultural lands (Photograph 5.17).

Photograph 5.16. Irrigation Ditch Passing Through Kfar Hamam Site

Photograph 5.17. Sewage Collection Network in Kfar Hamam Site

5.3.7. Mari Site

A 1000 – 1500 m^2 parcel of land was selected from the Mari Municipality property to build the WWTP on. The site is located at the Southwestern outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity (Photograph 5.18). Since the dominant wind directions in the region are W and WNW, then the village remains upwind of the site for a majority of the year.



Photograph 5.18. Site of the Proposed Mari WWTP Looking towards the South

The average land elevation in Mari is approximately 350 m above sea level. The western edge of the site is delineated by the perennial Hasbani River with the village falling to the north east of the proposed site. Average slope inclination of the surface topography is less than 5%, down sloping in a southern direction. Additionally, the proposed site is located at the edge the Mari open solids waste dump overlooking the Hasbani River and has the main village road on the Eastern side (Photograph 5.19). The site is accessible through an agricultural road that needs to be rehabilitated in order to allow building equipment and machinery to reach the site (Photograph 5.20).

Precipitation in the area ranges between 900 and 1000 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of W and WNW (Service Meteorologique du Liban, 1969). Average annual temperature at Mari is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

Photograph 5.19. Open Solid Waste Dump Adjacent to Mari Site

Photograph 5.20. Agricultural Road used to Reach the Site in Mari

The proposed WWTP would be located at a distance of approximately 1 Km from the residential area in the village of Mari and approximately 0.6 Km from the nearest household.

5.3.8. Rachaiya el Foukhar Site

An area of 1000 – 1500 m^2 in the village of Rachaiya el Foukhar which belongs to the municipality has been allocated for building the treatment plant on. The site is located at the Southern outskirts of the village, down gradient to most of the populated area therefore the wastewater would be easily collected by gravity (Photograph 5.21). The average land elevation is approximately 670 m above sea level. Appendix A presents a Geological Map overlain on the Topographic Map of Rachaiya el Foukhar area showing the proposed location of the treatment plant. The site is delineated by a perennial river called Hasbani on the southwestern side of the location.

The land is mainly flat with no slopes to be mentioned. The proposed site then is located within a flat area close to the Hasbani River. The site is mainly covered by oak trees and various shrubs and has the main village road on the Southern side in close proximity to old olive orchard towards the South. (Photograph 5.22). The site is accessible through an agricultural road that needs to be rehabilitated in order to allow building equipment and machinery to reach the site.

Precipitation in the area ranges between 900 and 1100 mm/year (Service Meteorologique du Liban, 1977). Wind direction varies between orientations of ENE and E (Service Meteorologique du Liban, 1969). Average annual temperature at Rachaiya el Foukhar is approximately 15 ^{o}C (Service Meteorologique du Liban, 1977).

Photograph 5.21. General View of the Proposed Site for the WWTP in Rachaiya el Foukhar

Photograph 5.22. Intermittent River Stream on the Southern edge of the Site in Rachaiya el Foukhar

5.4. TECTONIC SETTING AND SEISMICITY

Lebanon is located on the eastern coast of the Mediterranean Sea, along the Dead Sea Transform fault system. The Dead Sea Transform fault system in Lebanon has several surface expressions, represented in major faults (Yammouneh, Roum, Hasbaya, Rashaya and Serghaya faults), in uplifts as high mountainous terrain (Mount Lebanon and Anti Lebanon), and from the seismic activity record. Recent work has categorized the Lebanese section of the Dead Sea Transform fault as being a strong seismic activity zone (Khair et al., 2000).

The studied area lies south east of the Yammouneh Fault and between Hasbaya and Rachaya Faults. Appendix A presents the Tectonic Map of Lebanon to scale. Harajli et al. (1994) proposed ground acceleration in this part of Lebanon, where the area of study is allocated, to be approximately 0.20g.

5.5. GEOLOGICAL SETTING

The geology of the studied area, including subsurface stratigraphy and structure, was developed based on: 1) review of available maps and literature, 2) analysis of aerial photographs, and 3) geological surveys and site visits conducted by ELARD geologists. The result was the generation of a geological map at a scale of 1:20,000 covering the area of study. The map is included in Appendix A. Geological cross-sections are also presented in Appendix A.

5.5.1. Stratigraphy

The geological formations that outcrop within the surveyed areas extend from the Jurassic Period to Upper Cretaceous in age, Quaternary deposits were also found in some of the sites. These formations are described hereafter in chronological order, from oldest to youngest.

5.5.1.1. Jurassic Formations

5.5.1.1.1 The Bikfaya and Kesrouane Formations (J_4 – J_5)

Both Bickfaya and Kesrouane formations were found in site sites of Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar. It was not possible to differentiate between these two formations in all cases because of their similarity and because of the possible absence of the Bhannes Formation (J_5), which separates them. The Kesrouane and

Bikfaya Formations belong to the Jurassic Period. They outcrop in the middle and the eastern parts of the study areas of Chouaia and Hebbariye or in the eastern part of the Kfar Hamam village. The formation consists mainly of massive beds of gray dolomitic limestone. The thickness of these two formations in Lebanon reaches in excess of approximately 1100m. The upper boundary of these formations is the beginning of the yellowish brown oolitic limestone of the Salima Formation which is not outcropping the study area in the case of Kfar Hamam and Rachaiya el Foukhar. The lower boundary is not outcropping in the study area but from the cross-section the thickness should be in excess of 600 m (for Chouaia and Hebbriye) or 400 m (for Kfar Hamam and Rachaiya el Foukhar) (Geological Map, Appendix A).

In contrast, The Kesrouane Formation is the only formation outcropping in the study area in Chebaa. The thickness of this formation in the study area reaches approximately 1000m. The lower and upper boundaries of this formation is not outcropping in the study area but from the cross section the thickness should be in excess of 600 m.

5.5.1.1.2 The Bhannes Formation (J5)

The Bhannes formation was identified in the sites of Kfar Hamam and Rachaiya el Foukhar. In both cases, patches of volcanic rocks are present in the Bikfaya-Kesrouane Formation. These are mainly intrusive volcanic rocks, which are mostly considered to belong to the Bhannes Formation. The color of these volcanic rocks is mainly pink to dark green. These can be clearly observed in the valley underneath Kfar Hamam were the proposed location of the plant is present (Photograph 5.23).

Photograph 5.23. Volcanic Rocks of the Bhannes Formation Outcropping the Proposed Site in Kfar Hamam

5.5.1.1.3 The Salima Formation (J7)

This Jurassic formation, present under the Hebbariye site, outcrops as a small stretch above the Kesrouane Formation and below the Chouf Sandstone Formation. This formation consists mainly of intercalations of marls, and yellowish brown oolitic limestone. The thickness of this formation is quite variable and it does not exceed 10 meters.

5.5.1.2. Cretaceous Formations

5.5.1.2.1 Chouf Sandstone Formation (C1)

The Chouf Sandstone formation was identified in Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar. In Hebbariye, this formation outcrops in the Bou Djaje valley below Ain Jarfa village and west of the Hebbariye village. As for Chouaia, this formation outcrops on the highs of Ain Qenia and Chouaia villages in the middle parts of the study area. For Rachaiya el Foukhar and Kfar Hamam, this formation outcrops in the Kfar Hamam village. It is mainly composed of cross bedded, hematitic sandstone and sands. Lenses of bluish gray clay and marl with peat are also found in this formation. This formation reaches a thickness of 100 - 200m in the study area.

5.5.1.2.2 The Abeih Formation (C2a)

The Abeih formation was found in Hebbariye, El Fardis, Kfar Hamam, Mari and Rachaiya el Foukhar sites. This formation is outcropping in the eastern part of the Hebbariye, west and southwest of Ain Jarfa village, in east of Mari village and northestern part of Rachaiya el Foukhar village. This formation consists in its upper part of yellowish and brownish fossiliferous limestone, while it consists in its lower parts, of intercalations of blue and green marls, and yellowish limestone. This formation reaches a thickness of 100 - 200m in the study area.

5.5.1.2.3 The Mdairej Formation (C_{2b})

The Mdairej formation was found in Hebbariye, El Fardis, Kfar Hamam, Mari and Rachaiya el Foukhar sites. This formation consists in a cliff extended above the Abeih Formation. This cliff consists of hard grayish micritic massive limestone rich in calcite veins. This formation is approximately 50m thick.

5.5.1.2.4 The Hammana Formation (C_3)

This formation outcrops mainly in the extreme northwestern corner of Hebbariye, in the Mari village, in the northern and northwestern parts of Rachaiya el Foukhar, northern and northwestern parts of Kfar Hamam and in El Fardis village. It is characterized by creamish to greenish marly limestone. Quartz geode can be found along ephemeral streambeds. This formation is also highly fossileferous, as molded gastropods and fossilized oysters are frequently found.

5.5.1.2.5 The Sannine Formation (C4)

The Sannine Formation is present in El Fardis, Kaoukaba, Mari, Kfar Hamam and Rachaiya el Foukhar. This formation consists in its lower levels of marly limestone that grades into thin beds of gray limestone especially along streambeds in the valleys. In its upper part, this formation is composed of massive gray limestone. The thickness of this formation in the studied area reaches approximately 600m. The upper boundary of this formation is not outcropping in the study area. Massive limestones and dolomites, above the green or grey marls of the Hammana Formation, characterize the lower limit of the Sannine Formation.

5.5.1.2.6 The Chekka Formation (C6)

The Chekka Formation outcrops in the central parts of the study area, and was only identified in Kaoukaba and El Fardis sites. The outcrops are present between the Hasbani River and Kaoukaba village or the El Fardis village. This formation consists mainly of chalky limestone and marls with extensive chert bands and nodules. The thickness of this formation was estimated to be around 400 m.

5.5.1.3. Tertiary Formations

The three tertiary formations (Pliocene, Eocene and Pliocene Basalts) were found in Kaoukaba. Also, both El Fardis and Mari sites contain Pliocene Basalts, the three different Tertiary Formations are described below.

5.5.1.3.1 Pliocene Formation

The Pliocene Formation outcrops north of Kaoukaba village. They are mainly composed of chalks and marly limestone. The thickness of this formation is approximately 300m as represented on the cross section (Geological map Appendix A).

5.5.1.3.2 Eocene Formation

The Eocene Formation outcrops north of in the northwestern part of the Kaoukaba site. They are mainly composed of dolomitic limestone and limestones with distinctive fossils of the Eocene stage Nummulites. The upper boundary of this formation is not outcropping in the study area.

5.5.1.3.3 Pliocene Basalts

A patch of Pliocene volcanic rocks, mainly basalts, is present in the southeastern part of Kaoukaba, in the northwestern part of El Fardis site and in the southern part of Mari. They extend as an elongate patch along a ridge facing the Hasbani River. These basalts are unconformably overlying the Sannine Formation. The thickness of these basalts is approximately 10-20 m.

5.5.1.4. Quaternary Deposits

The sites of El Fardis, Kaoukaba, Mari and Rachaiya el Foukhar were found to contain quaternary deposits. In fact, these are mainly present along the flood plain of the Hasbani River. These deposits are mainly alluvial deposits of conglomerates, sands and clays. The thickness of these deposits is usually less than 5 m.

5.5.2. Structure

In Chebaa, the beds of the Kesrouane Formation are gently to moderately dipping generally towards the east and southeast at angles that range between 5º and 10º. The dip varies from its general trend, mainly due to structural disturbances, especially close to the faults. Two sets of faults are present Chebaa. The first set trending N-S is represented in the area with 6 faults. These faults are mainly concentrated in the central parts of the study area. It was not possible to document the type of movement on these faults. The second set of faulting is trending NW-SE and are present in the central part of the map. It was not also possible to document the type of movement on these faults.

Formations in Chouaia are gently dipping towards the northwest and northeast at angles that range between 05º and 22º. Structural disturbances mainly through faults have a slight influence on the bedding attitude in the study area. Three sets of faults are present in Chouaia. One set of faults trends in the NE-SW direction, the other trends in the NW-SE and one trending N-S. It was not possible to define the type of movement and amount of displacement on these faults.

Formations in El Fardis are gently dipping generally towards the west at angles that range between 10º and 45º. The dip increases from east to west. Structural disturbances mainly through faults have a slight influence on the bedding attitude in the study area. Two faults are present in the area, one which is trending NNE-SSW and the other which is E-W, appear to predominate in El Fardis. Faults in the study area are strike slip faults with unclear amounts of displacement.

In Hebbariye, formations in the study area are gently dipping towards the west at angles that range between 10º and 15º. The dip increases from east to west. Structural disturbances mainly through faults have a slight influence on the bedding attitude in the study area. One E-W suspected fault is present in the southern parts of the area northwest of

Hebbariye village. This fault is a possible strike slip faults with unclear displacement values.

In Kaoukaba, formations in the study area are gently to moderately dipping generally towards the north west at angles that range between 18º and 45º. The dip varies from the general trend, mainly due to structural disturbances, in the western sections in the Sannine Formation outcrops. Dips generally are steeper in the southeastern parts of the study area and generally decrease gradually towards the northwestern parts. One set of faults represented in the area with three faults are present in the northwestern part of the study. The general trend of these faults is NW-SE. These faults have both normal and strike slip type of movement both of which are in the order of 100's of meters.

In Mari, formations are gently dipping generally towards the west at angles that range between 15º and 35º. The dip varies from the general trend, mainly due to structural disturbances, in the western sections in the Sannine Formation outcrops. Two faults are present in the southwestern part of the study area. Both faults are present in the Sannine Formation and are trending NNE-SSW. The type of displacement of these faults was not clear.

Formations in Kfar Hamam and Rachaiya el Foukhar sites are gently dipping towards the west at angles that range between 5º and 15º. The dip increases from east to west. Structural disturbances mainly through faults have a slight influence on the bedding attitude in the two study areas. One E-W suspected fault is present in the northwestern parts of both Kfar Hamam and Rachaiya el Foukhar. This fault is a possible strike slip fault with unclear displacement values.

5.6. HYDROGEOLOGICAL SETTING

The hydrogeology of the surveyed areas was developed based on: 1) the review of available maps and literature; 2) the Hydrogeological surveys and site visits conducted by ELARD specialists. More precisely, the hydrogeology of the eight studied areas was studied based upon geological maps, pluviometric and climatic data related to the studied area, field surveys undergone by ELARD specialists.

In Chebaa, the Kesrouane Formation, which is the only formation that outcrops in the study area, is a major aquifer.

The important aquifer present in Chouaia is the Bikfaya - Kesrouane karstic aquifer. It is underlain by the Chouf Sandstone Semi-Aquifer (C1). The neighboring village of Ain Qenia, which lies approximately 0.6 Km west of Chouaia, possesses the same hydro-geologic character as Chouaia.

In El Fardis, the Mdairej Aquifer is underlain by the Abeih Aquiclude, and the Sannine Aquiferous Formation is underlain by the Hammana Aquiclude and overlain by the Chekka Aquiclude.

In Hebbariye, the Mdairej Aquifer is underlain by the Abeih Aquiclude, and the Bikfaya- Kesrouane Aquiferous Formation is overlain by the Salima Aquiclude and Chouf Sandstone Semi-Aquifer.

There exist in Kaoukaba two main aquifers the Sannine and Eocene Aquifers. The Pliocene and Chekka aquicludes underlies the Eocene aquiferous Formation, and the overly lie the Sannine aquiferous Formation.

The Kfar Hamam and Rachaiya el Foukhar sites have the same hydrogeologic character. There exist in the two study areas three main aquifers. The Mdairej Aquifer underlain by the Abeih Aquiclude, the Bikfaya- Kesrouane Aquiferous Formation overlain by the Salima Aquiclude and the Chouf Sandstone Semi-Aquifer. Although the Sannine Formation is considered as a major aquifer in Lebanon, due to its limited surface area in the study, it will not be considered as one.

In Mari, the Abeih Aquiclude underlies the Mdairej Aquifer, and the Hammana Aquiclude underlies the Sannine Aquiferous Formation.

5.6.1. Aquifers

5.6.1.1. Bikfaya-Kesrouane Aquifer (J_{4-6} Formation)

The Bikfaya-Kesrouane Formation constitutes the most important aquifer in the Jurassic sequence. It is a karstic aquifer characterized by significant amount of groundwater flowing in channels, faults, and fractures. The Sannine aquifer is composed of a recharge zone in the study area. According to the UNDP (1970) report, the infiltration coefficient of this aquifer reaches 39%.

The Bikfaya-Kesrouane aquifer represents one of the main aquifers in Lebanon and is the most productive aquifer in the Jurassic sequence. It is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels, which is a typical occurrence in karstic aquifers.

The Bikfaya-Kesrouane aquifer acts as a source for several types of karstic springs. The Bikfaya-Kesrouane aquifer is considered the major aquifer in the study area, covering approximately 60 %. Surface and underground features reveal the advanced karstic nature of this aquifer. These features include solution joint, solution pits, lapiaz, grooves, and sinkholes. Cavities in the rock are often filled with calcite and cave deposits. The thickness of the topsoil on this formation ranges from few centimeters up to few meters.

5.6.1.2. Chouf Sandstone Semi-Aquifer (C_1)

The nature Chouf Sandstone Formation resulted in its ability to produce water in small quantities makes it a semi-aquifer. The permeability of the sands and the presence of relatively impermeable clay and marl lenses results in presence of springs with relatively small discharges at different levels in this formation. The Abeih Formation above it acts as a relatively impermeable horizon while it is not a far-fetched idea that seepage from this formation through the Salima Formation and into the major Bikfaya-Kesrouane Formation might occur.

5.6.1.3. Mdairej Aquifer (C_{2b})

Fifty meters of massive limestone cliff constitute the aquiferous member of the Mdairej Formation. Being located between two aquicludes; namely the Abeih Formation at the bottom, and the Hammana Formation at the top, the Mdairej Formation has a high potential of water bearing capacity, which remains, however limited due to the relatively small thickness. Its position between two aquitards improves its ability to maintain all water infiltrating in the form of recharge.

5.6.1.4. Sannine Aquifer (C_4 Formation)

The Sannine Formation constitutes the most important aquifer in the Cretaceous sequence. It is a karstic aquifer characterized by significant amount of groundwater flowing in channels, faults, and fractures. The Sannine aquifer is composed of a recharge zone in the study area. According to the UNDP (1970) report, the infiltration coefficient of this aquifer reaches 40%.

The Sannine aquifer acts as a source for several types of karstic springs. The Sannine aquifer is considered the major aquifer in the study area, covering approximately 60 % of the area. Surface and underground features reveal the advanced karstic nature of this aquifer. These features include solution joint, solution pits, lapiaz, grooves, and sinkholes. Cavities in the rock are often filled with calcite and cave deposits. The thickness of the topsoil on this formation ranges from few centimeters up to few meters.

5.6.1.5. Eocene Aquifer (e)

The Eocene Formation constitutes the most important aquifer in the Tertiary sequence It can attain a thickness of 900 m but in the study area less than 100m are present. It is a karstic aquifer characterized by significant amount of groundwater flowing in channels, faults, and fractures. However, its water capacity is limited due to the relatively small thickness.

5.6.2. Aquicludes

5.6.2.1. Abeih and Hammana Aquicludes (C_3 -C_{2b} Formations)

The Hammana and Abeih Formation constitute aquicludes with poor hydraulic properties because of the low porosity, consequently the low hydraulic conductivity for argillaceous limestone, clays, and marls forming relatively impermeable boundaries for the Sannine and Mdairej Aquifers that prohibit exchange of water between the different hydrostratigraphical units. According to the UNDP (1970) report, the infiltration coefficient of this aquifer does not exceed 10-15%.

5.6.2.2. Chekka and Pliocene Aquicludes (C_6 –P Formations)

The Chekka and Pliocene Formations constitute aquicludes with poor hydraulic properties because of the low porosity, consequently the low hydraulic conductivity for marls forming relatively impermeable boundaries for the Sannine and Eocene Aquifers that prohibit exchange of water between the different hydrostratigraphical units. According to the UNDP (1970) report, the infiltration coefficient of this aquifer does not exceed 10-15%.

5.6.3. Well Survey

The well survey in the region revealed the presence of around 17 wells: Five wells nearby Hebbariye (one in Hebbariye village and four in Ain Jarfa Village), two wells in the neighboring Ain Qenia village approximately 1 Km west of Chouaia, two abandoned wells in El Fardis village, five wells in Kaoukaba area, one well in Kfar Hamam village and one in Rachaiya el Foukhar village (the well in Kfar Hamam is providing the village with water when the water from Chebaa village is not enough) and finally one public well in Mari which is not yet in operation

As it is noticeable, the number of wells present in the region is limited; this is because abundant sources of water are available and the major source of water for both villages is from Chebaa Village. The surveyed wells characteristics (owner, discharge, and usage) are listed in Table 5.1, whereas, the locations of identified wells are presented on the geological map (Geological Map, Appendix A).

Table 5.1. Characteristics of Surveyed Wells in Hasbaiya

Well's name	*Area*	*Owner*	*X Coordinate*	*Y Coordinate*	*Z(m)*	*Discharge l/sec*	*Tapping aquifer*	*Usage*
1	Hebbariye	Public	159256	145355	671	-	C1	Ab
2	Ain Jarfa	Private	161000	145309	780	-	C1	Do.
3	Ain Jarfa	Private	160900	145190	768	-	C1	Do.
4	Ain Jarfa	Private	160820	145090	766	-	C1	Do.
5	Ain Jarfa	Private	160700	145000	760	-	C1	Do.
6	Kaoukaba	Public	140300	161455	634	-	e-P	Ab
7	Kaoukaba	Private	141550	162200	546	-	C6	Ab
8	Kaoukaba	Private	141600	162100	545	-	C6	Ab
9	Kaoukaba	Private	141600	161530	520	-	C6	Ab
10	Kaoukaba	Private	141950	162700	550	-	C6	Irr.
11	Rachaiya el Foukhar	Public	157300	141300	650	-	C3-C4	Ab
12	Kfar Hamam	Private	156050	142990	850	-	J4-J6	Do.

Do.: Domestic
Dr.: Drinking
Irr.: Irrigation
NA: Not Available
Ab.: Abandoned

5.6.4. Spring Survey

For the purpose of the hydrogeological study of the area, a spring survey was conducted by ELARD team in the eight concerned villages and in the areas surrounding the different WWTP sites. The spring survey results are presented in Table 5.2.

Table 5.2. Characteristics of Surveyed Springs

Spring name	Aquifer	X coordinate	Y coordinate	Z coordinate	Discharge (L/sec)
Ain Qenia Spring	C1	162900	147085	930	0.25
Ain el Hara	C1	162400	147400	1010	0.25-
Ain El Daya	C1	162130	147780	1050	1
Ain el Mecheye	C1	162000	148300	960	0.0.2
S1 Spring (Chouaia)	C1	162400	148400	920	<0.02
Ain Aarab	e	140400	161450	625	<0.1
Nabaa el Quraqat	C6	140500	161800	650	-
Ain el Reshaha	Boundary e-P	141000	162300	660	0.25
Kaoukaba Spring	Boundary e-P	141150	162400	640	0.25
Ain el Ajrame	Boundary e-P	141750	163050	660	4
S1 Spring (Kaoukaba)	C6	142450	162700	550	Seepage zone
Ain el Marj	C1	156400	143000	772	<0.1
Ain el Ghabra	C1	156400	143650	760	<0.1
Ain Khoury	C3	156300	142500	560	<0.1
Ain Mitri	C3	156900	142200	547	<0.1
S1 spring	C3	157400	142600	600	0.05
Ain el Ram	C3	157390	142700	600	Seepage zone
Rachaiya el Foukar Spring	C3	157700	143200	753	0.3

This survey revealed the presence of 2 major springs in Chebaa. The location of one of the springs, Chebaa Spring (Nabaa el Mghara), is presented on the geological map (Appendix A). The other spring is outside the study area present toward the northeast. Both of these springs are used to supply domestic and drinking water for several villages in the area. Both of these springs issue form the karstic limestone of the Kesrouane Formation. Photograph 5.24 shows Chebaa Spring. Most springs with low yields are used locally by surrounding houses for domestic purposes, whereas some other springs are not used at all for domestic or drinking purposes but are still used for irrigation. Both these springs are located up gradient from the spring at a higher elevation. Their discharge is in the order of 0.5to 1 m^3/s (Edgell, 1997).

Photograph 5.24. Chebaa Spring (Nabaa el Mghara) in Chebaa Village

In Ain Qenia and Chouaia villages, the spring survey conducted by the ELARD team revealed the presence of five springs. They are located in the Chouf Sandstone Formations. These springs are relatively small and are considered as seepage zones. The main use of those springs is for irrigation and sometimes for domestic usage when the water supply from Chebaa village is not available. Other small seepages are present especially in the Chouf Sandstone Formations. The discharge of these springs decreases significantly in the summer time and most of them dry out.

The spring survey conducted in El Fardis village revealed the presence of 2 springs. Both springs are located in the Hammana Formation. The El Fardis spring is located inside the village of El Fardis; it is a seepage zone in a small intermittent valley. The Ain es Srajie is located on the road connecting the El Fardis village and Ain Jarfa village. Other small seepages are present especially in the Hammana and Abeih Formations. The discharge of these springs decreases significantly in the summer time and both dry out. Both of these springs are used locally by surrounding houses for domestic and irrigation purposes.

The spring survey conducted in Hebbariye and Ain Jarfa villages revealed the presence of three springs. They are located in the Abeih and the Chouf Sandstone Formations. These springs are relatively small and are considered as seepage zones. The Hallabeh spring is located inside the village as a collection tank. The main use of those springs is for irrigation. Other small seepages are present especially in the Hammana, Abeih and Chouf Sandstone Formations. The discharge of these springs decreases significantly in the summer time and both dry out.

The spring survey conducted in the village of Kaoukaba revealed the presence of 6 major springs. The springs do not have a significant discharge and most are discharging from the Chekka and Pliocene-Eocene boundary. Most of the springs are small and almost dry out during the summer season. Photograph 5.25 shows Kaoukaba spring being measured by ELARD geologist. Most springs with low yields are used locally by surrounding houses for domestic purposes, whereas some other springs are not used at all for domestic or drinking purposes but are still used for irrigation. Most of the spring are located above the site and northwest of it.

Photograph 5.25. Ain Kaoukaba in Kaoukaba Village

The spring survey in Rachaiya el Foukhar and Kfar Hamam villages revealed the presence of seven springs. They are located in the Chouf Sandstone and Hammana

Formations. Two are present in the Chouf Sandstone Formation in Kfar Hamam village and five are in the Hammana Formation. These springs are relatively small and are considered as seepage zones. The main use of those springs is for irrigation. The location of these springs is present on the geological map. Other small seepages are present. The discharge of these springs decreases significantly in the summer time when they almost dry out. Photograph 5.26 shows Ain el Marj collection tank the spring fills the tank from seepages below it.

The spring survey conducted in Mari revealed the presence of 2 springs. Both these springs are located in the Hammana Formation. Nabaa el Qershe is located in the southern part of the study area. It discharge was measured to be 3.3 L/s on April 21/2004. Ain Merj is located east of the village. Other small seepages are present especially in the Hammana and Abeih Formations. The discharge of these springs decreases significantly in the summer time and both dry out. Both of these springs are used locally by surrounding houses for domestic and irrigation purposes.

Photograph 5.26. Ain el Marj in Kfar Hamam Village

Photograph 5.27. Nabaa el Qershe South of Mari

5.6.5. Hydrogeological Site Setting

5.6.5.1. Chebaa Plant

The WWTP is located on the northern banks of Chebaa Valley on the surficial fertile soil cover, few meters in thickness, which overlie the Kesrouane Formation. The Kesrouane Formation constitutes a highly permeable karstic formation. This Formation is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels, which is a typical occurrence in karstic aquifers. The site is located on a recharge area for the Kesrouane Aquifer; therefore, advanced levels of wastewater treatment are imperative in order to protect the groundwater. In addition, a protective seal is required underneath the plant to protect the Sannine Aquifer from any leak, mal function or disaster.

5.6.5.2. Chouaia Plant

The WWTP is located on the western side of a small valley Bou Aatme on the Chouf Sandstone Formation. The Chouf Sandstone Formation acts as a semi-aquifer. The outcrops close to the vicinity of the proposed site revealed the presence of sandstone with lenses of clay and marl. Moreover, from the cross section constructed revealed that the Chouf Sandstone Formation is relatively thin underneath the site approximately 20 m in thickness. The Chouf Sandstone Formation overlies the Bikfaya-Kesrouane Formation. The Bikfaya-Kesrouane Formation constitutes a highly permeable karstic formation. This Formation is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels, which is a typical occurrence in karstic aquifers.

5.6.5.3. El Fardis Plant

The WWTP is located on the southern banks of Chebaa Valley on the Quaternary deposits overlying the Sannine Formation. The Quaternary deposits are mainly surficial alluvial deposits of few meters in thickness. The Sannine Formation constitutes a highly permeable karstic formation. This Formation is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels, which is a typical occurrence in karstic aquifers.

5.6.5.4. Hebbariye Plant

The WWTP is located on the southern banks of Chebaa Valley a fertile soil cover, few meters in thickness, overlies the Bikfaya-Kesrouane Formation. The Bikfaya-Kesrouane Formation constitutes a highly permeable karstic formation. This Formation is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels, which is a typical occurrence in karstic aquifers. The site is located on a recharge area for the Bikfaya-Kesrouane Aquifer; therefore, advanced levels of wastewater treatment are imperative in order to protect the groundwater. In addition, a protective seal is required underneath the plant to protect the Bikfaya-Kesrouane Aquifer from any leak, mal function or disaster.

5.6.5.5. Kaoukaba Plant

The WWTP is located on the northern banks of the Hasbani River on the Quaternary deposits overlying the Chekka Formation (Photograph 5.28). The Quaternary deposits are mainly surficial alluvial deposits of few meters in thickness. The Chekka Formation acts as an aquiclude, which is relatively impermeable and protects the underlying Sannine Aquifer. The abandoned and unproductive well close to the site revealed that the Chekka Formation underneath the site is more than 50 m thick and the lithology is mainly marl. Moreover, from the cross section constructed revealed that the Chekka Formation is more than 100 m thick.

Photograph 5.28. Outcrops of Chekka Formation on Kaoukaba site

5.6.5.6. Kfar Hamam Plant

The WWTP is located on the southern banks of Ras En Nimer Valley on the Bhannes volcanic rocks. The volcanic rocks act as an aquiclude, which is relatively impermeable and protects the underlying Bikfaya-Kesrouane Aquifer. Moreover, from the cross section constructed revealed that the intrusive volcanic rocks of the Bhannes Formation is more than 10 m thick.

5.6.5.7. Mari Plant

The WWTP is located on the southern banks of Chebaa Valley on the Quaternary deposits overlying the Sannine and Hammana Formation. The Quaternary deposits are mainly surficial alluvial deposits of few meters in thickness. The Sannine Formation constitutes a highly permeable karstic formation. This Formation is characterized by its high secondary porosity causing ground water to flow mainly through fractures, joints and channels, which is a typical occurrence in karstic aquifers. The site is located close to the boundary between the Sannine and Hammana Formations. The Hammana Formation acts as an aquiclude. In order to protect the Sannine Aquifer a protective seal is required underneath the plant to protect the Sannine Aquifer from any leak, mal function or disaster.

5.6.5.8. Rachaiya el Foukhar Plant

The WWTP is located on the western side of a small valley on the Hammana Formation. The Hammana Formation acts as an aquiclude, which is relatively impermeable and protects the underlying Mdairej and Jurassic aquifers. The outcrops close to the vicinity of the proposed site revealed the presence of interbeds of marl, limestone and clay. Moreover, from the cross section constructed revealed that the Hammana Formation is more than 100 m thick underneath the site.

5.7. HYDROLOGICAL SETTING

The Chebaa site is located on the northern bank of Chebaa valley, which hosts an intermittent river that originates from the mountain of Chebaa village. The two main springs in Chebaa village along with snow and rain fall feed the intermittent river. The river almost completely dries out during the summer season. Because of the nature of the Kesrouane Formation, the river looses most of its water to the underground water through channels, fractures and fissure. This intermittent river discharges in the Hasbani River few kilometers towards the west near Fardis Village.

The Chouaia site is located on the western banks of Bou Aatme Valley, which hosts an intermittent Stream that originates from Ain Qenia village in the Chouf Sandstone Formation. This intermittent Stream discharges in the Hasbani River a few kilometers down stream towards the west. The Stream dries out most of the summer season. Because of the nature of the Kesrouane-Bikfaya Formation in which most of the valley exits in, the Stream looses most of its water to the underground water through channels, fractures and fissure. Visual observation during site visits in April 2004 revealed that the valley is dry.

The El Fardis site is located on the southern banks of Chebba valley, which hosts an intermittent river that originates from Chebba village. This intermittent river discharges in the Hasbani River further 500 m towards the east.

The Hebbariye site is located on the southern banks of Chebba valley, which hosts an intermittent river that originates from Chebba village. This intermittent river discharges in the Hasbani River further few kilometers down stream towards the west . The river dries out most of the summer season. Because of the nature of the Kesrouane-Bikfaya Formation, the river looses most of its water to the underground water through channels, fractures and fissure. Visual observation during site visits in April 2004 revealed that the flow in this section of the valley is much less than near it source close to Chebaa village.

In Kaoukaba, one major perennial river, the Hasbani River, passes through the study area. The site is located on the northern banks of this river.

The Kfar Hamam site is located on the southern banks of Ras En Nimer valley, which hosts an intermittent river that originates from Kfar Hamam village. This intermittent river discharges in the Hasbani River further few kilometers down stream towards the west. The river dries out most of the summer season. Because of the nature of the Kesrouane-Bikfaya Formation, the intermittent river looses most of its water to the underground water through channels, fractures and fissure. Visual observation during site visits in April 2004 revealed that the valley was completely dry.

The Mari site is located on the southern banks of Chebba valley, which hosts an intermittent river that originates from Chebba village. This intermittent river discharges in the Hasbani River further few kilometers down stream towards the west. The river dries out most of the summer season. Because of the nature of the Kesrouane-Bikfaya Formation, the river looses most of its water to the underground water through channels, fractures and fissure. Visual observation during site visits in April 2004 revealed that the flow in this section of the valley is much less than near it source close to Chebaa village.

The Rachaiya el Foukhar site is located on the southern banks of Ras En Nimer valley, which hosts an intermittent river that originates from Kfar Hamam village. This intermittent river discharges in the Hasbani River further few kilometers down stream towards the west. The river dries out most of the summer season. Because of the nature of the Kesrouane-Bikfaya Formation, the intermittent river looses most of its water to the underground water through channels, fractures, and fissure. Visual observation during site visits in April 2004 revealed that the valley was completely dry.

5.7.1. The Hasbani River

The Hasbani River is fed primarily by the Hasbani spring that is situated several kilometers north of the study area. Flow measurements previously conducted at that spring indicate that its flow varies between 0.5 and 1 m^3/s, at dry and wet seasons, respectively (Edgell, 1997). This range could be representative of the flow of the surface water close to the source of the river. Further down stream from the Hasbani Spring, along the Hasbaya section, a gauging station is present where records of discharge rate are presented in Figure 5.10. Further, down stream from the Hasbani River, along the Sreid section, a gauging station was positioned where records of discharge rate are presented below. The largest discharge is approximately 2.98 m^3/s and the lowest is approximately almost zero. Just before it leaves the Lebanese boarder and at the mouth of the Wazzani spring the gauging station is positioned and the hydrograph is presented. The largest discharge is 12.75 m^3/s and the lowest is 1.19 m^3/s.

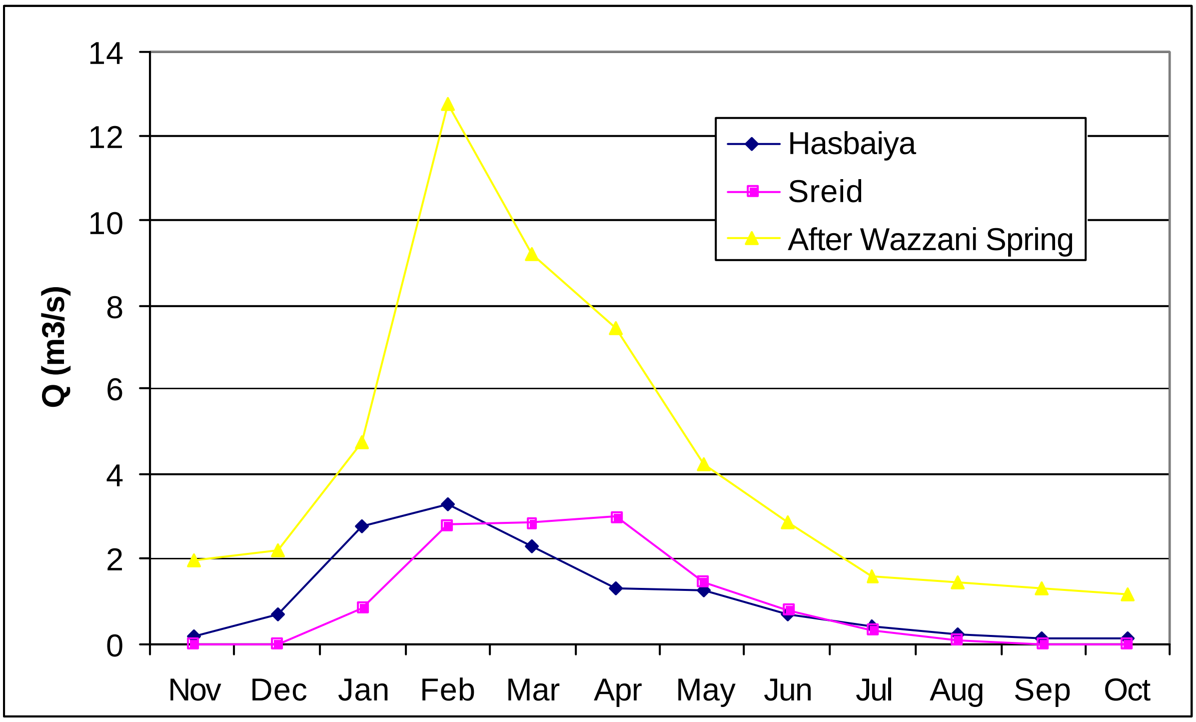


Figure 5.10. Hydrograph of the Hasbani River (1963-1968) at different Location starting from its mouth close to the Hasbani Spring and just before it leaves the Lebanese Territories. (UNDP, 1970).

5.8. WATER QUALITY

Spring Analysis

The springs of Chebaa are the main sources of water for the villages in the study area. It was observed that the local population, do use spring water for domestic and drinking purposes. Table 5.3 presents analytical results of water samples collected in the region. Few samples have shown extensive levels of bacteriological pollution.

The laboratory analytical reports of water samples collected from springs and rivers and analyzed during this study are included in Appendix B along with a Topographic Map indicating the spring sampling locations.

Other analytical results from spring analysis in the remaining villages are shown in Table 5.3.

Table 5.3. Laboratory Analytical Results of Surveyed Springs in the Hasbaiya Area (Samples Collected on 04/05/2004)

Sample ID	*Spring name / location*	*pH (pH unit)*	*Biochemical Oxygen Demand (mg/l)*	*Faecal Coliform (CFU/100 ml)*	*Total Coliform (CFU/100 ml)*
1	El Daya Spring/ Chouaia Village	6.57	<2	0	0
2	El Fardis Spring/ El Fardis village	6.79	<2	5	12
3	Halabeh Spring/ Ain Jarfa village	6.87	<2	47	>500
4	Kaoukaba Spring/ Kaoukaba village	7.18	<2	250	>1000
5	Nabaa el Qershe / Mari village	7.13	<2	0	2
6	S1 Spring/ Rashaya el Foukar village	6.92	<2	0	0
7	Rashaya el Foukhar Spring/ Rashaya el Foukar village	6.95	<2	0	4
8	Chebaa Spring/ Chebaa village	7.41	<2	0	2
	Maximum Allowable Levels *	-	5	0	0

Hasbani River Analysis

The Hasbani River, which originates from the Hasbani Spring, flows in the southward direction and leaves the Lebanese territories near the Wezzani Spring. The river was sampled at 3 random locations in order to measure the level of contamination or pollution due to the uncontrolled raw sewage and olive oil residue discharges into that river. Table 5.4 presents analytical results of water samples collected from the Hasbani River. The samples were collected at three different locations along the study area (Topographic Map Appendix B):

Location 1: In Kaoukaba village close to the potential location of the Kaoukaba Plant.

Location 2: Underneath the bridge, at the connection between the intermittent river in Chebaa Valley and the Hasbani River

Location 3: In El Mari Village close to the potential location of the El Mari Plant

According to a general quality assessment of rivers and canals presented in Table 5.5, the concerned river could be classified as of a grade A. Therefore, water quality in the Hasbani River is considered good, since there is no major industrial wastewater discharge in the area. However, this type of chemical grading does not take into consideration the bacteriological criteria of the water. It is then conclusive that the main cause of Hasbani river degradation is the uncontrolled raw sewage discharged and olive oil residue upstream of the sample collection locations.

Table 5.4. Laboratory Analytical Results of three samples collected from random locations over the Hasbani River (Results as population count per 100 ml)

Sample Location	*Ph (Ph Unit)*	*Conductivity (µSiemens/cm at 25°C)*	*Nitrates (mg/L NO3)*	*Ammonia (mg N/l)*	*BOD (mg/l)*	*COD (mg/l)*	*Faecal Coliform (CFU/100ml)*	*Total Coliform (CFU/100ml)*
Location 1	7.89	445	2.4	0.07	<2	<2	>500	>500
Location 2	7.98	442	2.4	0.06	<2	<2	>500	>500
Location 3	8.08	358	2.2	0.02	<2	<2	170	>1000

Table 5.5. Chemical grading for Rivers and Canals (Thames river-Standards 2000)

Water Quality	*Grade*	*Dissolved Oxygen (% saturation)*	*Biochemical Oxygen Demand (mg/l)*	*Ammonia (mg N/l)*
Good	A	80	2.5	0.25
	B	70	4	0.6
Fair	C	60	6	1.3
	D	50	8	2.5
Poor	E	20	15	9.0
Bad	F*			

* Quality which does not meet the requirements of grade E in respect of one or more determinates.

5.9. ECOLOGICAL CONTEXT (BIODIVERSITY)

Ecologically, all proposed locations are not in an area of special concern, such as areas designated as having national or international importance (e.g. world heritages, wetlands, biosphere reserve, wildlife refuge, or protected areas). The eight wastewater treatment plants projects will not lead to the extinction of endangered and endemic species, nor the degradation of critical ecosystems, and habitats. All project areas are situated in the Eu-mediterranean zone.

5.9.1. Chebaa Plant

In Chebaa, the Quercus sp. community covers the mountain above the proposed site along with some old olive and walnut trees. To the north of the proposed site, sparse Quercus sp. community dominates the steep mountainside with rock outcrop of 80% (Photograph 5.29). Surrounding the proposed site a dense shrub land of Quercus sp., olive and walnut trees and other shrub species are established.

Photograph 5.29. Sparse *Quercus sp*. North of the Proposed Site in Chebaa

5.9.2. Chouaia Plant

In Chouaia, a pine community is present only in scattered patches within the region. The dominant native community around the site consisted of *Pinus pinea* woodland.

However, activities such as deforestation, agriculture, and solid wastes dumping have altered the region's primary ecosystem into shrublands and terraces of agricultural plantations. Few of the original Pine communities are still present around the site (Photograph 5.30).

Photograph 5.30. View of Nearby Pine Trees Near the Chouaia Site

The Chouaia site is a marginal shrub-land with abundant *Sacropotarium sp.* and *Quercus sp.* shrubs (Photograph 5.31). Also, wild lavender (*Lavandula sp.)* and *Calycotome sp*. are plentiful in the site and its vicinity (Photograph 5.32).

Photograph 5.31. Shrubland Surrounding Chouaia Site

Photograph 5.32. *Sacropotarium sp*. on the WWTP location in Chouaia

5.9.3. El Fardis Plant

The project area in El Fardis *Quercus sp.* community is sparse covering small patches on the slope above the proposed site. However, the WWTP is proposed on a compacted barren plateau adjacent to the intermittent river dominated mainly by herbaceous plants such as *Cirsium sp*. (Photograph 5.33) and shrubs such as *Nerium oleander* (Photograph 5.34) are the main shrubs present on-site.

Photograph 5.33. *Cirsium sp*. Community and Olive Orchards Surrounding the Site in El Fardis

Photograph 5.34. *Nerium oleander* Community within El Fardis Site

Photograph 5.35. Area Surrounding the Proposed Site in El Fardis

5.9.4. Hebbariye Plant

Mainly, herbaceous plants and grasses (Photograph 5.37) and shrubs such as *Sacropotarium sp.* (Photograph 5.38) dominate the site. Surrounding the proposed site olive orchards are located are scattered over the area around west of the site, while on the east spares Quercus sp. trees are present.

Photograph 5.36. ***Quercus sp*. Community and Olive Orchards Surrounding the Site of Hebbariye**

Photograph 5.37. Herbaceous Plants and Grass Communities on WWTP Location in Hebbariye

Photograph 5.38. *Sacropotarium sp*. on the WWTP Location in Hebbariye

5.9.5. Kaoukaba Plant

In Kaoukaba, dominating *Quercus* community is still present covering the plain and hills surrounding the proposed site along with some old olive orchards. The *Quercus* sp. trees, shrubs and grasses are present on the exterior border of the site whereas, olive trees are within the internal border (Photograph 5.39).

Photograph 5.39. *Quercus* sp. Community and Olive Orchards Surrounding the Site in Kaoukaba

The dominant native community around the site is mainly composed of olive trees and *Quercus* spp. However, a variety of shrubs and grasses grow within this community such as *Spartium* sp.

Photograph 5.40. *Spartium* spp. at the Edge of the Kaoukaba Site.

5.9.6. Kfar Hamam Plant

Pine community is present only in scattered patches within the region. The dominant native community around the site consisted of *Pinus Pinea* woodland. However, activities such as deforestation, agriculture, and solid wastes dumping have altered the region's primary ecosystem into shrublands and terraces of agricultural plantations. Few of the original Pine communities are still present around the site (Photograph 5.41). The site is a marginal shrub-land with abundant weeds such as *Sacropotarium Spp.* Construction on the site will not lead to the significant removal of any native or endangered species, or to the destruction of wildlife habitat.

Photograph 5.41. View of Surrounding Ecology in Kafar Hamam

Photograph 5.42. Close up of Site Ecology

5.9.7. Mari Plant

A variety of wild grasses with few shrubs presently colonize the surroundings of the WWTP community with the exception of cultivated agricultural lands where olive trees are primarily grown. Weeds such as *Cirsium spp.* are also dominant in this community.

Photograph 5.43. View of Surrounding Ecology in Mari

Photograph 5.44. Existing Grass Fields and Olive Plantation Communities around the Site in Mari

Adjacent to the Hasbani River, the proposed site location lies at the border of the Mari village solid wastes dump. Exposed to open burning and dumping, the proposed site consists of a marginal destructed wasteland of no high ecological significance.

Photograph 5.45. Solid Wastes Dump Adjacent to Proposed Site in Mari

5.9.8. Rachaiya el Foukhar Plant

In Rachaiya el Foukhar project area, the dominating *Quercus* community is still present covering the mountain above and around the proposed site along with some old olive orchards. However, the site is proposed on the outskirts of an oak ecosystem, and near terraces intended for agricultural activity. The *Quercus* sp. trees, shrubs and grasses are present around the site (Photograph 5.46).

Photograph 5.46. *Quercus* sp. Community near the Site in Rachaiya el Foukhar

The dominant native community around the site is mainly composed of olive trees and *Quercus* spp. However, a variety of shrubs and grasses grow within this community such as *Spartium* sp. The identified plant site is located within this community however on a relatively less dense area with a variety of grasses and shrubs colonizing the area. The old olive orchards are scattered over the area around the site.

5.10. INFRASTRUCTURE STATUS

Wastewater treatment facilities are available in Chebaa and Hebbariye. However the Chebaa WWTP is not operational to date and is designed to serve only 30% of the village households, for the remaining 70% of Chebaa households, domestic sewage is generally disposed of into "unregulated" septic tanks or discharged directly onto open grounds. As for the Hebbariye plant, it is operational, but covers only 50% of the villages households. For the remaining 50% of Hebbariye, domestic sewage is generally disposed of into "unregulated" septic tanks or discharged directly onto open grounds. The construction of sewage networks has not been planned for both villages, however should be implemented prior to the operation of the plant.

An elementary sewage network infrastructure is present in the four villages of Chouaia, Kfar Hamam, Mari and Rachaiya el Foukhar, with the sewage collection main almost reaching the proposed WWTP location. The four municipalities will have to extend the primary collection line as well as rehabilitate parts of the secondary collection network ensuring that all the generated sewage in the villages will reach the corresponding treatment plant. The construction of sewage networks is planned in Chouaia, Kfar Hamam, Mari and Rachaiya el Foukhar and will be implemented prior to the operation of the plant. In addition, no wastewater treatment facilities are available in the four villages. Domestic sewage is generally disposed of in "unregulated" septic tanks or discharged directly into runoff ditches or open grounds.

Wastewater treatment facilities are not available in El Fardis and Kaoukaba municipalities. In Kaoukaba, the municipality is working on applying for different sources of funding in order to complete the project. Domestic sewage is generally disposed of into "unregulated" septic tanks or discharged directly onto open grounds. The construction of sewage networks has not been planned in El Fardis, however should be implemented prior to the operation of the plant. Hence, the two municipalities will complete the task of connecting the village's households to the main network, ensuring that all the generated sewage in the village will reach the WWTP. Note that all concerned municipalities will have to seek financing for the implementation of a main sewage network to connect village households to the proposed WWTPs.

Infrastructure within the towns is mainly limited to road network, telephone, electricity, and water supply. No solid waste management system exists neither on a public or private level. In all villages, the municipality is responsible for waste collection, however the waste is being openly dumped and burned along roadsides.

Photograph 5.47. Existing WWTP in Chebaa (currently not operational)

5.11. SOCIO-ECONOMIC STATUS

Socio-economic information about the village was obtained during informal meetings with municipal council members during the field visits. Table 5.6 presents some socio-economic information relevant to this study. Local inhabitants are mainly members of the active population (between 20 and 50 years old). The economy of the area is mainly driven by public and private sector employments. Trade and services are also prevalent. Money sent by expatriates (people from the town living abroad) is a main driver of the local economy as well. All Hasbaiya villages are considered as summer holiday destinations. This constitutes a major source of income for the residents of the region during the summer months. Industry is present mainly in the form of small-varied industries like welding, and carpentry. Average household income within the eight villages municipalities amounts to less than six million Lebanese pounds annually (or around 500,000 Lebanese pounds monthly).

Table 5.6. Socio-Economic Information in the Hasbaiya Caza

Village	*Population* Year-round/ Seasonal	*Community priority*	*Economy Driver*	*Health & Educational Services*	*Farms & Farming*	*Gas Stations Lube Oil Service Car Mechanics*	*Industry*
Chebaa	7,500 – 22,500	Wastewater treatment	Summer Holiday Destination	1 school , Red Cross Head Quarters, 1 Clinic	Stone fruits (cherry etc.)	2 Gas Stations	None
Chouaia	700-1000	Wastewater treatment	Mainly services and employment Agriculture	None	Olives, figs, grapes	None	None
El Fardis	1000	Wastewater treatment	Agriculture (30%), services and employment (70%)	1 school	Olives & grape vines	Two gas station	None
Hebbariye	3000-6000	Wastewater treatment	4 olive oil mills	1 school & 2 health clinics	Olives & grapevine s	None	None
Kaoukaba	800-3000	Wastewater treatment	Agriculture (90%), Industry (5%), services and employment (5%)	None	Fruit, vegetables , and olives	One gas station	None
Kfar Hamam	250 (winter) – 1500 (summer)	Wastewater treatment	Mainly services and employment Agriculture	1 closed school 1 clinic	Olives, figs, grapes	One gas station	None
Mari	1500	Wastewater treatment	Agriculture (80%), services, employment (10%), Expatriate resources	1 school	Fruit, vegetables , and olives	None	None
Rachaiya el Foukhar	1500 4000	Wastewater treatment	Agriculture (90%), Industry (5%), services and employment (5%)	1 clinic	Fruit, vegetables , and olives	One gas station	Olive Oil Mills Pottery Crafts

6. IMPACT IDENTIFICATION AND ANALYSIS

Both on-site and off-site impacts can be induced during the construction of the plants, and later during their operation. On-site impacts result from construction activities carried out within the construction site. The impacts of off-site work result from activities carried out outside the construction site, yet are directly related to the project. In the case of Wastewater Treatment Plants (WWTPs), the main potential receptors are soil, surface, and ground water bodies. Identification of potential impacts is facilitated by the use of a matrix that shows the main activities at the WWTPs, the major perturbation factors, and the environmental media affected (Table 6.1). The extent of impacts depends primarily on the effluents management practices that would be adopted during plant operation.

6.1. IMPACTS ON WATER RESOURCES

6.1.1. Impacts during Construction

No major on-site impacts on water resources are anticipated during the construction phase of the plants. Care should be exercised when handling fuel and oil (hydraulic, transmission, engine, etc.) to power and maintain the different machinery and equipment on site. Measures should be taken to avoid spillage of such material to the ground, as these contaminants would eventually leach and contaminate the groundwater and are persistent in the environment. Dumping excavated and construction material or other debris and litter into nearby watercourses should be prohibited. Additionally, all earth-moving and other equipment should be in good working condition and well maintained (no leaks).

Off-site impacts on water resources may occur from the reckless disposal of domestic as well as industrial wastes, typically liquid and solid, generated form the residential units, offices, and equipment and vehicles maintenance units at the contractor's constructions site. Where proper waste segregation and disposal is practiced, the likelihood of these impacts to occur will be negligible, if not non-existent.

Table 6.1. Impact Identification Matrix

	Perturbation factor	Sewage	Gas Emission	Solid waste	Odors	Heavy metals	Chemicals	Noise	Dust
Phase	***Activities***								
Construction	Earth moving			√					√
	Excavation							√	√
	Truck movement		√					√	
	Erection							√	
Operation	Sewage conveyance	√							
	Preliminary Treatment	√		√	√				
	Secondary Treatment		√		√			√	
	Sedimentation			√					
	Sludge holding			√	√				
	Sludge return							√	
	Sludge drying				√			√	
	Disinfection						√		
	Effluent disposal					√	√		
	Sludge disposal			√	√	√	√		
Environmental Media	River					√	√		
	Ground water	√		√		√	√		
	Agricultural soil					√	√		
	Nuisance		√	√	√			√	√
	Air quality		√						√
	Biodiversity		√		√	√	√	√	√

6.1.2. Impacts during Operation

During operation, the main activities that could possibly affect water resources are the effluent management practices. Proper management of both the treated wastewater and the generated sludge is essential. Less commonly, flooding of the wastewater plant as well as leakage form the treatment basins can threaten the groundwater resources and nearby surface waterbodies. These should be avoided by adopting proper engineering codes and adequate preventive measures.

The secondary treatment of the El Fardis, Kaoukaba and Mari WWTPs is expected to, at a minimum, meet the Environmental Limit Values (ELV) for wastewater discharged into surface waters, as specified by Ministerial Decision 8/1/2001. Since the guidelines are met, the effluent can be safely discharged into the nearby Hasbani River. The Hasbani River flow reaching more 0.1 m^3/sec, a dilution factor which is considered within the standards set by the MoE.

However, in the case of advanced treatment levels in the plants of Chebaa, Chouaia, Hebbariye, Kfar Hamam and Rachaiya el Foukhar, the tertiary treated effluent is expected to, at a minimum, meet the Environmental Limit Values (ELV) for wastewater discharged into surface waters, as specified by Ministerial Decision 8/1/2001, and will actually reach advanced levels of treatment (Table 4.20). Since stringent guidelines are met, the effluent can be safely discharged into the nearby intermittent river in each case.

The screenings, grit, grease, and sludge generated from the wastewater treatment process may impact the water resources if these byproducts are mismanaged. Disposal through landfilling can lead to the contamination of surrounding water bodies and groundwater supplies from mishandled leachate. In all eight WWTPs, however, these products shall be managed in a manner that complies with the MoE guidelines. With the adoption of appropriate practices on Sludge Management, the likelihood of these impacts to occur will be minimal.

The worst case scenario in the case of wastewater treatment plant is when the treatment plant is not operating properly due to malfunction of the EAAS for example, the impacts will be amplified due to sewage collection network that is expected to be built, this leading to a point source of pollution. Given the reliability of the EAAS system, the likelihood of this event is minimal.

6.2. IMPACTS ON SOIL

6.2.1. Impacts during Construction

The total volume of soil and rock that would be excavated during plant construction is relatively small and thus should not lead to major erosion problems and impacts on soils. Moreover, the excavated soil shall be used to rehabilitate abandoned quarries.

Soil quality may also be impacted in the construction phase by littering (wood and metal debris, concrete blocks, empty cement bags, empty paint containers and canisters, plastics from extension of electricity cables) that can be avoided by proper housekeeping and behavioral practices.

Soil pollution may also occur by intentional or accidental leakage of used chemicals, fuel, or oil products (from equipment and vehicles) on construction sites. Such practices should be strictly avoided and the utmost precautions and workmanship performance should be adopted for the disposal of such hazardous products.

6.2.2. Impacts during Operation

The main concern during operation of the plant is related to soil quality rather than soil quantity, and is primarily attributed to generated sludge management. Since the sludge generated from all Hasbaiya WWTPs shall be landfilled and not used as soil amendment for agriculture, it could not cause direct damage to soil fertility in the case of mismanagement.

6.3. IMPACTS ON HUMAN AMENITY

Human amenity is defined inhere as general comfort of persons that could eventually be disturbed by factors such as dust, noise, and odors.

6.3.1. Impacts during Construction

The main impacts on human amenity during plant construction are related to dust release, visual disturbance and noise generation. An increase in ambient particulate matter and dust may be observed primarily during the excavation activities and the movement of trucks transporting raw material and from the site. However, given the fact that excavation will last for a limited period, the impacts from potential dust generation will not be significant especially when the mitigation measures are implemented.

On the other hand, appreciable increases in noise levels shall occur during the excavation and construction of the plant. However, the location of the plant with respect to the village residential area, coupled with the short duration of the construction period, render this impact insignificant.

The visual quality of the site can also cause disturbance to human amenity, specifically from the scattering of wood and metal debris, concrete blocks, empty cement bags, empty paint containers and canisters, or plastics from extension of electricity cables. Good housekeeping practices of the laborers can secure the elimination of this impact.

6.3.2. Impacts during Operation

The main amenity impacts during plant operation are related to the generation of noise and odors from the WWTP. Noise may be generated mainly from the operation of blowers and electricity generator. However, if adequate noise reduction/suppression measures are undertaken, the generated noise should not significantly affect human amenity.

Odors emitted at a wastewater treatment works may easily reach the local inhabitants, especially if prevalent wind direction is towards the residential areas. Inlet works, grit channels, screening and grit handling, aeration tanks, and sludge holding and dewatering beds and are the main sources of odor at the wastewater treatment facility. However, in many instances, odors can be reduced or prevented through the design, housekeeping and operation and maintenance of the WWTPs. Odors may be also be produced from leaks or drying of sludge on-site; therefore, proper sludge management (proper storage, handling and off-site transportation and disposal) is critical in order to avoid obnoxious odors. Proper handling procedures are presented in Section 7 and should be abided by in order to ensure an extended life span for the plant and it sustainability.

The proposed WWTPs in the villages of Kaoukaba, Fardis and Mari may have an impact on the visual quality of their surroundings since all are located on the banks of the Hasbani River. However, the sites themselves are small in scale and are built on wasted shrubland, therefore the visual impact are not significant and can be overcome through landscaping with *Quercus Spp*.

The proposed WWTPs in the villages of Chebaa, Chouaia, Kfar Hamam, Hebbariye, Rachaiya el Foukhar have no impact on the visual quality of their surroundings since it all are secluded, of a small scale and build on wasted shrubland.

6.4. IMPACTS ON PUBLIC AND OCCUPATIONAL SAFETY

6.4.1. Impacts during Construction

In any civil works, public as well as construction staff safety risks can arise from various constructions activities such as deep excavations, operation, and movement of heavy equipment and vehicles, storage of hazardous materials, disturbance of traffic, and exposure of workers to running sewers. Construction workers are always in risk of inhaling, ingesting, or absorbing (skin) hazardous substances such as: volatile paints and thinners, asbestos fibers from asbestos containing material, exhaust of on-site machinery, power generators and vehicles, and the dust resulting from excavation and the movement of trucks.

Because of the short duration and non-complexity of the construction phase, such activities are controlled and consequently the associated risks are minimal. Proper supervision, high workmanship performance, and provision of adequate safety measures will suppress the likelihood of such impacts on public and occupational safety.

6.4.2. Impacts during Operation

During the operational phase of the plants, occupational safety is at a higher risk than public safety. Fortunately, various mitigation measures can be easily adopted to minimize occupational hazards. Such measures are detailed in section 7 and should be stringently considered.

6.5. IMPACTS ON BIODIVERSITY

6.5.1. Impacts during Construction

The proposed site is on a disturbed, degraded, and wasteland therefore the proposed project will not lead to significant negative impacts on biodiversity. However, throughout construction efforts should be taken to conserve present trees. Potential negative impacts affecting biodiversity during project construction are summarized in Table 6.2. The main construction activities having negative results on the biodiversity are earth-moving activities, erection of the plant, and construction waste material and effluent discharges. However, the potential negative impacts are not considered very significant since the project only affects a degraded portion of the ecosystem.

Table 6.2. Potential Negative Impacts on Biodiversity

Impact	Cause
Habitat loss or destruction	Construction works
Altered abiotic/site factors	Soil compaction, erosion
Mortality of individuals	Destruction of vegetation
Loss of individuals through emigration	Following disturbance or loss of habitat
Habitat fragmentation	Habitat removal and/or introduction of barriers like roads
Disturbance	Due to construction noise, traffic, or presence of people
Altered species composition	Changes in abiotic conditions, habitats…
Vegetation loss	Soil contamination due to disposal of oils and hazardous material

On the other hand, the project could include an ecosystem rehabilitation plan to regenerate and protect the *Pinus Spp* present around the sites of Kfar Hamam and Chouaia therefore leading to great positive impacts on the biodiversity level.

6.5.2. Impacts during Operation

With proper management of effluent material, negative impacts on biodiversity during operation of the plants should be minimal. On the contrary, the projects could lead to positive environmental impacts on the biodiversity level if plans are developed to protect surrounding areas. Inclusion of original species in the proposed landscape plan could be adopted to alleviate visual impacts and compensate loss of communities, if any. The surrounding community of Pine and Olive trees as well as oak trees present in Chebaa, El Fardis, Hebbariye, Kaoukaba and Mari sites should be preserved in order to act as a windbreak and eventually reduce the dispersion of odors around the plant.

6.6. IMPACTS ON HUMAN HEALTH AND SANITATION

The current lack of proper solid and liquid waste management is surely having a negative impact on human health and the environment. Current and historical dumping of wastes, whether in open dumps or in sinkholes, is directly polluting the environment and water resources of the area, and is furnishing breeding habitats for rodents and diseases to flourish. Such impacts will be mitigated by the deployment of a proper sewer collection system by the concerned municipality and by the treatment of the collected sewage in the WWTPs. Wherever a property cannot deliver to the system its sewage by gravity drainage, proper measures in the form of secure septic systems or pumping stations should be installed.

However, during the construction phase, littering by the workmen should be controlled to avoid any of its associated impacts on human health through the spread of pests and diseases. Infectious diseases may also be contacted through the inhalation of pathogenic aerosols within the plant. However, the possibility of this to occur is both limited to the facility personnel and generally negligible.

As a whole, the projects would lead to POSITIVE impacts with respect to human health. Improvements in health conditions are likely to occur as the result of improvements in surface, groundwater, and spring water quality as well as sanitation conditions.

6.7. SOCIO-ECONOMIC IMPACTS

Additional POSITIVE impacts would be observed at the socioeconomic and agriculture levels. The proposed projects will create certain job opportunities for skilled and unskilled labor. Moreover, if the villagers decide to use the treated effluent for irrigation in the future, the projects will have long-term positive impacts on agriculture.

Moreover, the stabilized sludge can also be potentially used in the future in agricultural, municipal landscape or silviculture (as portrayed before) fertilization practices, therefore alleviating organic or synthetic fertilizer costs on farmers. With careful operation and monitoring of an onsite-windrow system and sludge quality, the sludge would be of a benefit and ensure a quick acceptance of this byproduct in the market or would be used in the rehabilitation process of quarries.

6.8. IMPACTS ON ARCHAEOLOGICAL, TOURISTIC AND CULTURAL SITES

The proposed WWTPs are not located on or close to any nature reserves, archaeological or cultural heritage sites. However, the Hasbaiya area is of considerable touristic value because of its vast natural resources. Therefore, the impact of the construction and operation of the eight WWTPs in Hasbaiya is only positive since it improves the eco-tourism capabilities of the region by resolving the sewage crisis in all villages

7. ENVIRONMENTAL MANAGEMENT PLAN

The proper implementation of a comprehensive environmental management plan (EMP) will ensure that the proposed Wastewater Treatment Plants (WWTPs) meet regulatory and operational performance (technical) criteria.

7.1. OBJECTIVES OF THE ENVIRONMENTAL MANAGEMENT PLAN

Environmental management is essential for ensuring that identified impacts are maintained within the allowable levels, unanticipated impacts are mitigated at an early stage (before they become a problem), and the expected project benefits are realized. Thus, the aim of an EMP is to assist in the systematic and prompt recognition of problems and the effective actions to correct them, and ultimately good environmental performance is achieved. A good understanding of environmental priorities and policies, proper management of the plants (at the level of the municipality), knowledge of regulatory requirements and keeping up-to-date operational information are basic to good environmental performance.

7.2. MITIGATION MEASURES

7.2.1. Defining Mitigation

As part of the EMP, mitigation refers to the set of measures taken to eliminate, reduce, or remedy potential undesirable effects resulting from the construction and operation of the proposed municipal wastewater treatment plant. Generally, mitigation should be considered in all the developmental stages of the facility, namely, the site selection process, as well as the design, construction, and operation phases. Once set, tender documents should clearly describe mitigation measures and level of workmanship that need to be adopted by the contractors and operators.

7.2.2. Mitigating Adverse Project Impacts

As identified earlier, potential adverse impacts of the proposed wastewater treatment plants may include dust emissions, odor and aerosol generation, noise generation, degradation of natural resources, production of residuals, public health hazards, and adverse aesthetic impacts. Proposed mitigation measures for the above-mentioned adverse impacts are discussed in the following paragraphs. Table 7.2 summarizes such mitigation measures, their monitoring for actions affecting environmental resources and human amenity. Such measures should be set as primary conditions on the contractor, the supervising engineers, the concerned WWTP administration, and operating staff in order to assure a proper management of the plant as well as the implementation of the Environmental Management Plan (EMP) discussed in this section.

7.2.2.1. Mitigating Degradation of Receiving Water Quality

In general, secondary wastewater treatment systems, specifically EAAS treatment system, produces a highly treated and well-nitrified effluent that meets effluent quality standards. Disinfection further suppresses bacterial population in the discharged effluent. Thus, the proposed facilities' discharge effluent quality is expected at a minimum to meet the Environmental Limit Values (ELV) for wastewater discharged into surface waters, as specified in the National Standards for Environmental Quality. In the case of tertiary treatment discharge, it is essential that discharge points be downstream of vital springs. The geological setting of the area was thoroughly considered and studied before discharging the effluent into the karstic aquifers such as the Bickfaya-Kersrouane formation in Chebaa. It is noteworthy to mention that a protective seal is required underneath the sites of Mari, Fardis, and Hebbariye to protect the underlying highly permeable (karstic) formations.

To attain the expected safe effluent discharge, a skilled and trained operator is necessary for proper process loading, optimization, control, and thus performance. Furthermore, the discharge of industrial wastewater and oil/grease into the treatment facility should be prohibited and illegal discharge controlled by the concerned authority. In instances where high levels of grease and oils are present in incoming raw sewage (as is the case in Kfar Hamam), larger Grease and Oil interception tanks should be integrated in the facility designs; the detention time should exceed a period of 30 minutes.

Operational upsets due to ambient temperature variations should be overcome by the provision of adequate preventive measures such as proper covers and thermal accessories.

The implementation of training recommendations, maintenance plans, and process and effluent monitoring programs should be *mandatory*. The manufacturer's operation and maintenance (O&M) instructions on pumps, bearings, and motors should be followed. All equipment must be tested and calibrated as recommended by the equipment manufacturer. A routine O&M schedule should be developed and followed for the WWTP. Additionally, it is critical that the plant be pilot tested prior to operation to ensure that it will meet effluent discharge permit requirements for that particular site.

Sufficient instrumentation and standby equipment (blowers, pumps, and electric generators) should be provided to ensure an uninterrupted and controlled operation, thus avoid inefficient process performance. Drains and bypasses should be designed for emergency cases.

7.2.2.2. Mitigating Dust Emissions

Dust emissions from piles of soil or from any other material during earthwork, excavation, and transportation should be controlled by wetting surfaces, using temporary windbreaks, temporary ground cover, and covering truckloads. Piles and heaps of soil should not be left over by contractors after construction is completed. In addition, excavated sites should be covered with suitable solid material and vegetation growth induced after construction completion, no soil surface should be kept bare subject to wind or water erosion.

It is the responsibility of the Supervision Engineer to monitor for the mitigation of such impacts.

7.2.2.3. Mitigating Noise Pollution

Temporary noise pollution due to construction works should be controlled by proper maintenance and insulation of equipment and vehicles, and tuning of engines and mufflers. Construction works should be completed in as short a period as possible by assigning qualified engineers and supervisors. It is the responsibility of the Supervision Engineer to monitor for the mitigation of such impacts.

Noise pollution during operation would be generated by mechanical equipment, namely pumps, air blowers, and sludge dewatering units. Noise problems should be reduced to normally acceptable levels by incorporating low-noise equipment in the design, insulating the machinery, and/or secluding such mechanical equipment in acoustically insulated buildings or enclosures. In the presence of adequate buffer zones between the facility and residential areas, the need for noise control measures is minimized. Furthermore, dispersion of noise can be reduced by maintaining and/or establishing zones of olive or pine communities that will act as a wind and sound break.

7.2.2.4. *Mitigating Obnoxious Odors*

Odors emitted by the wastewater treatment works may be potential nuisance to the public. Inlet works, grit channels, screening and grit handling, aeration tanks, and sludge holding and drying units are the main sources of odor at the wastewater treatment facility. However, in many instances, odors can be reduced or prevented through normal housekeeping, improved operation, and maintenance design procedures. When kept clean, sludge transfer systems, such as conveyors, screw pumps, and conduits, will not generate odors.

The primary mitigation measure for odor control remains the proper siting of the facility. The plant should be located at a site where prevailing winds mostly blow away from nearby residential areas. In addition, adequate buffers from treatment units should be considered. As a guide, suggested minimum buffer distances from some treatment units are presented in Table 7.1.

Table 7.1. Suggested minimum buffer distances from treatment units

Operation Unit/Process	*Buffer Distance (m)*
Sedimentation tank	120
Aerated tank	150
Aerated lagoon	300
Sludge holding tank	300
Sludge thickening tank	300
Sludge drying beds (open)	150
Sludge drying beds (covered)	120
Sludge digester	150

Activated sludge tanks do not normally emit an objectionable odor when a dissolved oxygen level of $\geq$ 2 mg/L is maintained in the mixed liquor. Thus, it is essential to execute a regular program of maintenance to prevent the clogging of diffuser plates to maintain adequate dissolved oxygen levels in the aeration tanks, which in turn minimizes the chances for the production of odorous compounds. Regular cleaning of aeration tank walls and floors, washing weirs, and removing scum regularly, also helps in odor reduction.

Where odor emissions could lead to complaints, the provision of covers to the odor sources should be considered, especially for sludge holding tanks and sludge drying systems. To reduce odors from final settlement tanks and sludge holding tanks, logical operational solutions include increasing the pumping rate of the thickened sludge, monitoring a low sludge blanket level, and increasing the influent flow rate to the sludge-holding tank without losing thickening. Tank mixing during off-shifts will also minimize the release of trapped gas during the day. Occasional tank draining and filling it with chlorinated water further reduces odor problems. To reduce odors from drying units, pH adjustment or introduction of chemicals may be employed. The odorous air from enclosed unit operations may be collected at a central area and relevant odor treatment processes applied. An affordable measure to reduce partly odor problems can be storing produced residuals in closed containers and transporting them in enclosed container trucks. Flow regulating chambers, drainage valves, standby pumps, as well as electric standby generators shall be provided to reduce the possibility of wastewater flooding within the wastewater treatment plant site, which results in possible generation of obnoxious smell. The presence of multiple aeration basins in the plant also reduces overflowing problems.

Proper landscaping around every facility along with the existing landscape may serve as a natural windbreaker and minimize potential odor dispersions. When odor becomes an evident public nuisance, synthetic windbreakers (e.g. walls) should be employed to maintain odor nuisance within the site.

7.2.2.5. Mitigating Aerosol Emissions

The process of aeration may result in the emission of sprays or aerosols. To limit such emissions, adequate feedboards should be considered, or suppression hoods, splash plates or deflectors be incorporated on the rotors, if employed. Moreover, the edge of the aeration basin can be raised 50-60 cm above water level to reduce aerosol emission.

7.2.2.6. Mitigating Impact on Biodiversity

Recommended mitigation measures to minimize or eliminate the impacts on the biodiversity at proposed location include:

- Avoid deforestation activities: plan the building sites and roads on areas void of trees.

- Design a landscape plan that enhances the landscape esthetic value using local and native population flora.
- When detected, endangered species or sensitive habitats should be conserved.
- All waste resulting from construction works, land reclamation, or any other activity should be collected and disposed properly in an allocated disposal site. Littering in the project areas and surrounding areas should be prevented.

7.2.2.7. Mitigating Impacts from Residual Storage, Handling, Transport, and Reuse/Disposal

The residuals resulting from EAAS treatment system include screenings, grit, scum, and sludge. To reduce potential impacts of such residuals, proper handling, storage, transport, and disposal/reuse strategies should be adopted.

Screenings: Drained screenings should be collected in closed containers for ultimate transport and disposal at a nearby municipal solid waste disposal site. Hauling of screenings is to be carried by closed-top trucks.

Grit: Consisting of sand and gravel, from properly designed and operated gravity grit separators, is generally inert in nature, low in organic content, and relatively innocuous. Thus, the proper design and operation of grit chamber serves as the primary mitigation measure. Grit is to be washed daily and separated such that organic particles that are trapped with the grit will be recycled back into the flow stream. This will maintain odorless clean grit in open storage. The washed grit is then transported to an allocated municipal solid waste disposal site.

Scum: Adequate scum collection and removal facilities are to be provided in the final settlement tanks of the extended aeration activated sludge system to prevent floating material and scum to be carried with the effluent and deteriorate its quality. Collected scum can be treated with the sludge.

Oil and grease should not pose a serious problem since their discharge into the wastewater treatment plants is limited to ensure high purification efficiency and avoid operational upsets. However, the safe incorporation of an interceptor tank to trap grease will reduce any chances encountering troublesome grease persistence in the system.

Sludge: Due to the EAAS system, the generated sludge is somewhat reduced and relatively more stable. The proper design and operation of proposed sludge handling and treatment units will mitigate sludge-induced impacts. The dewatered sludge storage area should be bounded to contain any surplus liquids, which should be returned to the inlet works. Adequate storage capacities are to be provided on-site. Transport of sludge should be by top-covered trucks. Truck drivers should be instructed not to have the truck wheels come in contact with the sludge when loading, and not to overload to avoid spillage along travel roads. Although it is recommended to use the produced sludge for agricultural landscape fertilization programs, land reclamation, no such plans have been prepared for this at the present moment; In the absence of adequate markets for sludge reuse, the alternative environmentally sound sludge management strategies is proper landfilling, or use for land and quarries rehabilitation.

In the future, agreements are set with proper authorities or private individuals for sludge reuse, the generated sludge can be reused instead of landfilled. Since the wastewater discharged into the plants is basically of domestic origin, the concentration of heavy toxic metals in the sludge is expected to be very low.

Nitrification and denitrification are expected to occur in the extended aeration system, thus the impact of excess nitrates on the soil will also be overcome.

7.2.2.8. Mitigating Adverse Aesthetic Impacts

To avoid possible visual impacts resulting from the existence of wastewater treatment facilities, the following steps are to be implemented:

- Maintaining cleanliness within each treatment plant (preventing spillovers, cleaning roads and ground, etc.).
- Appropriate landscaping of each treatment plant grounds with planting of suitable trees, grass, and flowers.
- Fencing and screening all sites with appropriate trees to obstruct plants' components from onlookers and area inhabitants. (All along with some noise reduction).
- Preserve the surrounding forest that will provide appropriate visual cover of the facility.

7.2.2.9. Mitigating Public and Occupational Health Hazards

Care should be taken to avoid ponding of the wastewater especially on the dual media filter and GAC filter due to excessive biological growth. Ponding provides pests such as mosquitoes and disease vectors with the ideal conditions for breeding. Ponding can be avoided by: reducing organic loading (partial recirculation of treated effluent); increasing hydraulic loading to increase sloughing; using high-pressure stream of water to flush filter surface (recycled water); maintaining 1 to 2 mg/L residual chlorine on the filter for several hours; flooding filter for 24 hours; shutting down filter to dry out media; replacing the media if necessary; or removing debris. Another potential problem related to improper operation and maintenance of the WWTPs is poor housekeeping which can also potentially cause for the propagation of pests such as flies and mosquitos. To avoid this, premises of all WWTPs should be regularly cleaned, and the surrounding area mowed regularly and have weeds and shrubs removed. Other mitigation measures that can significantly suppress the likelihood of impacts on public and occupational safety include:

- Restricting unattended public access to the wastewater treatment plants by proper fencing, gate and guarding
- Surrounding excavated locations with proper safety barriers and signs
- Properly labeling and storing chemicals (Chlorine gas or powder), oils, and fuel to be used on-sites
- Emphasizing safety education and training for system staff. Enforcing adherence to safety procedures
- Providing appropriate safety equipment, fire protection measures, and monitoring instruments
- Providing hand railing around all open treatment units, except where sidewalls extend $\geq$1.1 meters above ground level.
- Properly rating electrical installations and equipment and, where applicable, protecting them for use in flammable atmosphere.
- Providing sufficient lighting that should comply with zoning requirements.

As a conclusion, proper supervision, high workmanship performance, and provision of adequate safety measures will alleviate public and occupational risks.

Table 7.2. Mitigation Measures, Monitoring, and Estimated Costs for Actions Affecting Environmental Resources and Human Amenity

Action	*Potential impact*	*Mitigation measures*	*Monitoring of mitigation measures / responsibility*	*Estimated cost of mitigation (USD)*
A. During Construction				
Excavation and earth movement	• Dust emission	• Wetting excavated surfaces • Using temporary windbreaks • Covering truck loads	Supervision engineers	Required in tender/ Included within contract
	• Noise generation	• Restriction of working hours to daytime • Employing low noise equipment • Proper maintenance of equipment and vehicles, and tuning of engines and mufflers	Supervision engineers	Priced within contract
	• Erosion	• Proper resurfacing of exposed areas • Inducing vegetative cover	Supervision engineers	ditto
	• Disturbance to biodiversity	• Conservation of present trees and used as wind brakes and esthetic cover for the facility. • Inducing vegetative growth	Supervision engineers	ditto
Dumping of excavated and construction material into nearby watercourses	• Surface and groundwater pollution	• Prohibition of uncontrolled dumping. Disposal at appropriate locations • Education of workers on environmental protection • Reusing all excavated soils for rehabilitation of abandoned quarries, or disposal in an environmentally acceptable manner (inert waste landfill)	Supervision engineers	ditto

Discharge of wastes (chemicals, oils, lubricants, etc.) on-site	• Soil and water pollution	• Prohibition of uncontrolled discharge. Proper disposal of hazardous products • Collecting all solid wastes, according to type, in storage containers and presenting it to the entity authorized for its reuse, recycling, or disposal. • Proper collection and disposal of used oil and grease generated by the maintenance of machinery and equipment • Education of workers on environmental protection	Supervision engineers	ditto
Storage of hazardous material, traffic deviation, deep excavation, movement of heavy vehicles, exposure to running sewers, etc.	• Hazards to public and occupational safety	• Proper supervision for high workmanship performance • Provision of adequate safety measures, and implementation of health and safety standards • Providing workers with personal protective equipment such as gloves, eye protection, sound protection and respirators when necessary	Supervision engineers	ditto

B. During Design & Operation				
Inadequate process design and control	• Generation of obnoxious odors	• Adopting a sound hydraulic design to control daily flow • Improving operation and maintenance design procedures • Provision of covers where possible • Landscaping a proper natural windbreaker around the facility • Preservation of the Pinus spp trees around the plant site act as windbreaks. • Use corrosion-resistant material in the reactor, pipelines and valves to void leakage. • Prohibiting anaerobic conditions throughout the WWTP • Precipitating odor-causing compounds through the use of chemicals such as, potassium permanganate, mineral salts, … • Collecting and treating gaseous byproducts by using appropriate technologies (activated carbon filters, biofilters)	Design engineers	ditto
		• Maintaining proper cleanliness and housekeeping • Transportation of odorous byproducts in enclosed container trucks • Diluting, masking or treatment of odorous emissions	WWTP administration and operating staff	
	• Impaired aesthetics	• Maintaining cleanliness around and within the plant • Proper fencing and landscaping an area equivalent to 10 % of the site's area • Preservation of the Pinus spp trees around the plant site.	WWTP administration and operating staff	ditto

	• Aerosol emissions	• Allowing adequate feedboards for aeration basins • Employing suppression hoods or splash deflectors on rotors	Design engineers	ditto
	• Noise generation	• Incorporating low-noise equipment • Locating mechanical equipment in proper acoustically-insulated enclosures • Preservation of the Pinus spp trees around the plant site	Design engineers	ditto
	• Public & occupational hazards	• Restricting unattended public access • Supplying personnel with personal protective equipment (gloves, eye and noise protection, and respirators when necessary • Providing adequate safety measures and monitoring equipment • Providing adequate safety measures and monitoring equipment • Emphasizing safety education and training for system staff • Implementing health and safety standards	WWTP administration and operating staff	ditto
Inappropriate effluent management practices	• Pollution of effluent receiving water bodies	• Monitoring of effluent quality for surface water, groundwater, or marine discharge • Effluent discharge in accordance with MoE's ELV	MoE or MoEW	N/A
	• Contamination of crops and vegetables irrigated with effluent	• Monitoring the suitability of effluent for crop irrigation • Training farmers for the proper handling of effluent	MoE or MoA	N/A

Inappropriate screenings and grit management practices	• Soil and groundwater pollution at storage and disposal sites	• Proper washing, draining, and separating of screenings and grit • Hauling in closed-top trucks and disposal at an allocated municipal solid waste disposal site.	WWTP administration and operational staff	Operation and maintenance
Inappropriate sludge management practices	• Soil and groundwater pollution at sludge storage, disposal, or reuse sites	• Proper design and operation of sludge handling and treatment units • Provision of adequate storage areas and capacities on-site • Proper sludge transport by top-covered trucks • Monitoring of sludge quality prior to disposal or reuse • Training farmers for the proper handling and use of sludge at the agricultural sites	• Design engineers and operational staff • Design engineers • WWTP admin/ and operation staff • WWTP admin and operation staff • MoA or private companies	Operation and maintenance

7.3. MONITORING PLAN

Two monitoring activities have to be initiated for the proposed Wastewater Treatment Plants (WWTPs) to ensure the environmental soundness of the project. The first is *compliance monitoring*, and the second is *impact detection monitoring*. Compliance monitoring provides for the control of wastewater treatment operational activities, while impact detection monitoring relates to detecting the impact of the operation on the environment. Together, the objective is to improve the quality and availability of data on the effectiveness of operation, equipment, and design measures and eventually on the protection of the environment.

7.3.1. Compliance Monitoring

In this context, compliance to the regulations set by the Ministry of Environment to limit air, water, and soil pollution shall be observed. Compliance monitoring requirements include *process control testing*, *process performance testing*, and *occupational health monitoring*. Compliance monitoring shall be the responsibility of the corresponding treatment plant administration (municipality), thus monitoring activities shall be budgeted for accordingly.

For effective compliance monitoring, the following shall be assured:

- Trained staff (plant operator, laboratory staff, maintenance team, etc.) and defined responsibilities
- Adequate analytical facility(ies), equipment, and materials, if possible.
- Authorized Standard Operating Protocols (SOPs) for representative sampling, laboratory analysis, and data analysis.
- Maintenance and calibration of monitoring equipment.
- Provision of safe storage and retention of records.

In the proposed wastewater treatment facility, qualified plant operators and laboratory staff should carry out process control and performance testing. The technical staff that would run the plants should attend training programs to improve their qualifications and update their information. The contractors should be involved in knowledge transfer to operators and management through administering specialized technical workshops.

A comprehensive list of process control parameters is presented in Table 7.3 for all WWTPs. It is noteworthy to mention that every WWTP proprietor should cooperate with the technology provider for a better approach in process control. This course of action is needed since a precise and adapted process control strategy translates into a better process performance, and thus compliance. Accurate process control is even more essential at the start-up phase of the EAAS to ensure a subsequent uniform operational phase.

Table 7.3. Process Control Parameters for the EAAS System

Sampling Location	*Analytical Parameter*	*Sample*	
		Type [1]	*Frequency*[2]
Plant influent [3]	Flow	In situ	D
	pH	In situ	D
Mixed liquor	Dissolved oxygen	In situ	D
	pH	In situ	D
	Temperature	In situ	D
	Total Suspended Solids	C	1/W
	Volatile Suspended Solids	C	1/W
Return activated sludge line	Flow	In situ	D
	Total Suspended Solids	C	1/M
Waste activated sludge line	Flow	In situ	D
	Total Suspended Solids	C	1/M
Final clarifier effluent	Depth of blanket at mid tank	G	D
Post media filtration	Total Suspended Solids	C	1/W
Post GAC	Flow	Insitu	D
	Residual chlorine	G	D
Sludge holding tank contents (if applicable)	pH	G	D
	Temperature	G	D
	Dissolved oxygen	G	D
	Alkalinity	G	1/W
Settled sludge in holding tank (if applicable)	Volatile acids	G	1/W
	pH	G	D
Sludge supernatant	Biochemical Oxygen Demand $_5$	C	1/W

[1] G: grab sample; C: composite sample (usually 24-hr composite grab samples every 8 hours, or 24-hr automatic sampler)
[2] D: daily, 1/W: once per week, 1/M: once per month Frequency may be adjusted as needed.
[3] Metals and organic compounds are less often determined, usually until a problem arises.

As for process performance monitoring, the list of recommended parameters is exhaustive; however, abidance is highly recommended especially during the first months of plant operation. Once a preliminary database is built, less frequent analysis can be performed, especially for the relatively invariable parameters. Table 7.4 summarizes the recommended process performance parameters for an extended aeration activated sludge system. Note that sampling frequencies are reduced at later stages of the operational phase. The plant operators may adjust the schedule of sampling in accordance to the operational characteristics of the system, and previous monitoring experience; however, utmost responsibility should be taken for uninterrupted compliance. Table 7.5 presents the recommended process performance parameters suggested in a draft decision by the MoE.

The manufacturer's operation and maintenance (O&M) instructions on pumps, bearings, and motors should be followed. All equipment must be tested and calibrated as recommended by the equipment manufacturer. A routine O&M schedule should be developed and followed specifically for the EAAS system components, chlorine disinfection system, dual media filter, and GAC filter. It is critical that the EAAS be pilot tested prior to installation and operation to ensure that it will meet effluent discharge permit requirements for that particular site.

Table 7.4. Process Performance Parameters for the EAAS System

Sampling Location	*Analytical Parameter*	*Sample Type* [1]	*Sampling Frequency*[2]		
			Early Operational Phase	*Advanced Operational Phase*	*Minimum sampling*
Plant influent [3]	Biochemical Oxygen Demand $_5$	C	1/M	1/2M	1/3M
	Total Suspended Solids	C	1/M	1/2M	1/3M
	Total Nitrogen	G	M [4]	1/2M [4]	1/3M
	Ammonia	G	M [4]	1/2M [4]	1/3M
Final effluent	Biochemical Oxygen Demand $_5$	C	1/W	1/2W	M
	Total Suspended Solids	C	1/W	1/2W	M
	pH	In Situ	D	D	D
	Fecal coliforms	G	1/W	1/2W	M
	Total Nitrogen	G	1/2W [4]	M [4]	1/2M
	Ammonia	G	1/2W [4]	M [4]	1/2M
	Nitrates	G	1/2W [4]	M [4]	1/2M
	Nitrites	G	1/2W [4]	M [4]	1/2M
Sludge holding tank contents (if applicable)	Nitrates	G	1/W	M	1/2M
	Ammonia	G	1/W	M	1/2M
	Total solids	C	1/W	1/2W	M
	Volatile solids	C	1/W	1/2W	M
Settled sludge in holding tank (if applicable)	Nitrates	G	1/W	M	1/2M
	Ammonia	G	1/W	M	1/2M
	Total solids	C	1/W	1/2W	M
	Volatile solids	C	1/W	1/2W	M

[1] G: grab sample; C: composite sample (usually 24-hr composite grab samples every 8 hours, or 24-hr automatic sampler)
[2] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months, Frequency could be reduced if compliance violations are infrequent.
[3] Metals and organic compounds are less often determined, usually until a problem arises.
[4] Total nitrogen, ammonia, nitrates, and nitrites analyses can be excluded if influent concentrations for these parameters are within set standards, or if nitrogen removal is not within the capabilities of the employed wastewater treatment scheme.

Table 7.5. Process Performance Parameters Suggested in a Draft Decision Set by the MoE

Sampling Location	*Analytical Parameter*	*Sampling Frequency*
Plant Influent	Flow	Daily
	pH	Daily
Primary treatment Effluent	BOD_5	Daily
	pH	Daily
	Total Suspended Solids	Weekly
	Volatile Suspended Solids	Weekly
	Temperature	Daily
Secondary Treatment Effluent	BOD_5	Daily
	pH	Daily
	Total Suspended Solids	Once in 2Weeks (1/2 week)
	Volatile Suspended Solids	Once in 2Weeks (1/2 week)
	Temperature	Daily
	Total Nitrogen	Once in 2Weeks (1/2 week)
	Total Phosphorus	Once in 2Weeks (1/2 week)
Tertiary Treatment Effluent / final effluent.	BOD_5	Daily
	pH	Daily
	Total Suspended Solids	Once in 2Weeks (1/2 week)
	Volatile Suspended Solids	Once in 2Weeks (1/2 week)
	Temperature	Daily
	Total Nitrogen	Once in 2Weeks (1/2 week)
	Total Phosphorus	Once in 2Weeks (1/2 week)
	Residual Chlorine	Daily

It is noteworthy to mention that initial comprehensive characterization of the wastewater to be treated is necessary for proper plant design, operation, and future monitoring. The tender documents presented for the bidders include plant influent characterization. Moreover, though analytical monitoring is essential, frequent observations of the aeration tanks and clarifier characteristics, such as filter ponding, aeration patterns, turbulence, foaming, and effluent clarity play an important part in performance monitoring. The frequency of monitoring can be reduced if it is necessary after constant recorded compliant values are obtained over a period of 2-3 years of normal operation.

During plant start-up, when a thorough monitoring schedule is recommended, monitoring efforts can be limited to regular checks (weekly or bi-weekly, as needed) of effluent quality for the following parameters:

- pH and temperature
- BOD_5 and COD
- Suspended solids
- Total Nitrogen
- Total Phosphorus
- Ammonia-nitrogen
- Nitrate–nitrogen
- Phosphate
- Coliform bacteria

However, in case of any sudden change in the trend of any parameter, it is imperative to reapply the advanced operational phase frequency in order to depict the anomaly.

The quality of dried sludge should also be checked before its disposal or reuse as soil fertilizer. Typically, analysis of wastewater treatment plant sludge is performed on composite samples for the parameters set forth in Table 7.6. Since the sewage discharged into the plants is mainly of domestic origin, concentrations of toxic compounds such as PCBs and pesticides are expected to be negligible. Thus, analyzing the sludge for such compounds is not mandatory, especially that they incur relatively high analysis costs. Additionally, high levels of metals are not expected to be present. However, it is advisable to test the generated sludge for metal content and toxic organic compounds on a 6-month or annual basis. Moreover, bacterial and nutrient levels (NPK value) in the wastewater sludge should be determined regularly. It is important that contractors/suppliers of all eight proposed plants shall account for the presence of gas stations, lube oil service shops and auto-mechanics in their final plant design, even in the case of their absence and that is to account for future growth of concerned village. Good housekeeping and the installation of oil/water separators or grease traps would be requested for such facilities especially that cooking oil can be as well disposed into domestic sewage.

Table 7.6. Sludge quality monitoring parameters

Total Solids	Copper
pH	Lead
Total Nitrogen	Mercury
Ammonia-Nitrogen	Molybdenum
Nitrate-Nitrogen	Nickel
Phosphorus	Selenium
Potassium	Zinc
Arsenic	Polychlorinated Biphenyls
Cadmium	Pathogens

It is necessary to install in-line analytical meters and measuring devices, especially for regular daily measurements, to ensure sampling reproducibility. Automatic samplers may also be useful at specific locations. The on-site presences of analytical components facilitate process control and performance monitoring and subsequently ensure compliance.

7.3.2. Impact Detection Monitoring

As mentioned earlier, impact detection monitoring relates to detecting the impact of the operation on the environment. Such monitoring shall be the responsibility of the municipal authorities. An independent monitoring organization shall be set up and financed by the concerned municipalities, or monitoring activities will be contracted to a specialized private organization. Impact monitoring includes periodic sampling from downstream wells, springs, and surface waters, and analyzing samples by preset biological as well as chemical quality control tests. The tests performed over the various springs, wells and rivers in this study, prior to the implementation of the various treatment plants, should be used as a basis in order to assess the expected positive effects or impacts of wastewater management over the various receiving water bodies in the area subsequently over the environment.

An additional impact assessment should be performed for the El Fardis Spring, El Daya Spring (in Chouaia village), Nabaa el Qershe Spring (in the village of Mari), Ain Kaoukaba Spring, S1 and Rashaiya el Foukhar Springs (located in Rashaiya el Foukhar to the border of Kfar Hamam) and the Kfar Hamam Well. Samples should be taken every 6 months (preferably in low-flow and high-flow seasons). It is recommended to perform quarterly monitoring (every three months) of the following water bodies (such as the nearby intermittent rivers).

As for the plants of Kaoukaba Fardis and Mari, it is recommended to perform quarterly monitoring (every three months) of the Hasbani River at the following locations (Topographic Map Appendix B):

Location 1: In Kaoukaba village close to the potential location of the Kaoukaba Plant.

Location 2: Underneath the bridge, at the connection between the intermittent river in Chebaa Valley and the Hasbani River

Location 3: In the village of Mari close to the potential location of the Mari Plant. The following parameters should be monitored for both river and spring samples.

- Fecal Coliform
- Residual Chlorine
- BOD_5

7.4. COST OF MONITORING

As mentioned earlier, monitoring activities for all WWTPs are the reponsibility of the municipal authorities. In order to determine the budget to be allocated for the monitoring plan, the costs of tests suggested in accordance to the draft decision by the Ministry of Environment have been tabulated along with the sampling frequency. Table 7.7 presents sampling costs and the total cost for monitoring per month. Appendix I shows detailed costs on a monthly basis for process performance parameters in early, advanced and minimal sampling phases, as recommended earlier in the monitoring plan.

Table 7.7. Monitoring Cost for Process Performance Parameters

Sampling Location	*Analytical Parameter*	*Sampling frequency**	*Unit price (L.L.)*	*Total/month (L.L.)*
Plant influent	Flow	D		
	pH	D		0
Primary treatment Effluent	BOD_5	D	30,000.00	900,000.00
	pH	D		0
	Total Suspended Solids	W	22,500.00	90,000.00
	Volatile Suspended Solids	W	22,500.00	90,000.00
	Temperature	D		0
Secondary Treatment Effluent	BOD_5	D	30,000.00	900,000.00
	pH	D		0
	Total Suspended Solids	1/2W	22,500.00	45,000.00
	Volatile Suspended Solids	1/2W	22,500.00	45,000.00
	Temperature	D		0
	Total Nitrogen**	1/2W	181,000.00	362,000.00
	Total Phosphorus	1/2W	73,000.00	146,000.00
Tertiary Treatment Effluent / final effluent.	BOD_5	D	30,000.00	900,000.00
	pH	D		0
	Total Suspended Solids	1/2W	22,500.00	45,000.00
	Volatile Suspended Solids	1/2W	22,500.00	45,000.00
	Temperature	D		0
	Total Nitrogen	1/2W	181,000.00	362,000.00
	Total Phosphorus	1/2 W	73,000.00	146,000.00
	Residual Chlorine	D	22,500.00	675,000.00
		subtotal		4,751,000.00

* D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months

** Carbon, Hydrogen, Nitrogen and Sulfur are sampled together using Elemental Analyzer method

The unit cost for temperature as well as pH measurement is 8,000 L.L. This cost was not included in the above price list as it is highly recommended that each WWTP facility would acquire the necessary equipment for both pH and temperature daily sampling. The cost of good quality pH meters and thermometers revolve around 600,000 L.L. per unit.

Another suggestion is the establishement of a common laboratory for all Hasbaiya villages for sampling and analysis for the eight WWTPs and six OORTPs to be constructed. This laboratory would serve in developing databases, managing records and thus ensure better compliance in monitoring. More capital cost is required for laboratory equipment, and later for the permanent staff and expenses. However, this suggested on-site monitoring center laboratory would increase the overall effectiveness and ensure autonomy, and thus reduce the overall costs of monitoring in the long-run.

7.5. RECORD KEEPING AND REPORTING

Monitoring efforts would be in vain in the absence of an organized record keeping practice. It is the responsibility of the treatment plant administration, in this case the municipality, to ensure the development of a database that includes a systematic tabulation of process indicators, performed computations, maintenance schedules and logbook, and process control and performance monitoring outcomes. Such a historical database benefits both the plant operator and design engineers. The treatment plant should submit a periodic Discharge Monitoring Report (DMR) to the assigned regional authority, namely the Mohafaza and subsequently to the MoE. Such record keeping shall be requested and assured by the municipality of Kfar Hamam.

7.6. CONTINGENCY PLAN

The contingency plan in case of emergency was tackled in the design consideration of all plants in Hasbaiya by building a large equalization tank in order to balance the variations in the hydraulic loads of the plant that can eventually occur during a regular day or between winter and summer seasons.

Furthermore, all plant designs took into consideration a generous per capita consumption of water of 100 liters/day along with a peak population growth rate of 2%. In addition, the plant has extra blowers on stand-by to operate replacing any defective blower within the aeration tank. The standby blower also allow an increase in aeration time in

case of increased biological loads. In addition to stand-by blowers, the design also allows for a stand-by filter feed pump and power supply (generator of electricity).

All materials used in the construction of the plant that are in contact with the wastewater shall be corrosion resistant. Also, a 2mm HDPE protective seal shall be installed under all the tanks including the sludge drying beds to protect from any malfunctioning or accidental leakage. Valves in the filters shall not allow water bypassing the filters during the rinse and backwash cycles. Moreover, the plant will be equipped with an emergency stop button, an alarm, and a test button to secure its proper functioning.

According to the requirements, set in the tender document the awarded contractor will have to perform regular and frequent maintenance check ups of the plant since he will be responsible for the operation of the plant during the first year and eventually convey technical expertise to the appointed future plant operators. These preventive measures and design considerations will ensure a continuous and uninterrupted operation of the plant.

7.7. CAPACITY BUILDING

Considered as corner stone of the EMP, the contractor will provide one year training to all municipalities staff that will operate the eight plants. This allows the overall sustainability of the project and eventually the transfer of technical expertise to the future appointed plant operators.

7.8. INSTITUTIONAL ARRANGEMENTS

No matter how meticulously an environmental management scheme has been prepared, it will fail in the absence of predefined responsibilities and strong technical bodies. Compliance monitoring shall be the responsibility of the concerned treatment plant administration (municipality or a contracted operator) and thus its activities shall be budgeted for accordingly. However, in accordance with the requirements of the regulatory authority (MoE), the treatment plant should submit a periodic Discharge Monitoring Report (DMR) to the assigned enforcement authority (Mohafaza/MoIM). The assigned authority will be responsible for drawing conclusions based on the monitoring data, and deciding on specific actions to alleviate pollution impacts. The coordination with the South Lebanon Water and Wastewater Establishment is also important since they are responsible for wastewater monitoring in their new mandate.

On the other hand, impact detection monitoring shall be the responsibility of the municipal authorities. Ideally, an independent monitoring organization is set up and financed by the concerned municipality, or monitoring activities are contracted to a specialized private organization. Figure 7.1 is an illustration of such institutional arrangement.

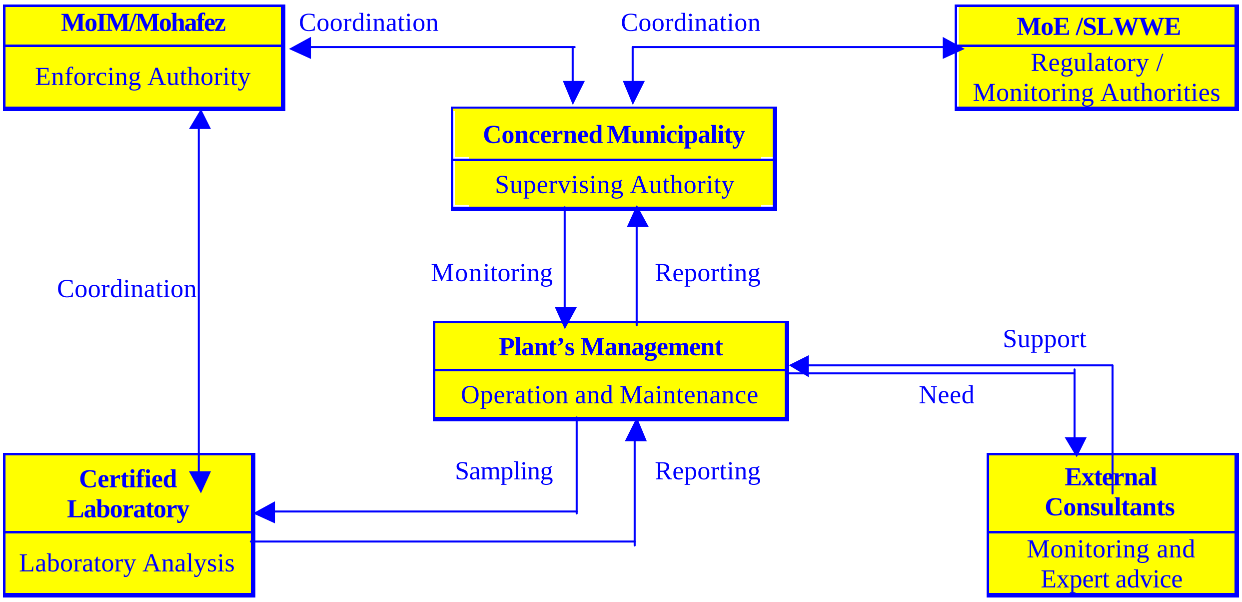


Figure 7.1. Proposed Institutional Setting

8. PUBLIC INVOLVEMENT AND PARTICIPATION

Public involvement started early in the process when it became apparent that the foremost issue being requested by the Chebaa, Chouaia, El Fardis, Hebbariye, Kaoukaba, Kfar Hamam, Mari and Rachaiya el Foukhar municipalities was a WWTP for each village. MCI meetings with municipality members kept them abreast of the project, since it was a publicly initiated and supported project, and public involvement was vital.

During this EIA study, the consultant met numerous times with the Mayors and heads of Municipalities of the villages of Hasbaiya. With the assistance of MCI representatives, the consultant presented the findings regarding many aspects concerning the site location, network distribution, springs assessments, most appropriate technologies and many other aspects required to finalize the study. Additional meetings were also set between ELARD and MCI to set the Specifications, Requirements and Standards requested for compliance of contractors in the bidding process

In the preliminary stages of the study, the municipalities were requested to fill out a questionnaire tailored towards obtaining additional relevant and specific information. The requested information related to the physical and biological environment, the socio-economic situation in the various municipalities, and general requirements pertinent to the EIA process. Appendix G includes a list of the names and contact information for key members of the municipalities of each village.

Also in conformity with EIA guidelines, a notice was posted for duration of at least 18 days at the concerned municipality informing the public about the EIA study that is being conducted and the proposed treatment plant, and soliciting comments. Remarks would be welcome and clarifications would be made for all interested parties for the 18 days during which the notice was publicized and an additional 7 days following its removal. A copy of the notice is included in Appendix H ***along with the EMP compliance form signed by the concerned municipality.***

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APPENDIX A
TECTONIC MAP OF LEBANON; GEOLOGICAL MAP OF STUDY AREA; CROSS SECTION

APPENDIX B
TOPOGRAPHIC MAP INDICATING SAMPLING LOCATION; LABORATORY ANALYTICAL RESULTS

APPENDIX C
ARCHITECTURAL DRAWINGS

APPENDIX D
CONFIRMATION OF LAND OWNERSHIP

APPENDIX E
SLUDGE AND EFFLUENT MANAGEMENT

INTRODUCTION

Sludge and effluent disposal by surface application is performed in an environmentally safe manner according to different restrictions and considerations. The US EPA formulated 40 CFR Part 503 to regulate the use or disposal of sludge in order to protect public health and the environment. In specific, subpart B of the part 503 rule prohibits the land application of sewage sludge that exceeds specified limits. Those standards should be followed as they represent the most comprehensive international standards developed according to risk analysis.

Effluent cannot be directly disposed to land unless it complies with the wastewater quality standards (guidelines for water re-use or disposal suggested by the EPA). Furthermore, sludge cannot be frequently disposed on the same soil. if land application is to be performed, sludge should be collected and stored, and then applied according to an application rate, which depends on the site characteristics, and on the sludge quality (level of pollutants) (according to sludge disposal guidelines suggested by the EPA).

The present appendix presents the restrictions preventing land application of the proposed effluent and provides the standards and considerations that should be achieved if land application was to be the sludge disposal method. The difference between sludge disposal and effluent disposal should be considered: effluent disposal is performed according to the wastewater quality standards, and sludge disposal according to sewage sludge standards, and with different application rates.

LAND TREATMENT

Land treatment is characterized as spreading the waste (effluent or sludge) on the soil surface or incorporating it into the upper few centimeters by mechanical manipulation. The method of application depends on the physical, chemical, and toxic nature of the waste and the rate of biodegradation desired. Sprinkler, flood, or drip-type application could be used to apply liquids. Because of their fluid nature, they penetrate the soil and thus, do not require mechanical soil incorporation unless they carry significant amounts of solids. The single purpose of land treatment as opposed to land utilization is final disposal of the waste with little or no demand of the waste to function as a resource.

Destruction of the soil for vegetative growth is not a part of land treatment. Land treatment must provide sound, environmentally safe disposal of waste residuals through biological, chemical, and physical interactions occurring in soils. The inorganic metal components are expected to biodegrade through the activity of the indigenous soil microorganisms. The inorganic metal components are expected to attenuate (or immobilize) primarily through physical-chemical interactions with the soil (Fuller, 1988).

Table E.1 and Table E.2, present the general requirement for sludge disposal and effluent disposal on forestlands. Detailed analysis and considerations will be presented in the report.

Table E.1. Summary of typical characteristics of sewage sludge land application practices (EPA, 1992)

Characteristics	***Forest land application***
Application rates	Varies: normal range in dry weight of 10 to 220 t/ha/yr. (4 to 100 T/ac/yr.) depending on soil, tree species, sludge quality, etc. typical rate is about 18 t/ha/yr. (8 T/ac/yr.)
Application frequency	Usually applied annually or at 3 to 5-year intervals
Useful life of application site(s)	Usually limited by accumulated metal loading in total sewage sludge applied. With most sewage sludge a useful life of 20 to 55 years or more is typical.
Sewage sludge scheduling	Scheduling affected by climate and maturity of trees.
Application constraints	Limited by part 503 agronomic rate management practice requirement.

Table E.2. EPA guidelines for water reuse in wildlife habitats (EPA, 1992)

Factor	***Requirement***
Treatment	Secondary and disinfection
Effluent quality	BOD< 30 mg/l SS<30 mg/l Fecal coliform <200 fecalcoli/100ml (The number of fecal coliform organisms should not exceed 800/100 ml in any sample)
Effluent monitoring	BOD – weekly SS - daily Coliform - daily Cl_2 residual – continuous
Other considerations	Ground water monitoring Temperature pH

SLUDGE DISPOSAL

EPA requirements for sludge disposal

EPA developed the federal part 503 rule (40 CFR Part 503) that establishes requirements for land application of sewage sludge. Subpart B of the part 503 rule prohibits the land application of sludge that exceeds pollutant limits termed “ceiling concentration limits” for 10 metals and places restrictions on sludge exceeding additional pollutant limits which are the cumulative pollutant loading rate limits and the annual pollutant loading rate limits. The requirements for land disposal are presented in Table E.3, and further explained in the following sections.

Table E.3. Part 503 land application pollutant limits for sewage sludge (EPA, 1995)

Pollutant	*Ceiling concentration limits (mg/kg)*	*Cumulative pollutant loading rate limits (kg/ha)*	*Annual pollutant loading rate limits (kg/ha per 365-day period)*
Arsenic	75	41	2.0
Cadmium	85	39	1.9
Chromium	3,000	3,000	150
Copper	4,300	1,500	75
Lead	840	300	15
Mercury	57	17	0.85
Molybdenum	75	--	--
Nickel	420	420	21
Selenium	100	100	5.0
Zinc	7,500	2,800	140

Ceiling concentration limits (EPA, 1995)

All sewage sludge applied to land must meet part 503 ceiling concentration limits for 10 regulated pollutants. Ceiling concentration limits are the maximum allowable concentration of a pollutant in sewage sludge to be land applied. If the ceiling concentration of any one of the regulated pollutants is exceeded, the sewage sludge cannot be land applied.

Cumulative pollutant loading rates (CPLRs)

A CPLR is the maximum amount of pollutant that can be applied to a site by all sludge applications. When the CPLR is reached at the application site for any one of the 10 metals no additional sludge can be applied.

Annual pollutant loading rates (APLRs)

APLR is the maximum amount of a pollutant that can be applied to a site within a 12-month period from sludge. The pollutant concentration in sludge multiplied by the "whole annual sludge application rate" must not cause any of the APLR to be exceeded.

Pathogen requirements (EPA, 1995)

The density of fecal coliform in the sewage sludge must be less than 1,000 most probable number (MPN) per gram total solids (dry-weight basis) or the density of Salmonella sp. bacteria in the sewage sludge must be less than 3 MPN per 4 grams of total solids (dry-weight basis).

Vector Attraction Reduction Requirements (EPA, 1995)

Subpart D in Part 503 establishes 10 options for demonstrating that sludge that is land applied meets requirements for vector attraction reduction (Table E.4). The options can be divided into two general approaches for controlling the spread of disease via vectors (such as insects, rodents, and birds):

- Reducing the attractiveness of the sewage sludge to vectors (Options 1 to 8).
- Preventing vectors from coming into contact with the sewage sludge (Options 9 and 10).

Compliance with the vector attraction reduction requirements using one of the options described below must be demonstrated separately from compliance with requirements for reducing pathogens in sewage sludge. Thus, demonstration of adequate vector attraction reduction does not demonstrate achievement of adequate pathogen reduction. Part 503 vector attraction reduction requirements are summarized below:

Table E.4. Summary of Vector Attraction Reduction Requirements for Land Application of Sewage Sludge Under Part 503 (U.S. EPA 1992b)

Requirement	What Is Required?	Most Appropriate For:
Option 1: Reduction in volatile solid content 503.33(b)(1)	At least 38% reduction in volatile solids during sewage sludge treatment	Sewage sludge processed by: · Anaerobic biological treatment · Aerobic biological treatment · Chemical oxidation
Option 2: Additional digestion of anaerobically digested sewage sludge 503.33(b)(2)	Less than 17% additional volatile solids loss during bench-scale anaerobic batch digestion of the sewage sludge for 40 additional days at 30°C to 37°C (86°F to 99°F)	Only for anaerobically digested sewage sludge
Option 3: additional digestion of aerobically digested sewage sludge 503.33(b)(3)	Less than 15% additional volatile solids reduction during bench-scale aerobic batch digestion for 30 additional days at 20°C (68°F)	Only for aerobically digested sewage sludge with 2% or less solids—e.g., sewage sludge treated in extended aeration plants
Option 4: specific oxygen uptake rate for aerobically digested sewage sludge treated in an aerobic process 503.33(b)(4)	SOUR at 20°C (68°F) is <1.5 mg oxygen/hr/g total sewage sludge solids	Sewage sludge from aerobic processes (should not be used for composted sludge). Also for sewage sludge that has been deprived of oxygen for longer than 1–2 hours.
Option 5: aerobic processes at greater than 40°C 503.33(b)(5)	Aerobic treatment of the sewage sludge for at least 14 days at over 40°C (104°F) with an average temperature of over 45°C (113°F)	Composted sewage sludge (Options 3 and 4 are likely to be easier to meet for sewage sludge from other aerobic processes)
Option 6: addition to alkali 503.33(b)(6)	Addition of sufficient alkali to raise the pH to at least 12 at 25°C (77°F) and maintain a pH =12 for 2 hours and a pH <11.5 for 22 more hours	Alkali-treated sewage sludge (alkalies include lime, fly ash, kiln dust, and wood ash)
Option 7: moisture reduction of sewage sludge containing no un-stabilized solids 503.33(b)(7)	Percent solids <75% prior to mixing with other materials	Sewage sludge treated by an aerobic or anaerobic process (i.e., sewage sludge that do not contain un-stabilized solids generated in primary wastewater treatment)
Option 8: moisture reduction of sewage sludge containing un-stabilized solids 503.33(b)(8)	Percent solids <90% prior to mixing with other materials	Sewage sludge that contain un-stabilized solids generated in primary wastewater treatment (e.g., any heat-dried sewage sludge)
Option 9: injection of sewage sludge 503.33(b)(9)	Sewage sludge is injected into soil within 8 hours after the pathogen reduction process so that no significant amount of sewage sludge is present on the land surface 1 hour after injection,	Liquid sewage sludge applied to the land.
Option 10: incorporation of sewage sludge into the soil 503.33(b)(10)	Sewage sludge must be applied to the land surface within 8 hours after the pathogen reduction process, and must be incorporated within 6 hours after application.	Sewage sludge applied to the land.

Physical characteristics of potential land application sites (EPA, 1995)

The physical characteristics of concern are:

- Topography (Table E.5)
- Soil permeability, infiltration, and drainage patterns
- Depth to ground water
- Proximity to surface water

Potentially unsuitable areas for sewage sludge application:

- Areas bordered by ponds, lakes, rivers, and streams without appropriate buffer areas.
- Wetlands and marshes
- Steep areas with sharp relief.
- Undesirable geology (karst, fractured bedrock) (if not covered by a sufficiently thick soil column).
- Undesirable soil conditions (rocky, shallow).
- Areas of historical or archeological significance.
- Other environmentally sensitive areas such as floodplains or intermittent streams, ponds, etc., as specified in the Part 503 regulation.

Table E.5. Recommended Slope Limitations for Land Application of Sludge

Slope	Comment
0-3%	Ideal; no concern for runoff or erosion of liquid or dewatered sludge.
3-6%	Acceptable for surface application of liquid or dewatered sludge; slight risk of erosion.
6-12%	Injection of liquid sludge required in most cases, except in closed drainage basin and/or areas with extensive runoff control. Surface application of dewatered sludge is usually acceptable.
12-15%	No liquid sludge application without effective runoff control; surface application of dewatered sludge is acceptable, but immediate incorporation is recommended.
Over 15%	Slopes greater than 15% are only suitable for sites with good permeability (e.g., forests), where the steep slope length is short (e.g., mine sites with a buffer zone downslope), and/or the steep slope is a minor part of the total application area.

Soil Permeability and Infiltration

Permeability (a property determined by soil pore space, size, shape, and distribution) refers to the ease with which water and air are transmitted through soil. Fine-textured soils generally possess slow or very slow permeability, while the permeability of coarse-textured soils ranges from moderately rapid to very rapid. A medium textured soil, such as a loam, tends to have moderate to slow permeability.

Soil Drainage

Soils classified as (1) very poorly drained, (2) poorly drained, or (3) somewhat poorly drained may be suitable for sewage sludge application if runoff control is provided. Soils classified as (1) moderately well drained, (2) well drained, or (3) somewhat excessively drained are generally suitable for sewage sludge application. Typically, a well-drained soil is at least moderately permeable.

Surface Hydrology, Including Floodplains and Wetlands

The number, size and nature of surface water bodies on or near a potential sludge land application site are significant factors in site selection due to potential contamination from site runoff. Areas subject to high runoff have severe limitations for sludge application.

Ground Water

For preliminary screening of potential sites, it is recommended that the following ground water information for the land application area be considered:

- Depth to ground water (including historical highs and lows).
- An estimate of ground water flow patterns.

The greater the depth to the water table, the more desirable a site is for sludge application. Sludge should not be placed where there is potential for direct contact with the ground-water table. The actual thickness of unconsolidated material above a permanent water table constitutes the effective soil depth. The desired soil depth may vary according to sludge characteristics, soil texture, soil pH, method of sludge application, and sludge application rate. Recommended Depth to Ground Water:

- Drinking Water Aquifer: 2 m
- Excluded Aquifer (not used as potable water supplies): 0.7 m

The type and condition of consolidated material above the water table is also of major importance for sites where high application rates of sewage sludge are desirable. Fractured rock may allow leachate to move rapidly. Unfractured bedrock at shallow depths will restrict water movement, with the potential for ground water mounding, subsurface lateral flow, or poor drainage. Limestone bedrock is of particular concern where sinkholes may exist. Sinkholes, like fractured rock, can accelerate the movement of leachate to ground water. Thus, potential sites with potable ground water in areas underlain by fractured bedrock, by unfractured rock at shallow depths, or with limestone sinkholes should be avoided.

Table E.6. Soil Limitations for Sewage Sludge Application to Agricultural Land at Nitrogen Fertilizer Rates

Soil features affecting use	Degree of soil limitation		
	Slight	Moderate	Severe
Slope[a]	Less than 6%	6 to 12%	More than 12%
Depth to seasonal water table	More than 1.2 m	0.6 to 1.2 m	Less than 1 m
Flooding and ponding	None	None	Occasional to frequent [b]
Depth to bedrock	More than 1.2 m	0.6 to 1.2 m	Less than 0.61 m
Permeability of the most restricting layer above a 1-m depth	0.24 to 0.8 cm/hr	0.8 to 2.4 cm/hr 0.08 to 0.24 cm/hr	Less than 0.08 cm/hr More than 2.4 cm/hr
Available water capacity	More than 2.4 cm	1.2 to 2.4 cm	Less than 1.2 cm

[a] Slope is an important factor in determining the runoff that is likely to occur. Most soils on 0 to 6% slopes will have slow to very slow runoff; soils on 6 to 12% slopes generally have medium runoff; and soils on steeper slopes generally have rapid to very rapid runoff.
b Land application may be difficult under extreme flooding or ponding conditions.
Metric conversions: 1 ft = 0.3048 m, 1 in = 2.54 cm.

Climate

Analysis of climatological data is an important consideration for the preliminary planning phase. Rainfall, temperature, evapotranspiration, and wind may be important climatic factors affecting land application of sludge, selection of land application practices, and site management. Table E.7 highlights the potential impacts of some climatic regions on the land application of sludge.

Table E.7. Potential Impacts of Climatic Regions on Land Application of Sewage Sludge

Impact	Warm/Arid	Warm/Humid	Cold/Humid
Operation Time	Year-round	Seasonal	Seasonal
Salt Buildup Potential	High	Low	Moderate
Leaching Potential	Low	High	Moderate
Runoff Potential	Low	High	High

Selection of land application practice (EPA, 1995)

Table E.8 presents an example of a ranking system for forest sites, based on consideration of topography, soils and geology, vegetation, water re-sources, climate, transportation, and forest access. Several other considerations should be integrated into the decision-making process, including:

- Compatibility of sewage sludge quantity and quality with the specific land application practice selected.
- Public acceptance of both the practice(s) and site(s) selected.
- Anticipated design life, based on assumed application rate, land availability (capacity), projected heavy metal loading rates (if Part 503 cumulative pollutant loading rates are being met), and soil properties.

Table E.8. Relative Ranking for Forest Sites for Sewage Sludge Application

Factor	***Relative Rank***
Topography	
Slope	
Less than 10%	High
10-20%	Acceptable
20-30%	Low
Over 30%	Low
Site continuity (somewhat subjective)	
No draws, streams, etc., to buffer	High
1 or 2 requiring buffers	Acceptable
Numerous discontinuities	Low
Forest System	
Percent of forest system in place	Low-High
Erosion hazard	
Little (good soils, little slope)	High
Great	Low-Acceptable
Soil and Geology	
Soil type	
Sandy gravel (outwash, Soil Class I)	High
Sandy (alluvial, Soil Class II)	High
Well graded loam (ablation till, Soil Class IV)	Acceptable
Silty (residual, Soil Class V)	Acceptable
Clayey (lacustrine, Soil Class IV)	Low
Organic (bogs)	Low
Depth of soil	
Deeper than 10 ft	High
3-10 ft	High
1-3 ft	Acceptable
Less than 1 ft	Low
Geology (subjective, dependent upon aquifer)	
Sedimentary bedrock	Acceptable-High
Andesitic basalt	Acceptable-High
Basal tills	Low-Acceptable
Lacustrine	Low
Vegetation (sensitive-rare)	Low-high

Soil sampling and analysis to determine agronomic rates (EPA, 1995)

Designing the agronomic rate for land application of sewage sludge is one of the key elements in the Part 503 rule for ensuring that land application does not degrade ground water quality through nitrate contamination. The Part 503 rule defines agronomic rate as: the whole sludge application rate (dry weight basis) designed: (1) to provide the amount of nitrogen needed by the vegetation on the land and (2) to minimize the amount of nitrogen in the sludge that leach beyond the root zone of the vegetation grown on the land to the ground water (40 CFR 503.11(b).

Designing the agronomic rate for a particular area requires knowledge of (1) soil fertility, especially available N and P; and (2) characteristics of the sludge, especially amount and forms of N (organic N, NH_4, and NO_3). The complex interactions between these factors and climatic variability (which affects soil-moisture related N transformations) make precise prediction of crop N requirements difficult.

Major constituents that may need to be tested in soils include:

- NO_3-N as an indicator of plant-available N in the soil. Where applicable, these tests should be made for calculating initial sludge application rates, and can possibly be used in subsequent years.

- C/N ratio, which provides an indication of the potential for immobilization of N in sludge as a result of decomposition of plant residues in the soil and at the soil surface. This is especially relevant for forestland application sites as well as for agricultural purposes.

Determining sewage sludge application rates for forest sites (EPA, 1995)

Sewage sludge application rates at forest sites usually are based on tree N requirements.

Nitrogen dynamics of forest systems are somewhat complex because of recycling of nutrients in decaying litter, twigs and branches, and the immobilization of the NH_4^+ contained in sludge as a result of decomposition of these materials.

Concentrations of trace elements (metals) in sludge may limit the cumulative amount of sewage sludge that can be placed on a particular area.

<u>Nitrogen applications cannot exceed the ability of the forest plants to utilize the N applied, with appropriate adjustments for losses.</u>

<u>Cumulative metal loading limits cannot exceed the cumulative pollutant loading rates (CPLRs) in the Part 503 rule.</u>

Nitrogen Uptake and Dynamics in Forests

In general, uptake and storage of nutrients by forests can be large if the system is correctly managed and species respond to sludge. The trees and understory utilize the available N from sludge, resulting in an increase in growth. There is a significant difference between tree species in their uptake of available N. In addition, there is a large difference between the N uptake by seedlings, vigorously growing trees, and mature trees. Finally, the amount of vegetative understory on the forest floor will affect the uptake of N; dense understory vegetation markedly increases N uptake.

Calculation of sludge application rates requires considerations of nitrogen transformations in addition to N mineralization and ammonia volatilization from the sewage sludge: (1) denitrification, (2) uptake by under-story, and (3) soil immobilization for enhancement of forest soil organic-N (ON) pools.

Nitrogen Leaching

Typically, N is the limiting constituent for land applications of sludge because when excess N is applied, it often results in nitrate leaching. The N available from sludge addition can be microbially transformed into NO3 - through a process known as nitrification. Because NO3 - is negatively charged, it easily leaches to the ground water with percolating rainfall.

Equipment for sewage sludge application at forest sites (EPA, 1995)

There are four general types of methods for applying sewage sludge to forests: (1) direct spreading; (2) spray irrigation with either a set system or a traveling gun; (3) spray application by an application vehicle with spray cannon; and (4) application by a manure-type spreader.

The main criterion used in choosing a system is the liquid content of the sewage sludge. Methods 1, 2, and 3 are effective for liquid sewage sludge (2% to 8% solids); Methods 1 and 2 can be used for semi-solid sewage sludge (8% to 18% solids); and only Method 4 is acceptable for solid sewage sludge (20% to 40% solids).

Scheduling (EPA, 1995)

Sludge applications to forest sites can be made either annually or once every several years. Annual applications are designed to provide N only for the annual uptake requirements of the trees, considering volatilization and denitrification losses and mineralization from current and prior years. An application one-year followed by a number of years when no applications are made utilizes soil storage (immobilization) of nitrogen to temporarily tie up excess nitrogen that will become available in later years.

In a multiple-year (e.g., every 3 to 5 years) application system, the forest floor, vegetation, and soil have a prolonged period to return to normal conditions, and the public can use the site for recreation in the non-applied years. Application rates, however, are not simply an annual rate multiplied by the number of years before reapplication, but rather need to be calculated so that no NO_3 - leaching occurs.

Scheduling sludge application also requires a consideration of climatic conditions and the age of the forest. High rainfall periods and/or freezing conditions can limit sewage sludge applications in almost all situations. The Part 503 regulation prohibits bulk sewage sludge from being applied to forestland that is flooded, frozen, or snow-covered so that the sewage sludge enters wetlands or other surface waters.

EFFLUENT DISPOSAL

Criteria determining effluent disposal (Fuller, 1988)

Effluent acceptable for disposal should meet certain criteria of quality. Superimposed on these are loading rates. The effluent should first meet the following requirements before the loading rate is determined:

- Capability of biodegradation of solids or soluble components
- No long-term toxicity to plants or microorganisms
- Each migration at practical rates of application to the ground water
- No adverse influence on the natural physical and chemical properties of the soil at reasonable rates of application
- No long-term limitation of land productivity

Further criteria and explanations will be provided in the following section.

The criteria determining loading rates are:

1. Effluent quality: Organic matter, BOD, COD, total organic carbon, TOC, heavy metals, total dissolved solids (TDS), suspended solids (SS), nitrogen, phosphorus, sodium absorption ratio (SAR), boron, bacteriological composition, organic chemicals, organic solvents.
2. Soil quality: Texture, structure, permeability, infiltration, presence of confining soil barriers, depth to water table, drainage

3. Climate: Rainfall amount and intensity factor, temperature, wind velocity and direction, evapotranspiration.

4. Topography: Slope, soil and water erosion potential, flood hazard, topography of watershed

5. Geologic formation: Depth to bedrock, limestone

6. Groundwater: depth to ground water, direction, and rate of flow, perched water tables, and location, depth, and quality of wells.

EPA effluent re-use criteria

The effluent should not alter the natural ecosystem present in the site, meaning that it should not lead to plant toxicity or underground water contamination. Effluents from tanneries are not usually disposed in forestlands, and this application is currently examined and studied. Until further advances and clarifications, the effluent should have the quality of reclaimed water for irrigation (which is developed to protect plant and human health) if it is to be disposed in forests. The following criteria and requirements should be achieved (Table E.9 and Table E.10).

Reclaimed water quality

The constituents in reclaimed water of concern are salinity, sodium, trace elements, excessive chlorine residual, and nutrients.

- Salinity: Salt accumulation can be especially detrimental during germination and when plants are young even at relatively low concentrations. Salinity may be reported as TDS. (TDS mg/l * 0.00156 = EC mmhos/cm). Salinity depends on the plant salt tolerance, and on the soil drainage and leaching characteristics (soils should be properly drained and adequately leached (leaching requirements) to prevent salt buildup). The extent of salt accumulation in the soil depends on the salt concentration in the water and the rate at which it is removed by leaching.

- Sodium: the potential influence sodium may have on soil properties is indicated by the sodium-adsorption-ratio (SAR = NA/{v [(Ca + Mg)/2]}). Sodium salts influence the exchangeable cation composition of the soil, which lowers the permeability, which impairs the infiltration of water into the soil.

- Trace elements of greatest concern at elevated levels are Cd, Co, Mb, Ni, and Zn.

- Chlorine residual: free chlorine residual at concentrations less than 1mg/l usually poses no problems to plants. However, some sensitive plants may be damaged at levels as low as 0.05 mg/l. some woody plants may accumulate chlorine in the tissue to toxic levels. Excessive chlorine has similar leaf-burning effect as sodium and chloride when sprayed directly on foliage. Chlorine at concentrations greater than 5 mg/l causes severe damage to most plants.

Table E.9. Recommended limits for constituents in reclaimed water for irrigation of plants (EPA, 1992)

Constituent	***Long-term use (mg/l)***	***Remark***
Aluminum	5.0	Can cause non-productivity in acid soils, soils with pH 5.5-8 will precipitate the ion and eliminate toxicity
Arsenic	0.1	Toxicity to plants varies widely ranging from 12 mg/l to < 0.05 mg/l
Beryllium	0.1	Toxicity to plants varies widely ranging from 5 mg/l to < 0.5 mg/l
Boron	0.75	Toxicity to many sensitive plants at 1 mg/l, most grasses relatively tolerant at 2.0 to 10 mg/l
Cadmium	0.01	Toxic to some plants at levels as low as 0.1 mg/l
Chromium	0.1	Lack of knowledge on toxicity to plants
Cobalt	0.05	Tends to be inactivated by neutral and alkaline soils
Copper	0.2	Toxic to a number of plants at 0.1 to 1.0 mg/l
Fluoride	1.0	Inactivated by neutral and alkaline soils
Iron	5.0	Contributes to soil acidification and loss of essential P and Molybdenum.
Lead	5.0	Can inhibit plant cell growth at high concentrations
Lithium	2.5	Mobile in soil, toxic to some plants at low doses (0.075mg/l)
Manganese	0.2	Toxic to some plants at a few tenths to a few mg/l in acid soils
Molybdenum	0.01	
Nickel	0.2	Toxic to a number of plants at 0.5 to 1.0 mg/l; reduced toxicity at neutral or alkaline pH
Selenium	0.02	Toxic to plants at low concentrations
Vanadium	0.1	Toxic to many plants
Zinc	2.0	Reduced toxicity at increased pH (6 or above) and in fine textured soils
Other parameter		
Constituent	Recommended limit	Remarks
pH	6.0	Indirect effects on plant growth
TDS	500-2,000 mg/l	Above 2,000 mg/l can be regularly used only if all plants are tolerant and soils are permeable
Free chlorine residual	< 1 mg/l	

Table E.10. EPA suggested guidelines for water reuse in wildlife habitats

Factor	Requirement
Treatment	Secondary and disinfection
Effluent quality	BOD< 30 mg/l, SS=30 mg/l Fecal coliform =200 fecalcoli/100ml (The number of fecal coliform organisms should not exceed 800/100 ml in any sample)
Effluent monitoring	BOD – weekly, SS – daily, Coliform – daily, Cl_2 residual – continuous
Other considerations	Ground water monitoring, Temperature, pH

APPENDIX F
WASTEWATER TREATMENT AND USE IN AGRICULTURE - FAO IRRIGATION AND DRAINAGE PAPER 47. (SECTION 5)

Irrigation with wastewater

Conditions for successful irrigation

Irrigation may be defined as the application of water to soil for the purpose of supplying the moisture essential for plant growth. Irrigation plays a vital role in increasing crop yields and stabilizing production. In arid and semi-arid regions, irrigation is essential for economically viable agriculture, while in semi-humid and humid areas, it is often required on a supplementary basis.

At the farm level, the following basic conditions should be met to make irrigated farming a success:

- The required **amount** of water should be applied;
- The water should be of acceptable **quality;**
- Water application should be properly **scheduled;**
- Appropriate irrigation **methods** should be used;
- Salt accumulation in the root zone should be prevented by means of **leaching;**
- The rise of water table should be controlled by means of appropriate **drainage;**
- Plant **nutrients** should be managed in an optimal way.

The above requirements are equally applicable when the source of irrigation water is treated wastewater. Nutrients in municipal wastewater and treated effluents are a particular advantage of these sources over conventional irrigation water sources and supplemental fertilizers are sometimes not necessary. However, additional environmental and health requirements must be taken into account when treated wastewater is the source of irrigation water.

Amount of water to be applied

It is well known that more than 99 percent of the water absorbed by plants is lost by transpiration and evaporation from the plant surface. Thus, for all practical purposes, the water requirement of crops is equal to the evapotranspiration requirement; ETc. Crop evapotranspiration is mainly determined by climatic factors and hence can be estimated with reasonable accuracy using meteorological data. An extensive review of this subject and guidelines for estimating ETc, prepared by Doorenbos and Pruitt, are given in Irrigation and Drainage Paper 24 (FAO 1977). A computer program, called CROPWAT, is available in FAO to determine the water requirements of crops from climatic data. Table F-1presents the water requirements of some selected crops, reported by Doorenbos and Kassam (FAO 1979). It should be kept in mind that the actual amount of irrigation water to be applied will have to be adjusted for effective rainfall, leaching requirement, application losses, and other factors.

Quality of water to be applied

The guidelines presented are indicative in nature and will have to be adjusted depending on the local climate, soil conditions, and other factors. In addition, farm practices, such as the type of crop to be grown, irrigation method, and agronomic practices, will determine largely the quality suitability of irrigation water. Some of the important farm practices aimed at optimizing crop production when treated sewage effluent is used as irrigation water will be discussed in this chapter.

Table F 1: WATER REQUIREMENTS, SENSITIVITY TO WATER SUPPLY AND WATER UTILIZATION EFFICIENCY OF SOME SELECTED CROPS

Crop	Water requirements (mm/growing period)	Sensitivity to water supply (ky)	Water utilization efficiency for harvested yield, Ey, kg/m^3 (% moisture)
Alfalfa	800-1600	low to medium-high (0.7-1.1)	1.5-2.0 hay (10-15%)
Banana	1200-2200	high (1.2-1.35)	plant crop: 2.5-4 ratoon: 3.5-6 fruit (70%)
Bean	300-500	medium-high (1.15)	lush: 1.5-2.0 (80-90%) dry: 0.3-0.6 (10%)
Cabbage	380-500	medium-low (0.95)	12-20 head (90-95%)
Citrus	900-1200	low to medium-high (0.8-1.1)	2-5 fruit (85%, lime: 70%)
Cotton	700-1300	medium-low (0.85)	0.4-0.6 seed cotton (10%)
Groundnut	500-700	low (0.7)	0.6-0.8 unshelled dry nut (15%)
Maize	500-800	high (1.25)	0.8-1.6 grain (10-13%)
Potato	500-700	medium-high (1.1)	4-7 fresh tuber (70-75%)
Rice	350-700	high	0.7-1.1

			paddy (15-20%)
Safflower	600-1200	low (0.8)	0.2-0.5 seed (8-10%)
Sorghum	450-650	medium-low (0.9)	0.6-1.0 grain (12-15%)
Wheat	450-650	medium high (spring: 1.15; winter: 1.0)	0.8-1.0 grain (12-15%)

Source: FAO(1979)

Scheduling of Irrigation

To obtain maximum yields, water should be applied to crops before the soil moisture potential reaches a level at which the evapotranspiration rate is likely to be reduced below its potential. The relationship of actual and maximum yields to actual and potential evapotranspiration is illustrated in the following equation:

$$\left(1-\frac{Y_a}{Y_m}\right) = ky\left(1-\frac{ET_a}{ET_m}\right)$$

Where:

Y_a = actual harvested yield
Y_m = maximum harvested yield
ky = yield response factor
ET_a = actual evapotranspiration
ET_m = maximum evapotranspiration

Several methods are available to determine optimum irrigation scheduling. The factors that determine irrigation scheduling are: available water holding capacity of the soils, depth of root zone, evapotranspiration rate, and amount of water to be applied per irrigation, irrigation method and drainage conditions.

Irrigation methods

Many different methods are used by farmers to irrigate crops. They range from watering individual plants from a can of water to highly automated irrigation by a centre pivot system. However, from the point of wetting the soil, these methods can be grouped under five headings, namely:

i. **Flood irrigation -** water is applied over the entire field to infiltrate into the soil (e.g. wild flooding, contour flooding, borders, basins, etc.).

ii. **Furrow irrigation -** water is applied between ridges (e.g. level and graded furrows, contour furrows, corrugations, etc.). Water reaches the ridge, where the plant roots are concentrated, by capillary action.

iii. **Sprinkler irrigation -** water is applied in the form of a spray and reaches the soil very much like rain (e.g. portable and solid set sprinklers, travelling sprinklers, spray guns, centre-pivot systems, etc.). The rate of application is adjusted so that it does not create ponding of water on the surface.

iv. **Sub-irrigation -** water is applied beneath the root zone in such a manner that it wets the root zone by capillary rise (e.g. subsurface irrigation canals, buried pipes, etc.). Deep surface canals or buried pipes are used for this purpose.

v. **Localized irrigation -** water is applied around each plant or a group of plants so as to wet locally and the root zone only (e.g. drip irrigation, bubblers, micro-sprinklers, etc.). The application rate is adjusted to meet evapotranspiration needs so that percolation losses are minimized.

Table F 2 presents some basic features of selected irrigation systems as reported by Doneen and Westcot (FAO 1988).

Table F 2: BASIC FEATURES OF SOME SELECTED IRRIGATION SYSTEMS

Irrigation method	Topography	Crops	Remarks
Widely spaced borders	Land slopes capable of being graded to less than 1 % slope and preferably 0.2%	Alfalfa and other deep rooted close-growing crops and orchards	The most desirable surface method for irrigating close-growing crops where topographical conditions are favourable. Even grade in the direction of irrigation is required on flat land and is desirable but not essential on slopes of more than 0.5%. Grade changes should be slight and reverse grades must be avoided. Cross slops is permissible when confined to differences in elevation between border strips of 6-9 cm. Water application efficiency 45-60%.
Graded contour furrows	Variable land slopes of 2-25 % but preferable less	Row crops and fruit	Especially adapted to row crops on steep land, though hazardous due to possible erosion from heavy rainfall. Unsuitable for rodent-infested fields or soils that crack excessively. Actual grade in the direction of irrigation 0.5-1.5%. No grading required beyond filling gullies and removal of abrupt ridges. Water application efficiency 50-65%.
Rectangular checks (levees)	Land slopes capable of being graded so single or multiple tree basins will be levelled within 6 cm	Orchard	Especially adapted to soils that have either a relatively high or low water intake rate. May require considerable grading. Water application efficiency 40-60%.
Sub-irrigation	Smooth-flat	Shallow rooted crops such as potatoes or grass	Requires a water table, very permeable subsoil conditions and precise levelling. Very few areas adapted to this method. Water application efficiency 50-70%.
Sprinkler	Undulating 1->35% slope	All crops	High operation and maintenance costs. Good for rough or very sandy lands in areas of high production and good markets. Good method where power costs are low. May be the only practical method in areas of steep or rough topography. Good for high rainfall areas where only a small supplementary water supply is needed. Water

			application efficiency 60-70 %.
Localized (drip, trickle, etc.)	Any topographic condition suitable for row crop farming	Row crops or fruit	Perforated pipe on the soil surface drips water at base of individual vegetable plants or around fruit trees. Has been successfully used in Israel with saline irrigation water. Still in development stage. Water application efficiency 75-85 %.

Source: FAO (1988)

Leaching

Under irrigated agriculture, a certain amount of excess irrigation water is required to percolate through the root zone to remove the salts, which have accumulated as a result of evapotranspiration from the original irrigation water. This process of displacing the salts from the root zone is called leaching and that portion of the irrigation water that mobilizes the excess of salts is called the leaching fraction, LF.

$$\text{Leaching Fraction (LF)} = \frac{\text{depth of water leached below the root zone}}{\text{depth of water applied at the surface}}$$

Salinity control by effective leaching of the root zone becomes more important as irrigation water becomes more saline.

Drainage

Drainage is defined as the removal of excess water from the soil surface and below to permit optimum growth of plants. Removal of excess surface water is termed surface drainage while the removal of excess water from beneath the soil surface is termed sub-surface drainage. The importance of drainage for successful irrigated agriculture has been well demonstrated. It is particularly important in semi-arid and arid areas to prevent secondary salinization. In these areas, the water table will rise with irrigation when the natural internal drainage of the soil is not adequate. When the water table is within a few meters of the soil surface, capillary rise of saline groundwater will transport salts to the soil surface. At the surface, water evaporates, leaving the salts behind. If this process is not arrested, salt accumulation will continue, resulting in salinization of the soil. In such cases, sub-surface drainage can control the rise of the water table and hence prevent salinization.

Strategies for managing treated wastewater on the farm

To overcome salinity hazards
To overcome toxicity hazards
To prevent health hazards

Success in using treated wastewater for crop production will largely depend on adopting appropriate strategies aimed at optimizing crop yields and quality, maintaining soil productivity and safeguarding the environment. Several alternatives are available and a combination of these alternatives will offer an optimum solution for a given set of conditions. The user should have prior information on effluent supply and its quality, as indicated in Table F-3, to ensure the formulation and adoption of an appropriate on-farm management strategy.

The components of an on-farm strategy in using treated wastewater will consist of a combination of:

- Crop selection,
- selection of irrigation method, and
- adoption of appropriate management practices.

Furthermore, when the farmer has additional sources of water supply, such as a limited amount of normal irrigation water, he will then have an option to use both the effluent and the conventional source of water in two ways, namely:

- By blending conventional water with treated effluent, and
- using the two sources in rotation.

These are discussed briefly in the following sections.

Table F-3: INFORMATION REQUIRED ON EFFLUENT SUPPLY AND QUALITY

Information	Decision on irrigation management
Effluent supply	
The total amount of effluent that would be made available during the crop growing season.	Total area that could be irrigated.
Effluent available throughout the year.	Storage facility during non-crop growing period either at the farm or near wastewater treatment plant, and possible use for aquaculture.
The rate of delivery of effluent either as m^3 per day or litres per second.	Area that could be irrigated at any given time, layout of fields and facilities and system of irrigation.
Type of delivery: continuous or intermittent, or on demand.	Layout of fields and facilities, irrigation system, and irrigation scheduling.

Mode of supply: supply at farm gate or effluent available in a storage reservoir to be pumped by the farmer.	The need to install pumps and pipes to transport effluent and irrigation system.
Effluent quality	
Total salt concentration and/or electrical conductivity of the effluent.	Selection of crops, irrigation method, leaching and other management practices.
Concentrations of cations, such as Ca^{++}, Mg^{++} and Na^{+}.	To assess sodium hazard and undertake appropriate measures.
Concentration of toxic ions, such as heavy metals, Boron and Cl^{-}.	To assess toxicities that are likely to be caused by these elements and take appropriate measures.
Concentration of trace elements (particularly those which are suspected of being phyto-toxic).	To assess trace toxicities and take appropriate measures.
Concentration of nutrients, particularly nitrate-N.	To adjust fertilizer levels, avoid over-fertilization and select crop.
Level of suspended sediments.	To select appropriate irrigation system and measures to prevent clogging problems.
Levels of intestinal nematodes and faecal coliforms.	To select appropriate crops and irrigation systems.

Crop selection

To overcome salinity hazards

Not all plants respond to salinity in a similar manner; some crops can produce acceptable yields at much higher soil salinity than others. This is because some crops are better able to make the needed osmotic adjustments, enabling them to extract more water from a saline soil. The ability of a crop to adjust to salinity is extremely useful. In areas where a build-up of soil salinity cannot be controlled at an acceptable concentration for the crop being grown, an alternative crop can be selected that is both more tolerant of the expected soil salinity and able to produce economic yields. There is an 8-10 fold range in the salt tolerance of agricultural crops. This wide range in tolerance allows for greater use of moderately saline water, much of which was previously thought to be unusable. It also greatly expands the acceptable range of water salinity (ECw) considered suitable for irrigation.

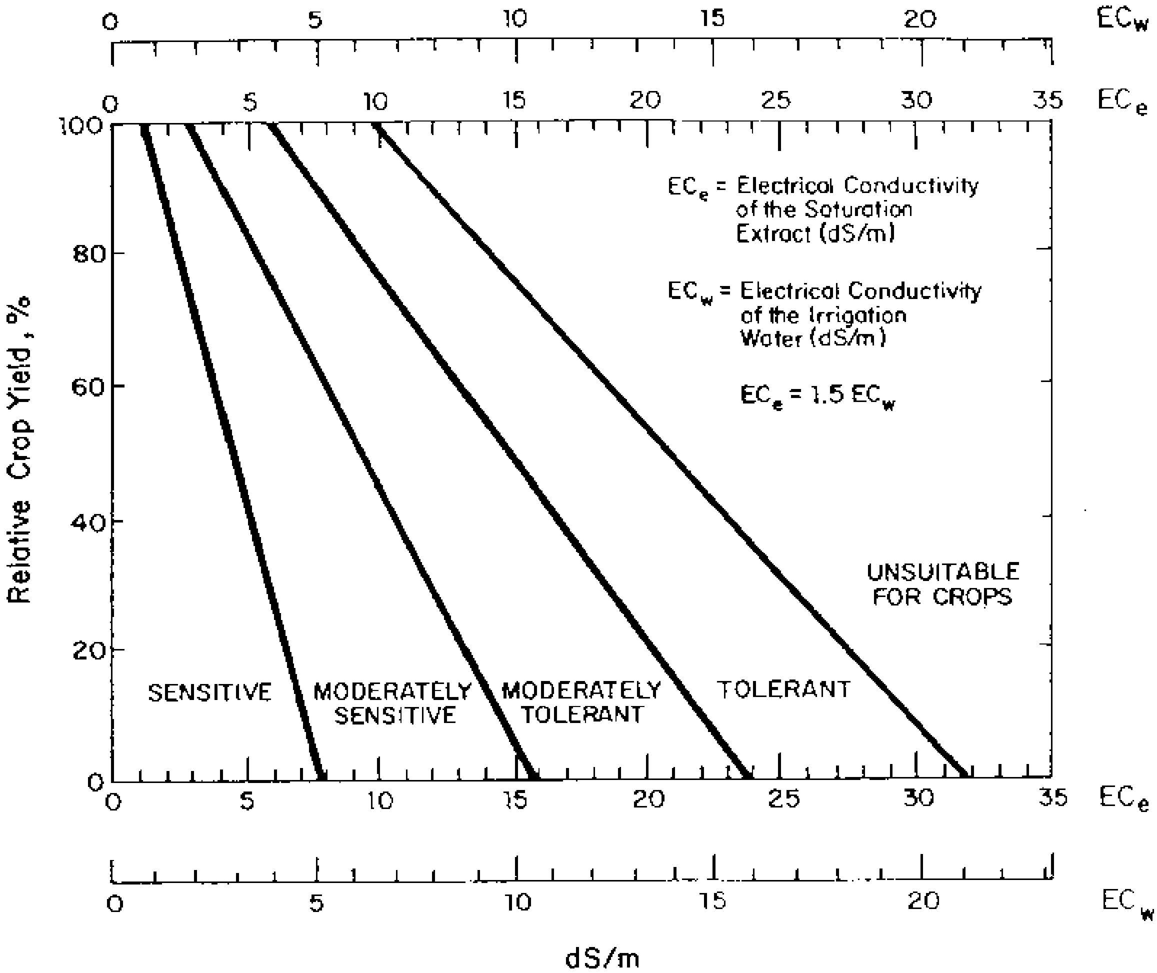
The relative salt tolerance of most agricultural crops is known well enough to give general salt tolerance guidelines. Table F-4 presents a list of crops classified according to their tolerance and sensitivity to salinity. Figure F-1 presents the relationship between relative crop yield and irrigation water salinity with regard to the four crop salinity classes. The following general conclusions can be drawn from these data:

i. full yield potential should be achievable with nearly all crops when using a water with salinity less than 0.7 dS/m,

ii. When using irrigation water of slight to moderate salinity (i.e. 0.7-3.0 dS/m), full yield potential is still possible, but care must be taken to achieve the required leaching fraction in order to maintain soil salinity within the tolerance of the crops. Treated sewage effluent will normally fall within this group,

iii. For higher salinity water (more than 3.0 dS/m) and sensitive crops, increasing leaching to satisfy a leaching requirement greater than 0.25 to 0.30 might not be practicable because of the excessive amount of water required. In such a case, consideration must be given to changing to a more tolerant crop that will require less leaching, to control salts within crop tolerance levels. As water salinity (ECw) increases within the slight to moderate range, production of more sensitive crops may be restricted due to the inability to achieve the high leaching fraction needed, especially when grown on heavier, more clayey soil types.

Figure F-1: Divisions for relative salt tolerance ratings of agricultural crops (Maas 1984)



<u>Table F-4:</u> RELATIVE SALT TOLERANCE OF AGRICULTURAL CROPS

TOLERANT	
<u>Fibre, Seed and Sugar Crops</u>	
Barley	*Hordeum vulgare*
Cotton	*Gossypium hirsutum*
Jojoba	*Simmondsia chinensis*
Sugarbeet	*Beta vulgaris*
<u>Grasses and Forage Crops</u>	
Alkali grass	*Puccinellia airoides*
Alkali sacaton	*Sporobolus airoides*
Bermuda grass	*Cynodon dactylon*

Kallar grass	*Diplachne fusca*
Saltgrass, desert	*Distichlis stricta*
Wheatgrass, fairway crested	*Agropyron cristatum*
Wheatgrass, tall	*Agropyron elongatum*
Wildrye, Altai	*Elymus angustus*
Wildrye, Russian	*Elymus junceus*
Vegetable Crops	
Asparagus	*Asparagus officinalis*
Fruit and Nut Crops	
Date palm	*Phoenix dactylifera*
MODERATELY TOLERANT	
Fibre, Seed and Sugar Crops	
Cowpea	*Vigna unguiculata*
Oats	*Avena sativa*
Rye	*Secale cereale*
Safflower	*Carthamus tinctorius*
Sorghum	*Sorghum bicolor*
Soybean	*Glycine max*
Triticale	*X Triticosecale*
Wheat	*Triticum aestivum*
Wheat, Durum	*Triticum turgidum*
Grasses and Forage Crops	
Barley (forage)	*Hordeum vulgare*
Brome, mountain	*Bromus marginatus*
Canary grass, reed	*Phalaris, arundinacea*
Clover, Hubam	*Melilotus alba*
Clover, sweet	*Melilotus*

Fescue, meadow	*Festuca pratensis*
Fescue, tall	*Festuca elatior*
Harding grass	*Phalaris tuberosa*
Panic grass, blue	*Panicum antidotale*
Rape	*Brassica napus*
Rescue grass	*Bromus unioloides*
Rhodes grass	*Chloris gayana*
Grasses and Forage Crops	
Ryegrass, Italian	*Lolium italicum multiflorum*
Ryegrass, perennial	*Lolium perenne*
Sudan grass	*Sorghum sudanense*
Trefoil, narrowleaf birdsfoot	*Lotus corniculatus tenuifolium*
Trefoil, broadleaf	*L. corniculatus arvenis*
Wheat (forage)	*Triticum aestivum*
Wheatgrass, standard crested	*Agropyron sibiricum*
Wheatgrass, intermediate	*Agropyron intermedium*
Wheatgrass, slender	*Agropyron trachycaulum*
Wheatgrass, western	*Agropyron smithii*
Wildrye, beardless	*Elymus triticoides*
Wildrye, Canadian	*Elymus canadensis*
Vegetable Crops	
Artichoke	*Helianthus tuberosus*
Beet, red	*Beta vulgaris*
Squash, zucchini	*Cucurbita pepo melopepo*
Fruit and Nut Crops	
Fig	*Ficus carica*
Jujube	*Ziziphys jujuba*

Olive	*Olea europaea*
Papaya	*Carica papaya*
Pineapple	*Ananas comosus*
Pomegranate	*Punica granatum*
MODERATELY SENSITIVE	
Fibre, Seed and Sugar Crops	
Broadbean	*Vicia faba*
Castorbean	*Ricinus communis*
Maize	*Zea mays*
Flax	*Linum usitatissimum*
Millet, foxtail	*Setaria italica*
Groundnut/peanut	*Arachis hypogaea*
Rice, paddy	*Oryza sativa*
Sugarcane	*Saccarum officinarum*
Sunflower	*Helianthus annuus palustris*
Grasses and Forage Crops	
Alfalfa	*Medicago sativa*
Bentgrass	*Agrostisstoloniferapalustris*
Bluestem, Angleton	*Dichanthium aristatum*
Brome, smooth	*Bromus inermis*
Buffelgrass	*Cenchrus ciliaris*
Burnet	*Poterium sanguisorba*
Clover, alsike	*Trifolium hydridum*
Grasses and Forage Crops	
Clover, Berseem	*Trifolium alexandrinum*
Clover, ladino	*Trifolium repens*
Clover, red	*Trifolium pratense*

Clover, strawberry	*Trifolium fragiferum*
Clover, white Dutch	*Trifolium repens*
Corn (forage) (maize)	*Zea mays*
Cowpea (forage)	*Vigna unguiculata*
Dallis grass	*Paspalum dilatatum*
Foxtail, meadow	*Alopecurus pratensis*
Grama, vlue	*Bouteloua gracilis*
Lovegrass	*Eragrostis sp.*
Milkvetch, Cicer	*Astragalus deer*
Oatgrass, tall	*Arrhenatherum, Danthonia*
Oats (forage)	*Avena saliva*
Orchard grass	*Dactylis glomerata*
Rye (forage)	*Secale cereale*
Sesbania	*Sesbania exaltata*
Siratro	*Macroptilium atropurpureum*
Sphaerophysa	*Spaerophysa salsula*
Timothy	*Phleum pratense*
Vetch, common	*Vicia angustifolia*
Vegetable Crops	
Broccoli	*Brassica oleracea botrytis*
Brussel sprouts	*B. oleracea gemmifera*
Cabbage	*B. oleracea capitata*
Cauliflower	*B. oleracea botrytis*
Celery	*Apium graveolens*
Corn, sweet	*Zea mays*
Cucumber	*Cucumis sativus*
Eggplant	*Solanum melongena esculentum*

Kale	*Brassica oleracea acephala*
Kohlrabi	*B. oleracea gongylode*
Lettuce	*Latuca sativa*
Muskmelon	*Cucumis melon*
Pepper	*Capsicum annum*
Potato	*Solanum tuberosum*
Pumpkin	*Cucurbita peop pepo*
Radish	*Raphanus sativus*
Spinach	*Spinacia oleracea*
Squash, scallop	*C. pepo melopepo*
Sweet potato	*Ipomoea batatas*
Tomato	*Lycopersicon lycopersicum*
Turnip	*Brassica rapa*
Watermelon	*Citrullus lanatus*
Fruit and Nut Crops	
Grape	*Vitis sp.*
SENSITIVE	
Fibre, Seed and Sugar Crops	
Bean	*Phaseolus vulgaris*
Guayule	*Parthenium argentatum*
Sesame	*Sesamum indicum*
Vegetable Crops	
Bean	*Phaseolus vulgaris*
Carrot	*Daucus carota*
Okra	*Abelmoschus esculentus*
Onion	*Allium cepa*
Parsnip	*Pastinaca sativa*

Fruit and Nut Crops	
Almond	*Prunus dulcis*
Apple	*Malus sylvestris*
Apricot	*Prunus armeniaca*
Avocado	*Persea americana*
Blackberry	*Rubus sp.*
Boysenberry	*Rubus ursinus*
Cherimoya	*Annona cherimola*
Cherry, sweet	*Prunus avium*
Cherry, sand	*Prunus besseyi*
Currant	*Ribes sp.*
Gooseberry	*Ribes sp.*
Grapefruit	*Citrus paradisi*
Lemon	*Citrus limon*
Lime	*Citrus aurantifolia*
Loquat	*Eriobotrya japonica*
Mango	*Mangifera indica*
Orange	*Citrus sinensis*
Passion fruit	*Passiflora edulis*
Peach	*Prunus persica*
Pear	*Pyrus communis*
Persimmon	*Diospyros virginiana*
Plum: Prune	*Prunus domestica*
Pummelo	*Citrus maxima*
Raspberry	*Rubus idaeus*
Rose apple	*Syzgium jambos*
Sapote, white	*Casimiroa edulis*

Strawberry	*Fragaria sp.*
Tangerine	*Citrus reticulata*

Source: FAO (1985)

iv. if the salinity of the applied water exceeds 3.0 dS/m, the water might still be usable but its use may need to be restricted to more permeable soils and more salt-tolerant crops, where high leaching fractions are more easily achieved. This is being practiced on a large scale in the Arabian Gulf States, where drip irrigation systems are widely used.

If the exact cropping patterns or rotations are not known for a new area, the leaching requirement must be based on the least tolerant of the crops adapted to the area. In those instances, where soil salinity cannot be maintained within acceptable limits of preferred sensitive crops, changing to more tolerant crops will raise the area's production potential. If there is any doubt about the effect of wastewater salinity on crop production, a pilot study should be undertaken to demonstrate the feasibility of irrigation and the outlook for economic success.

To overcome toxicity hazards

A toxicity problem is different from a salinity problem in that it occurs within the plant itself and is not caused by water shortage. Toxicity normally results when certain ions are taken up by plants with the soil water and accumulate in the leaves during water transpiration to such an extent that the plant is damaged. The degree of damage depends upon time, concentration of toxic material, crop sensitivity, and crop water use and, if damage is severe enough, crop yield is reduced. Common toxic ions in irrigation water are chloride, sodium, and boron, all of which will be contained in sewage. Each can cause damage individually or in combination. Not all crops are equally sensitive to these toxic ions. Some guidance on the sensitivity of crops to sodium, chloride, and boron are given in Tables F-5, F-6, and F-7, respectively. However, toxicity symptoms can appear in almost any crop if concentrations of toxic materials are sufficiently high. Toxicity often accompanies or complicates a salinity or infiltration problem, although it may appear even when salinity is not a problem.

The toxic ions of sodium and chloride can also be absorbed directly into the plant through the leaves when moistened during sprinkler irrigation. This typically occurs during periods of high temperature and low humidity. Leaf absorption speeds up the rate of accumulation of a toxic ion and may be a primary source of the toxicity.

In addition to sodium, chloride, and boron, many trace elements are toxic to plants at low concentrations, as indicated in Table 10 in Chapter 2. Fortunately, most irrigation supplies and sewage effluents contain very low concentrations of these trace elements and are generally not a problem.

However, urban wastewater may contain heavy metals at concentrations which will give rise to elevated levels in the soil and cause undesirable accumulations in plant tissue and crop growth reductions. Heavy metals are readily fixed and accumulate in soils with repeated irrigation by such wastewaters and may render them either non-productive or the product unusable. Surveys of wastewater use have shown that more than 85 % of the applied heavy metals are likely to accumulate in the soil, most at the surface. The levels at which heavy metals accumulation in the soil is likely to have a deleterious effect on crops are discussed in Chapter 5. Any wastewater use project should include monitoring of soil and plants for toxic materials.

To prevent health hazards

From the point of view of human consumption and potential health hazards, crops and cultivated plants may be classified into the following groups:

Table F-4: RELATIVE TOLERANCE OF SELECTED CROPS TO EXCHANGEABLE SODIUM

Sensitive	Semi-tolerant	Tolerant
Avocado	Carrot	Alfalfa
(Persea americana)	*(Daucus carota)*	*(Medicago sativa)*
Deciduous Fruits	Clover, Ladino	Barley
Nuts	*(Trifolium repens)*	*(Hordeum vulgare)*
Bean, green	Dallisgrass	Beet, garden
(Phaseolus vulgaris)	*(Paspalum dilatatum)*	*(Beta vulgaris)*
Cotton (at germination)	Fescue, tall	Beet, sugar
(Gossypium hirsutum)	*(Festuca arundinacea)*	*(Beta vulgaris)*
Maize	Lettuce	Bermuda grass
(Zea mays)	*(Lactuca sativa)*	*(Cynodon dactylon)*
Peas	Bajara	Cotton
(Pisum sativum)	*(Pennisetum typhoides)*	*(Gossypium hirsutum)*
Grapefruit	Sugarcane	Paragrass
(Citrus paradisi)	*(Saccharum officinarum)*	*(Brachiaria mutica)*
Orange	Berseem	Rhodes grass
(Citrus sinensis)	*(Trifolium alexandrinum)*	*(Chloris gayana)*

Peach	Benji	Wheatgrass, crested
(Prunus persica)	*(Mililotus parviflora)*	*(Agropyron cristatum)*
Tangerine	Raya	Wheatgrass, fairway
(Citrus reticulata)	*(Brassica juncea)*	*(agropyron cristatum)*
Mung	Oat	Wheatgrass, tall
(Phaseolus aurus)	*(Avena sativa)*	*(Agropyron elongatum)*
Mash	Onion	Karnal grass
(Phaseolus mungo)	*(Allium cepa)*	*(Diplachna fusca)*
Lentil	Radish	
(Lens culinaris)	*(Raphanus sativus)*	
Groundnut (peanut)	Rice	
(Arachis hypogaea)	*(Oryza sativus)*	
Gram	Rye	
(Cicer arietinum)	*(Secale cereale)*	
Cowpeas	Ryegrass, Italian	
(Vigna sinensis)	*(Lolium multiflorum)*	
	Sorghum	
	(Sorghum vulgare)	
	Spinach	
	(Spinacia oleracea)	
	Tomato	
	(Lycopersicon esculentum)	
	Vetch	
	(Vicia sativa)	
	Wheat	
	(Triticum vulgare)	

Source: Adapted from data of FAO-Unesco (1973); Pearson (1960); and Abrol (1982).

i. Food crops

- those eaten uncooked
- those eaten after cooking

ii. Forage and feed crops

- Direct access by animals
- those fed to animals after harvesting

Table F-5: CHLORIDE TOLERANCE OF SOME FRUIT CROP CULTIVARS AND ROOTSTOCKS

Crop	**Rootstock or Cultivar**	**Maximum permissible Cl^- without leaf injury**[1]	
		Root zone (Cl_e) (me/l)	**Irrigation water (Cl_w)[2 3] (me/l)**
	Rootstocks		
Avocado *(Persea americana)*	West Indian	7.5	5.0
	Guatemalan	6.0	4.0
	Mexican	5.0	3.3
Citrus *(Citrus spp.)*	Sunki Mandarin	25.0	16.6
	Grapefruit		
	Cleopatra mandarin		
	Rangpur lime		
	Sampson tangelo	15.0	10.0
	Rough lemon		
	Sour orange		
	Ponkan mandarin		
	Citrumelo 4475	10.0	6.7
	Trifoliate orange		
	Cuban shaddock		
	Calamondin		
	Sweet orange		
	Savage citrange		

	Rusk citrange		
	Troyer citrange		
Grape*(Vitis spp.)*	Salt Creek, 1613-3	40.0	27.0
	Dog Ridge	30.0	20.0
Stone Fruits *(Prunus spp.)*	Marianna	25.0	17.0
	Lovell, Shalil	10.0	6.7
	Yunnan	7.5	5.0
	Cultivars		
Berries *(Rubus spp.)*	Boysenberry	10.0	6.7
	Olallie clackberry	10.0	6.7
	Indian SUmmer	5.0	3.3
	Raspberry		
Grape*(Vitis spp.)*	Thompson seedless	20.0	13.3
	Perlette	20.0	13.3
	Cardinal	10.0	6.7
	Black Rose	10.0	6.7
Strawberry *(Fragaria spp.)*	Lassen	7.5	5.0
	Shasta	5.0	3.3

[1] For some crops, the concentration given may exceed the overall salinity tolerance of that crop and cause some reduction in yield in addition to that caused by chloride ion toxicities.

[2] Values given are for the maximum concentration in the irrigation water. The values were derived from saturation extract data (EC_e) assuming a 15-20 percent leaching fraction and EC_d = 1.5 EC_w.

[3] The maximum permissible values apply only to surface irrigated crops. Sprinkler irrigation may cause excessive leaf bum at values far below these.

Source: Adapted from Maas (1984).

Table F-6: RELATIVE BORON TOLERANCE OF AGRICULTURAL CROPS[1]

VERY SENSITIVE (<0.5 mg/l)	
Lemon	*Citrus limon*
Blackberry	*Rubus spp.*
SENSITIVE (0.5-0.75 mg/l)	

Avocado	*Persea americana*
Grapefruit	*Citrus X paradisi*
Orange	*Citrus sinensis*
Apricot	*Prunus armeniaca*
Peach	*Prunus persica*
Cherry	*Prunus avium*
Plum	*Prunus domestica*
Persimmon	*Diospyros kaki*
Fig, kadota	*Ficus carica*
Grape	*Vitis vinifera*
Walnut	*Juglans regia*
Pecan	*Carya illinoiensis*
Cowpea	*Vigna unguiculata*
Onion	*Allium cepa*
SENSITIVE (0.75-1.0 mg/l)	
Garlic	*Allium sativum*
Sweet potato	*Ipomoea batatas*
Wheat	*Triticum eastivum*
Barley	*Hordeum vulgare*
Sunflower	*Helianthus annuus*
Bean, mung	*Vigna radiata*
Sesame	*Sesamum indicum*
Lupine	*Lupinus hartwegii*
Strawberry	*Fragaria spp.*
Artichoke, Jerusalem	*Helianthus tuberosus*
Bean, kidney	*Phaseolus vulgaris*
Bean, lima	*Phaseolus lunatus*

Groundnut/Peanut	*Arachis hypogaea*
MODERATELY SENSITIVE (1.0-2.0 mg/l)	
Pepper, red	*Capsicum annuum*
Pea	*Pisum sativa*
Carrot	*Daucus carota*
Radish	*Raphanus sativus*
Potato	*Solanum tuberosum*
Cucumber	*Cucumis sativus*
MODERATELY TOLERANT (2.0-4.0 mg/l)	
Lettuce	*Lactuca sativa*
Cabbage	*B. oleracea capitata*
Celery	*Apium graveolens*
Turnip	*Brassica rapa*
Bluegrass, Kentucky	*Poa pratensis*
Oats	*Avena sativa*
Maize	*Zea mays*
Artichoke	*Cynara scolymus*
Tobacco	*Nicotiana tabacum*
Mustard	*Brassica juncea*
Clover, sweet	*Melilotus indica*
Squash	*Cucurbita pepo*
Muskmelon	*Cucumis melo*
TOLERANT (4.0-6.0 mg/l)	
Sorghum	*Sorghum bicolor*
Tomato	*L. lycopersicum*
Alfalfa	*Medicago sativa*
Vetch, purple	*Vicia benghalensis*

Parsley	*Petroselinum crispum*
Beet, red	*Beta vulgaris*
Sugarbeet	*Beta vulgaris*
VERY TOLERANT (6.0-15.0 mg/l)	
Cotton	*Gossypium hirsutum*
Asparagus	*Asparagus officinalis*

[1] Maximum concentrations tolerated in soil water without yield or vegetative growth reductions. Boron tolerances vary depending upon climate, soil conditions and crop varieties. Maximum concentrations in the irrigation water are approximately equal to these values or slightly less.

Source: Maas (1984)

iii. Landscaping plants:

- Unprotected areas with public access
- semi-protected areas

iv. Afforestation plants:

- commercial (fruit, timber, fuel and charcoal)
- environmental protection (including sand stabilization)

In terms of health hazards, treated effluent with a high microbiological quality is necessary for the irrigation of certain crops, especially vegetable crops eaten raw, but a lower quality is acceptable for other selected crops, where there is no exposure to the public (see Table 8 in Chapter 2). The WHO (1989) Technical Report No. 778 suggested a categorization of crops according to the exposed group and the degree to which health protection measures are required, as shown in Example 4.

EXAMPLE 4 - CATEGORIZATION OF CROPS IN RELATION TO EXPOSED GROUP AND HEALTH CONTROL MEASURES

Category A:

- Protection required for consumers, agricultural workers, and the general public,

- Includes crops likely to be eaten uncooked, spray-irrigated fruits and grass (sports fields, public parks and lawns);

Category B:

- Protection required for agricultural workers only,

- Includes cereal crops, industrial crops (such as cotton and sisal), food crops for canning, fodder crops, pasture and trees,

- In certain circumstances some vegetable crops might be considered as belonging to Category B if they are not eaten raw (potatoes, for instance) or if they grow well above ground (for example, chillies), in such cases it is necessary to ensure that the crop is not contaminated by sprinkler irrigation or by falling on to the ground, and that contamination of kitchens by such crops, before cooking, does not give rise to a health risk.

Selection of irrigation methods

The different types of irrigation methods have been introduced earlier. Under normal conditions, the type of irrigation method selected will depend on water supply conditions, climate, soil, crops to be grown, cost of irrigation method and the ability of the farmer to manage the system. However, when using wastewater as the source of irrigation other factors, such as contamination of plants and harvested product, farm workers, and the environment, and salinity and toxicity hazards, will need to be considered. There is considerable scope for reducing the undesirable effects of wastewater use in irrigation through selection of appropriate irrigation methods.

The choice of irrigation method in using wastewater is governed by the following technical factors:

- the choice of crops,
- the wetting of foliage, fruits and aerial parts,
- the distribution of water, salts and contaminants in the soil,
- the ease with which high soil water potential could be maintained,
- the efficiency of application, and
- the potential to contaminate farm workers and the environment.

Table F-7 presents an analysis of these factors in relation to four widely practiced irrigation methods, namely border, furrow, sprinkler, and drip irrigation.

Table F-7: EVALUATION OF COMMON IRRIGATION METHODS IN RELATION TO THE USE OF TREATED WASTEWATER

Parameters of evaluation	Furrow irrigation	Border irrigation	Sprinkler irrigation	Drip irrigation
1 Foliar wetting and consequent leaf damage resulting in poor yield	No foliar injury as the crop is planted on the ridge	Some bottom leaves may be affected but the damage is not so serious as to reduce yield	Severe leaf damage can occur resulting in significant yield loss	No foliar injury occurs under this method of irrigation
2 Salt accumulation in the root zone with repeated applications	Salts tend to accumulate in the ridge which could harm the crop	Salts move vertically downwards and are not likely to accumulate in the root zone	Salt movement is downwards and root zone is not likely to accumulate salts	Salt movement is radial along the direction of water movement. A salt wedge is formed between drip points
3 Ability to maintain high soil water potential	Plants may be subject to stress between irrigations	Plants may be subject . to water stress between irrigations	Not possible to maintain high soil water potential throughout the growing season	Possible to maintain high soil water potential throughout the growing season and minimize the effect of salinity
4 Suitability to handle brackish wastewater without significant yield loss	Fair to medium. With good management and drainage acceptable yields are possible	Fair to medium. Good irrigation and drainage practices can produce acceptable levels of yield	Poor to fair. Most crops suffer from leaf damage and yield is low	Excellent to good. Almost all crops can be grown with very little reduction in yield

Source: Kandiah (1990b)

A border (and basin or any flood irrigation) system involves complete coverage of the soil surface with treated effluent and is normally not an efficient method of irrigation. This system will also contaminate vegetable crops growing near the ground and root crops and will expose farm workers to the effluent more than any other method. Thus, from both the health and water conservation points of view, border irrigation with wastewater is not satisfactory.

Furrow irrigation, on the other hand, does not wet the entire soil surface. This method can reduce crop contamination, since plants are grown on the ridges, but complete health protection cannot be guaranteed. Contamination of farm workers is potentially medium to high, depending on automation. If the effluent is transported through pipes and delivered into individual furrows by means of gated pipes, risk to irrigation workers will be minimum.

The efficiency of surface irrigation methods in general, borders, basins, and furrows, is not greatly affected by water quality, although the health risk inherent in these systems is most certainly of concern. Some problems might arise if the effluent contains large quantities of suspended solids and these settle out and restrict flow in transporting channels, gates, pipes and appurtenances. The use of primary treated sewage will overcome many of such problems. To avoid surface ponding of stagnant effluent, land levelling should be carried out carefully and appropriate land gradients should be provided.

Sprinkler, or spray, irrigation methods are generally more efficient in terms of water use since greater uniformity of application can be achieved. However, these overhead irrigation methods may contaminate ground crops, fruit trees and farm workers. In addition, pathogens contained in aerosolized effluent may be transported downwind and create a health risk to nearby residents. Generally, mechanized or automated systems have relatively high capital costs and low labour costs compared with manually-moved sprinkler systems. Rough land levelling is necessary for sprinkler systems, to prevent excessive head losses and achieve uniformity of wetting. Sprinkler systems are more affected by water quality than surface irrigation systems, primarily as a result of the clogging of orifices in sprinkler heads, potential leaf burns and phytotoxicity when water is saline and contains excessive toxic elements, and sediment accumulation in pipes, valves and distribution systems. Secondary wastewater treatment has generally been found to produce an effluent suitable for distribution through sprinklers, provided that the effluent is not too saline. Further precautionary measures, such as treatment with granular filters or micro-strainers and enlargement of nozzle orifice diameters to not less than 5 mm, are often adopted.

Localized irrigation, particularly when the soil surface is covered with plastic sheeting or other mulch, uses effluent more efficiently, can often produce higher crop yields and certainly provides the greatest degree of health protection for farm workers and consumers. Trickle and drip irrigation systems are expensive, however, and require a high quality of effluent to prevent clogging of the emitters through which water is slowly released into the soil. Table F-8 presents water quality requirements to prevent clogging in localized irrigation systems. Solids in the effluent or biological growth at the emitters will create problems but gravel filtration of secondary treated effluent and regular flushing of lines have been found to be effective in preventing such problems in Cyprus (Papadopoulos and Stylianou 1988). Bubbler irrigation, a technique developed for the localized irrigation of tree crops avoids the need for small emitter orifices but careful setting is required for its successful application (Hillel 1987).

Table F-8: WATER QUALITY AND CLOGGING POTENTIAL IN DRIP IRRIGATION SYSTEMS

Potential Problem	**Units**	**Degree of Restriction on Use**		
		None	**Slight to Moderate**	**Severe**
Physical				
Suspended Solids	mg/l	< 50	50- 100	> 100
Chemical				
pH		< 7.0	7.0 - 8.0	> 8.0
Dissolved Solids	mg/l	< 500	500-2000	> 2000
Manganese	mg/l	< 0.1	0.1 - 1.5	> 1.5
Iron	mg/l	< 0.1	0.1 - 1.5	> 1.5
Hydrogen Sulphide	mg/l	< 0.5	0.5 - 2.0	> 2.0
Biological	maximum			
Bacterial populations	number/ml	< 10000	10 000 - 50 000	> 50000

Source: Adapted from Nakayama (1982)

When compared with other systems, the main advantages of trickle irrigation seem to be:

i. increased crop growth and yield achieved by optimizing the water, nutrients and air regimes in the root zone,

ii. High irrigation efficiency - no canopy interception, wind drift or conveyance losses and minimal drainage losses,

iii. Minimal contact between farm workers and effluent,

iv. Low energy requirements - the trickle system requires a water pressure of only 100-300 k Pa (1-3 bar),

v. low labour requirements - the trickle system can easily be automated, even to allow combined irrigation and fertilization (sometimes terms fertigation).

Apart from the high capital costs of trickle irrigation systems, another limiting factor in their use is that they are only suited to the irrigation of row crops. Relocation of subsurface systems can be prohibitively expensive.

Clearly, the decision on irrigation system selection will be mainly a financial one but it is essential that the health risks associated with the different methods will be taken into account. As pointed out in Section 2.1, the method of effluent application is one of the health control measures possible, along with crop selection, wastewater treatment, and human exposure control. Each measure will interact with the others and thus a decision on irrigation system selection will have an influence on wastewater treatment requirements, human exposure control and crop selection (for example, row crops are dictated by trickle irrigation). At the same time the irrigation techniques feasible will depend on crop selection and the choice of irrigation system might be limited if wastewater treatment has already been decided before effluent use is considered.

Field management practices in wastewater irrigation

Management of water, soil, crop, and operational procedures, including precautions to protect farm workers, play an important role in the successful use of sewage effluent for irrigation.

Water management

Most treated wastewaters are not very saline, salinity levels usually ranging between 500 and 200 mg/l (ECw = 0.7 to 3.0 dS/m). However, there may be instances where the salinity concentration exceeds the 2000 mg/l level. In any case, appropriate water management practices will have to be followed to prevent salinization, irrespective of whether the salt content in the wastewater is high or low. It is interesting to note that even the application of a non-saline wastewater, such as one containing 200 to 500 mg/l, when applied at a rate of 20,000 m3 per hectare, a fairly typical irrigation rate, will add between 2 and 5 tones of salt annually to the soil. If this is not flushed out of the root zone by leaching and removed from the soil by effective drainage, salinity problems can build up rapidly. Leaching and drainage are thus two important water management practices to avoid salinization of soils.

Leaching

The concept of leaching has already been discussed. The question that arises is how much water should be used for leaching, i.e. what is the leaching requirement? To estimate the leaching requirement, both the salinity of the irrigation water (ECw) and the crop tolerance to soil salinity (ECe) must be known. The necessary leaching requirement (LR) can be estimated from Figure 14 for general crop rotations reported by Ayers and Westcot (FAO

1985). A more exact estimate of the leaching requirement for a particular crop can be obtained using the following equation:

(14)

$$LR = \frac{EC_w}{5(EC_e - EC_w}$$

Where:

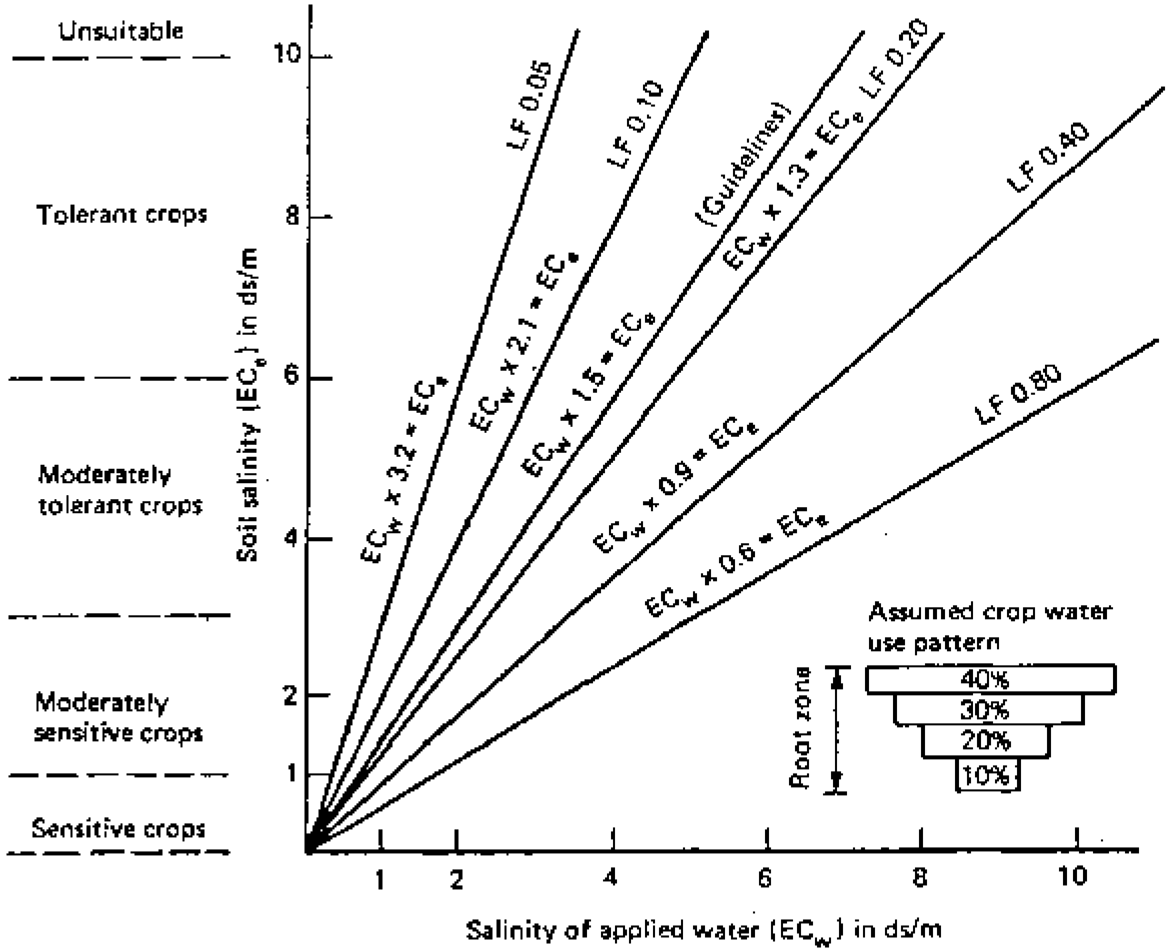
LR = minimum leaching requirement needed to control salts within the tolerance (EC_e) of the crop with ordinary surface methods of irrigation

EC_w = salinity of the applied irrigation water in dS/m

EC_e = average soil salinity tolerated by the crop as measured on a soil saturation extract. It is recommended that the EC_e value that can be expected to result in at least a 90% or greater yield be used in the calculation.

Figure F-2 was developed using ECe values for the 90% yield potential. For water in the moderate to high salinity range (>1.5 dS/m), it might be better to use the ECe value for maximum yield potential (100%) since salinity control is critical in obtaining good yields. Further information on this is contained in Irrigation and Drainage Paper 29, Rev. 1 (FAO 1985).

Figure F-2: Relationship between applied water salinity and soil water salinity at different leaching fractions (FAO 1985)



Where water is scarce and expensive, leaching practices should be designed to maximize crop production per unit volume of water applied, to meet both the consumptive use and leaching requirements. Depending on the salinity status, leaching can be carried out at each irrigation, each alternative irrigation or less frequently, such as seasonally or at even longer intervals, as necessary to keep the salinity in the soil below the threshold above which yield might be affected to an unacceptable level. With good quality irrigation water, the irrigation application level will usually apply sufficient extra water to accomplish leaching. With high salinity irrigation water, meeting the leaching requirement is difficult and requires large amounts of water. Rainfall must be considered in estimating the leaching requirement and in choosing the leaching method.

The following practices are suggested for increasing the efficiency of leaching and reducing the amount of water needed:

i. leach during cool seasons instead of during warm periods, to increase the efficiency and ease of leaching, since the total annual crop water demand (ET, mm/year) losses are lower,

ii. Use more salt-tolerant crops that require a lower leaching requirement (LR) and thus have a lower water demand,

iii. use tillage to slow overland water flow and reduce the number of surface cracks which bypass flow through large pores and decrease leaching efficiency,

iv. Use sprinkler irrigation at an application rate below the soil infiltration rate as this favours unsaturated flow, which is significantly more efficient for leaching than saturated flow. More irrigation time but less water is required than for continuous ponding,

v. use alternate ponding and drying instead of continuous ponding as this is more efficient for leaching and uses less water, although the time required to leach is greater. This may have drawbacks in areas having a high water table, which allows secondary salinization between pondings,

vi. Where possible, schedule leaching at periods of low crop water use or postpone leaching until after the cropping season,

vii. Avoid fallow periods, particularly during hot summers, when rapid secondary soil salinization from high water tables can occur,

viii. If infiltration rates are low, consider pre-planting irrigations or off-season leaching to avoid excessive water applications during the crop season, and

ix. Use one irrigation before the start of the rainy season if total rainfall is normally expected to be insufficient for a complete leaching. Rainfall is often the most efficient leaching method because it provides high quality water at relatively low rates of application.

Drainage

Salinity problems in many irrigation projects in arid and semi-arid areas are associated with the presence of a shallow water table. The role of drainage in this context is to lower the water table to a desirable level, at which it does not contribute to the transport of salts to the root zone and the soil surface by capillarity. What is important is to maintain a downward movement of water through soils. Van Schilfgaard (1984) reported that drainage criteria are frequently expressed in terms of critical water table depths; although this is a useful concept, prevention of salinization depends on the establishment, averaged over a period, of a downward flux of water. Another important element of the total drainage system is its ability to transport the desired amount of drained water out of the irrigation scheme and dispose of it safely. Such disposal can pose a serious problem, particularly when the source of irrigation water is treated wastewater, depending on the composition of the drainage effluent.

Timing of irrigation

The timing of irrigation, including irrigation frequency, pre-planting irrigation and irrigation prior to a winter rainy season can reduce the salinity hazard and avoid water stress between irrigations. Some of these practices are readily applicable to wastewater irrigation.

In terms of meeting the water needs of crops, increasing the frequency of irrigation will be desirable as it eliminates water stress between irrigations. However, from the point of view of overall water management, this may not always produce the desired results. For example, with border, basin and other flood irrigation methods, frequent irrigations may result in an unacceptable increase in the quantity of water applied, decrease in water use efficiency and larger amounts of water to be drained. However, with sprinklers and localized irrigation methods, frequent applications with smaller amounts may not result in decrease in water use efficiency and, indeed, could help to overcome the salinity problem associated with saline irrigation water.

Pre-planting irrigation is practised in many irrigation schemes for two reasons, namely: (i) to leach salts from the soil surface which may have accumulated during the previous cropping period and to provide a salt-free environment to germinating seeds (it should be noted that for most crops, the seed germination and seedling stages are most sensitive to salinity); and (ii) to provide adequate moisture to germinating seeds and young seedlings. A common practice among growers of lettuce, tomatoes and other vegetable crops is to pre-irrigate the field before planting, since irrigation soon after planting could create local water stagnation and wet spots that are not desirable. Treated wastewater is a good source for pre-irrigation as it is normally not saline and the health hazards are practically nil.

Blending of wastewater with other water supplies

One of the options that may be available to farmers is the blending of treated sewage with conventional sources of water, canal water, or ground water, if multiple sources are available. It is possible that a farmer may have saline ground water and, if he has non-saline treated wastewater, could blend the two sources to obtain a blended water of acceptable salinity level. Further, by blending, the microbial quality of the resulting mixture could be superior to that of the unblended wastewater.

Alternating treated wastewater with other water sources

Another strategy is to use the treated wastewater alternately with the canal water or groundwater, instead of blending. From the point of view of salinity control, alternate applications of the two sources will be superior to blending. However, an alternating application strategy will require duel conveyance systems and availability of the effluent dictated by the alternate schedule of application.

Land and soil management

Several land and soil management practices can be adopted at the field level to overcome salinity, sodicity, toxicity, and health hazards that might be associated with the use of treated wastewater.

Land development

During the early stages of on-farm land development, steps can be taken to minimize potential hazards that may result from the use of wastewater. These will have to be well planned, designed and executed since they are expensive and, often, one time operations. Their goal is to improve permanently existing land and soil conditions in order to make irrigation with wastewater easier. Typical activities include levelling of land to a given grade, establishing adequate drainage (both open and sub-surface systems), deep ploughing and leaching to reduce soil salinity.

Land grading

Land grading is important to achieve good uniformity of application from surface irrigation methods and acceptable irrigation efficiencies in general. If the wastewater is saline, it is very important that the irrigated land be appropriately graded. Salts accumulate in the high spots that have too little water infiltration and leaching, while in the low spots water accumulates, causing water logging and soil crusting.

Land grading is well accepted as an important farm practice in irrigated agriculture. Several methods are available to grade land to a desired slope. The slope required will vary with the irrigation system, length of run of water flow, soil type, and the design of the field. Recently, laser techniques have been applied to level land precisely to obtain high irrigation efficiencies and prevent salinization.

Deep cultivation

In certain areas, the soil is stratified, and such soils are difficult to irrigate. Layers of clay, sand, or hardpan in stratified soils frequently impede or prevent free movement of water through and beyond the root zone. This will not only lead to saturation of the root zone but also to accumulation of salts in the root zone. Irrigation efficiency as well as water movement in the soil can be greatly enhanced by sub-soiling and chiselling of the land. The effects of sub-soiling and chiselling remain for about 1 to 5 years but, if long term effects are required, the land should be deep, and slip ploughed. Deep or slip ploughing is costly and usually requires the growing of annual crops soon after to allow the settling of the land. Following a couple of grain crops, grading will be required to re-establish a proper grade to the land.

Crop management and cultural practices

Several cultural and crop management practices that are valid under saline water use will be valid under wastewater use. These practices are aimed at preventing damage to crops caused by salt accumulation surrounding the plants and in the root zone and adjusting fertilizer and agrochemical applications to suit the quality of the wastewater and the crop.

Placement of seed

In most crops, seed germination is more seriously affected by soil salinity than other stages of development of a crop. The effects are pronounced in furrow-irrigated crops, where the water is fairly to highly saline. This is because water moves upwards by capillarity in the ridges, carrying salts with it. When water is either absorbed by roots or evaporated, salts are deposited in the ridges. Typically, the highest salt concentration occurs in the centre of the ridge, whereas the lowest concentration of salt is found along the shoulders of the ridges. An efficient means of overcoming this problem is to ensure that the soil around the germinating seeds is sufficiently low in salinity. Appropriate planting methods, ridge shapes, and irrigation management can significantly decrease damage to germinating seeds. Some specific practices include:

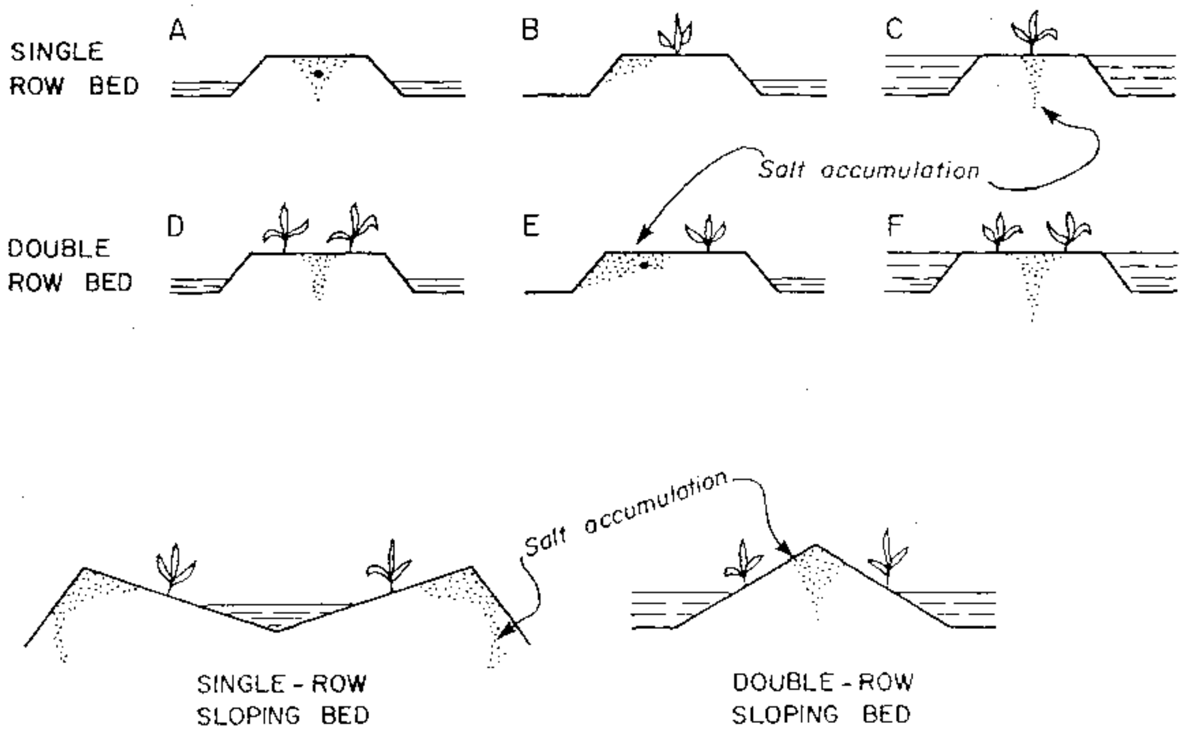
i. Planting on the shoulder of the ridge in the case of single row planting or on both shoulders in double row planting,

ii. Using sloping beds with seeds planted on the sloping side, but above the water line,

iii. Irrigating alternate rows so that the salts can be moved beyond the single seed row.

Figure F-3 presents schematic representations of salt accumulation, planting positions, ridge shapes and watering patterns.

Figure F-3: Schematic representations of salt accumulation and planting methods in ridge and furrow irrigation (Bernstein and Fireman 1957)



Planning for wastewater irrigation

Central planning

Government policy on effluent use in agriculture will have a deciding effect on what control measures can be achieved through careful selection of site and crops to be irrigated with treated effluent. A decision to make treated effluent available to farmers for unrestricted irrigation or to irrigate public parks and urban green areas with effluent will remove the possibility of taking advantage of careful selection of sites, irrigation techniques, and crops in limiting the health risks and minimizing environmental impacts. However, if a Government decides that effluent irrigation will only be applied in specific controlled areas, even if crop selection is not limited (that is, unrestricted irrigation is allowed within these areas), public access to the irrigated areas will be prevented and some of the control measures described in Chapter 2 can be applied. Without doubt, the greatest security against health risk and adverse environmental impact will be achieved by limiting effluent use to restricted irrigation on controlled areas to which the public has no access but even imposing restrictions on effluent irrigation by farmers, if properly enforced, can achieve a degree of control.

Cobham and Johnson (1988) have suggested that the procedures involved in preparing plans for effluent irrigation schemes are similar to those used in most forms of resource planning and summarized the main physical, social, and economic dimensions as in Figure F-4. They also indicated that a number of key issues or tasks were likely to have a significant effect on the ultimate success of effluent irrigation, as follows:

i. organizational and managerial provisions made to administer the resource, to select the effluent use plan and to implement it,

ii. The importance attached to public health considerations and the levels of risk taken,

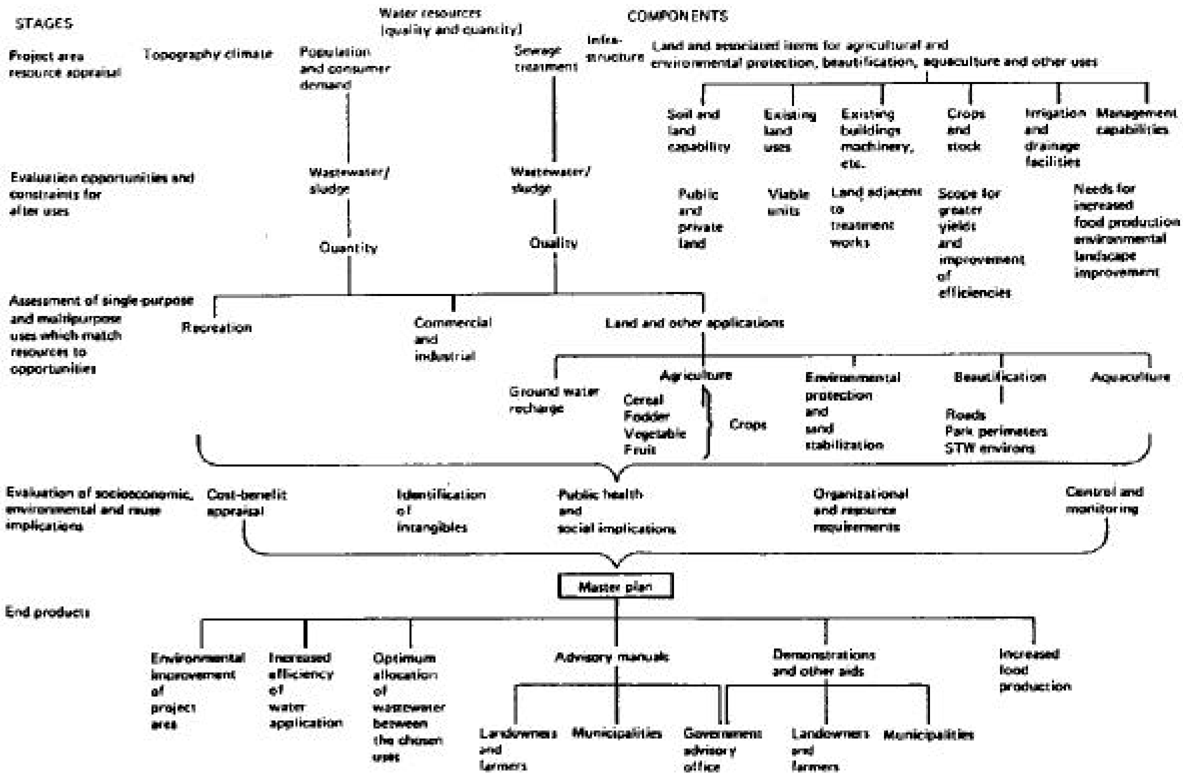
iii. The choice of single-use or multiple-use strategies,

iv. The criteria adopted in evaluating alternative reuse proposals,

v. The level of appreciation of the scope for establishing a forest resource.

Adopting a mix of effluent use strategies is normally advantageous in respect of allowing greater flexibility, increased financial security and more efficient use of the wastewater throughout the year, whereas a single-use strategy will give rise to seasonal surpluses of effluent for unproductive disposal. Therefore, in site and crop selection the desirability of providing areas for different crops and forestry so as to utilize the effluent at maximum efficiency over the whole yearly cycle of seasons must be kept in mind.

Figure F-4: Main components of general planning guidelines for wastewater reuse (Cobham and Johnson 1988)



Desirable site characteristics

The features which are critical in deciding the viability of a land disposal project are the location of available land and public attitudes. Land which is far distant from the sewage treatment plant will incur high costs for transporting treated effluent to site and will generally not be suitable. Hence, the availability of land for effluent irrigation should be considered when sewerage is being planned and sewage treatment plants should be strategically located in relation to suitable agricultural sites. Ideally, these sites should not be close to residential areas but even remote land might not be acceptable to the public if the social, cultural, or religious attitudes are opposed to the practice of wastewater irrigation. The potential health hazards associated with effluent irrigation can make this a very sensitive issue and public concern will only be mollified by the application of strict control measures. In arid areas, the importance of agricultural use of treated effluent makes it advisable to be as systematic as possible in planning, developing and managing effluent irrigation projects and the public must be kept informed at all stages.

The ideal objective in site selection is to find a suitable area where long-term application of treated effluent will be feasible without adverse environmental or public health impacts. It might be possible in a particular instance to identify several potential sites within reasonable distance of the sewered community and the problem will be to select the most suitable area or areas, considering all relevant factors. The following basic information on an area under consideration will be of value, if available:

- A topographic map,
- Agricultural soils surveys,
- Aerial photographs,
- Geological maps and reports,
- Groundwater reports and well logs,
- Boring logs and soil test results,
- Other soil and peizometric data.

At this preliminary stage of investigation, it should be possible to assess the potential impact of treated effluent application on any usable aquifer in the area(s) concerned. The first ranking of sites should take into account other factors, such as the cost and location of the land, its present use, and availability, and social factors, in addition to soil and groundwater conditions.

The characteristics of the soil profile underlying a particular site are very important in deciding on its suitability for effluent irrigation and the methods of application to be employed. Among the soil properties important from the point of view of wastewater, application and agricultural production are physical parameters (such as texture, grading, liquid, and plastic limits, etc.), permeability, water-holding capacity, pH, salinity, and chemical composition. Preliminary observation of sites, which could include shallow hand-auger borings and identification of vegetation, will often allow the elimination of clearly unsatisfactory sites. After elimination of marginal sites, each site under serious consideration must be investigated by on-site borings to ascertain the soil profile, soil characteristics, and location of the water table. Peizometers should be located in each borehole and these can be used for subsequent groundwater sampling. A procedure for such site assessment has been described by Hall and Thompson (1981) and, if applied, should not only allow the most suitable site among several possible to be selected but permit the impact of effluent irrigation at the chosen site to be modeled. When a site is developed, a long-term groundwater-monitoring programme should be an essential feature of its management.

Crop selection issues

Normally, in choosing crops, a farmer is influenced by economics, climate, soil and water characteristics, management skill, labour and equipment available and tradition. The degree to which the use of treated effluent influences crop selection will depend on Government policy on effluent irrigation, the goals of the user and the effluent quality. Government policy will have the objectives of minimizing the health risk and influencing the type of productivity associated with effluent irrigation. Regulations must be realistic and achievable in the context of national and local environmental conditions and traditions. At the same time, planners of effluent irrigation schemes must attempt to achieve maximum productivity and water conservation through the choice of crops and effluent application systems.

A multiple-use strategy approach will require the evaluation of viable combinations of the cropping options possible on the land available. This will entail a considerable amount of survey and resource budgeting work, in addition to the necessary soil and water quality assessments. The annual, monthly, and daily water demands of the crops, using the most appropriate irrigation techniques, have to be determined. Domestic consumption, local production, and imports of the various crops must be assessed so that the economic potential of effluent irrigation of the various crop combinations can be estimated. Finally, the crop irrigation demands must be matched with the available effluent to achieve optimum physical and financial utilization throughout the year. This process of assessment is reviewed by Cobham and Johnson (1988) for the case of effluent use in Kuwait, where afforestation for commercial purposes was found to offer significant potential in multiple-use effluent irrigation.

APPENDIX G
EMP COMPLIANCE FORM AND OFFICIAL NOTICE

APPENDIX H
COST OF THE PROPOSED MONITORING PLAN

Table H-1: MONTHLY COST OF PERFORMANCE MONITORING FOR THE EAAS SYSTEM DURING THE EARLY OPERATIONAL PHASE

Sampling Location	*Analytical Parameter*	*Early Operational Phase Sampling Frequency*[10]	*Cost per sample in L.L.*	*Cost/month in L.L.*
Plant Influent or UASB Influent	Biochemical Oxygen Demand $_5$	1/M	30,000.00	30,000.00
	Total Suspended Solids	1/M	22,500.00	22,500.00
	Total Nitrogen[11]	1/M	181,000.00	181,000.00
	Ammonia- nitrogen	M	12,000.00	12,000.00
UASB Effluent / EAAS Influent	BOD_5	1/W	30,000.00	120,000.00
	Total Nitrogen	1/2W	181,000.00	362,000.00
	Ammonia-nitrogen	1/W	12,000.00	48,000.00
	Total solids	1/W	35,000.00	140,000.00
Final settlement tank effluent	BOD_5	1/W	30,000.00	120,000.00
	Total Suspended Solids	1/W	22,500.00	90,000.00
	pH	D		
	Total Nitrogen	1/2W	181,000.00	362,000.00
	Ammonia- nitrogen	1/2W	12,000.00	24,000.00
	Nitrates	1/2W	13,500.00	27,000.00
	Nitrites	1/2W	13,500.00	27,000.00
Post-chlorination	Total & Fecal coliforms	1/W	24,000.00	96,000.00
Sludge holding tank contents (if applicable)	Nitrates	1/W	13,500.00	54,000.00
	Ammonia- nitrogen	1/W	12,000.00	48,000.00
	Total solids	1/W	35,000.00	140,000.00
	Volatile solids	1/2W	22,500.00	45,000.00
Settled sludge in holding tank	Nitrates	1/W	13,500.00	54,000.00
	Ammonia	1/W	12,000.00	48,000.00
	Total solids[12]	1/W	35,000.00	140,000.00
	Volatile solids	1/2W	22,500.00	45,000.00
			subtotal/month	2,235,500.00

[10] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months
[11] Carbon, Hydrogen, Nitrogen and Sulfur are sampled together using Elemental Analyzer method
[12] Sum of Total Suspended Solids and Total Dissolved Solids

Table H-2: MONTHLY COST OF PERFORMANCE MONITORING FOR THE EAAS SYSTEM DURING THE ADVANCED OPERATIONAL PHASE

Sampling Location	*Analytical Parameter*	*Advanced Operational Phase Sampling Frequency*[13]	*Cost per sample in L.L.*	*Cost/month in L.L.*
Plant Influent or UASB Influent	Biochemical Oxygen Demand $_5$	1/2M	30,000.00	15,000.00
	Total Suspended Solids	1/2M	22,500.00	11,250.00
	Total Nitrogen[14]	1/2M	181,000.00	100,000.00
	Ammonia- nitrogen	1/2M	12,000.00	6,000.00
UASB Effluent / EAAS Influent	BOD_5	1/2W	30,000.00	60,000.00
	Total Nitrogen	M	181,000.00	181,000.00
	Ammonia-nitrogen	M	12,000.00	12,000.00
	Total solids	1/2W	35,000.00	70,000.00
Final settlement tank effluent	BOD_5	1/2W	30,000.00	60,000.00
	Total Suspended Solids	1/2W	22,500.00	90,000.00
	pH	D	8,000.00	
	Total Nitrogen	M	181,000.00	181,000.00
	Ammonia- nitrogen	M	12,000.00	12,000.00
	Nitrates	M	13,500.00	13,500.00
	Nitrites	M	13,500.00	13,500.00
Post-chlorination	Total & Fecal coliforms	1/2W	24,000.00	48,000.00
Sludge holding tank contents (if applicable)	Nitrates Ammonia- nitrogen	M M	13,500.00 12,000.00	13,500.00 12,000.00
	Total solids[15]	1/2W	35,000.00	70,000.00
	Volatile solids	M	22,500.00	22,500.00
Settled sludge in holding tank	Nitrates	M	13,500.00	13,500.00
	Ammonia	M	12,000.00	12,000.00
	Total solids	1/2W	35,000.00	70,000.00
	Volatile solids	M	22,500.00	22,500.00
			subtotal/month	1,109,250.00

[13] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months
[14] Carbon, Hydrogen, Nitrogen and Sulfur are sampled together using Elemental Analyzer method
[15] Sum of Total Suspended Solids and Total Dissolved Solids

Table H-3: MONTHLY COST OF PERFORMANCE MONITORING FOR THE EAAS SYSTEM FOR MINIMAL SAMPLING

Sampling Location	*Analytical Parameter*	*Minimum sampling*[16]	*Cost per sample in L.L.*	*Cost/month in L.L.*
Plant Influent or UASB Influent	Biochemical Oxygen Demand $_5$	1/3M	30,000.00	10,000.00
	Total Suspended Solids	1/3M	22,500.00	7,500.00
	Total Nitrogen[17]	1/3M	181,000.00	60,333.33
	Ammonia- nitrogen	1/3M	12,000.00	4,000.00
UASB Effluent / EAAS Influent	BOD_5	M	30,000.00	30,000.00
	Total Nitrogen	1/2M	181,000.00	90,500.00
	Ammonia-nitrogen	1/2M	12,000.00	6,000.00
	Total solids	M	35,000.00	35,000.00
Final settlement tank effluent	BOD_5	M	30,000.00	30,000.00
	Total Suspended Solids	M	22,500.00	22,500.00
	pH	D	8,000.00	
	Total Nitrogen	1/2M	181,000.00	90,500.00
	Ammonia- nitrogen	1/2M	12,000.00	6,000.00
	Nitrates	1/2M	13,500.00	6,750.00
	Nitrites	1/2M	13,500.00	6,750.00
Post-chlorination	Total & Fecal coliforms	M	24,000.00	24,000.00
Sludge holding tank contents (if applicable)	Nitrates	1/2M	13,500.00	6,750.00
	Ammonia- nitrogen	1/2M	12,000.00	6,000.00
	Total solids[18]	M	35,000.00	35,000.00
	Volatile solids	M	22,500.00	22,500.00
Settled sludge in holding tank	Nitrates	1/2M	13,500.00	6,750.00
	Ammonia	1/2M	12,000.00	6,000.00
	Total solids	M	35,000.00	35,000.00
	Volatile solids	M	22,500.00	22,500.00
			subtotal/month	570,333.33

[16] D: daily, 1/W: once per week, 1/2W: once per two weeks, M: monthly, 1/2M: once per two months, 1/3M once per three months

[17] Carbon, Hydrogen, Nitrogen and Sulfur are sampled together using Elemental Analyzer method

[18] Sum of Total Suspended Solids and Total Dissolved Solids