Management Practices of Sludge and Bio-solids in Jordan
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Table of Contents

List of Tables

List of figures

List of Abbreviations

BDRC	:	Badia Research and Development Center.
ERC	:	Environmental Research Center.
IALC	:	International Arid Lands Consortium.
MWI	:	Ministry of Water and Irrigation.
MWTPs	:	Municipal Wastewater Treatment Plants.
RBCs	:	Rotating Biological Contactors.
RSS	:	Royal Scientific Society.
TFCC	:	Total Fecal Coliform Count.
USAID	:	United States Agency for International Development.
WAJ	:	Water Authority of Jordan.

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MANAGEMENT PRACTICES OF SLUDGE AND BIO-SOLIDS IN JORDAN

1. INTRODUCTION

Disposal of bio-solids (treated sewage sludge) represents an increasing challenge all over the world. The presence of pollutants and micro-organisms in sewage sludge is a potential health risk as a consequence of some ultimate disposal and utilization practices (i.e. ocean disposal, land application, landfill and incineration).

Recent changes in regulations concerning municipal wastewater treatment in Jordan have resulted in a significant increase in treated domestic wastewater production and, accordingly, bio-solids quantities. The majority of municipal wastewater treatment plants MWTPs in the country are of secondary type, achieving nutrient and pathogen reduction utilizing conventional and modified activated sludge processes that generate relatively huge amounts of Class B bio-solids. Bio-solids generated at MWTPs are usually thickened, dewatered using drying beds, then hauled by private contractors to dumping sites, while anaerobic lagoons are occasionally de-sludged for operational purposes, and bio-solids are inadequately stored in near-by areas. In other words, none of the bio-solids are currently being reused or recycled. Obviously, these current practices cannot be continued indefinitely. Adverse impacts may include potential operational problems such as leachate management (especially in rainy seasons) and gas hazards. Although a Jordanian standard (JS:1145/1996) was issued in 1996 to regulate the production and reuse of bio-solids for agricultural purposes, still there are no systematic data on generated quality and quantities. Treatment, handling and management practices in general are not well investigated and assessed.

Since 2003, the Royal Scientific Society RSS of Jordan is being involved in conducting applied research programs in fields of bio-solids characterization as well as agricultural land application of bio-solids. These activities have been financially supported by the Sustainable Development of Dry Lands Project that is funded by the United States Agency for International Development USAID (Washington and Jordan/ the office of Water Resources and Environment Office-Jordan) under a cooperative agreement with the International Arid Lands Consortium IALC / University of Arizona, and is run through the Jordan Badia Research & Development Center BRDC.

In September 2005, USAID approved a request by RSS through BRDC to financially support a field survey to investigate and assess current management practices of sludge and bio-solids in Jordan including treatment, handling, testing, disposal and application.

2. METHODOLOGY OF WORK

Representatives of RSS and the Ministry of Water & Irrigation MWI / Water Authority of Jordan WAJ (the official body responsible for the provision of water supply and sanitation services) met several times to set-up the work plan and issues need to be taken into consideration throughout the field survey. The following staff were directly involved in executing the survey that was conducted during the period (August-December 2005):

1. Eng. Saleh Malkawi: MWI/WAJ.
2. Eng. Ahmad Ulimat: Directorate of Water Quality, MWI/WAJ.
3. Eng. Wa'el Suleiman: Environmental Research Center ERC /RSS.
4. Eng. Asma Alsheraideh : Environmental Research Center ERC /RSS.

The following MWTPs operated by MWI/WAJ were covered by the survey: Abu-Nuseir, Baq'a, Salt, Fuheis, Central Irbid, Jerash, Wadi Arab, Kufranjeh, As-Samra, Mafraq, Karak, Tafilah, Wadi Mousa, Wadi Hassan, Aqaba, Ramtha, Wadi Al-seir, Madaba and Ma'an. The survey team visited each of these plants and met the persons in charge in order to collect the required data and obtain any important documents.

The following topics and issues were taken into account throughout the survey, and a checklist (see annex (1)) was prepared for this purpose:

1. Treatment processes of sludge (design criteria, resident time and others).
2. Available data on sludge/bio-solids quality (physical, chemical and microbial aspects).
3. Testing procedures adopted for bio-solids.
4. Available data on sludge/bio-solids generated quantities (liquid, dewatered and others).
5. Handling and disposal practices as well as costs entailed.
6. Fate of generated sludge/bio-solids.
7. Previous reuse/application (if any).

3. RESULTS AND OUTCOMES

3.1 Madaba Treatment Plant

Madaba wastewater treatment plant started operation in (1988). The treatment system used to be of waste stabilization ponds type, then later in (2002) it was changed to mechanical system (activated sludge). The treatment plant currently serves about (50,000) inhabitants living in Madaba city. In addition, a soft drink factory (Coca Cola) and an elevators factory discharge generated wastewater to the public sewerage network leading to the treatment plant. Table (1) below shows the design and actual hydraulic and organic loads for the treatment plant at different operational years. The trend shows an increase in both hydraulic as well as organic loading over the period (2002-2005). The treatment plant is currently operating at (72%) of its hydraulic capacity, while the organic and solids loads are (107%) and (145%) of the design values respectively.

Table(1): Actual and design loads for Madaba treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	4,176	4,422	4,542	5,500	7,600
BOD_5	mg/l	1,045	1,137	1,301	1,400	950
	kg/d	4,364	5,028	5,909	7,700	7,220
TSS	mg/l	965	1,218	1,226	2,000	1,000
	kg/d	4,030	5,386	5,568	11,000	7,600

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Wastewater Treatment :

Figure (1) shows a schematic flowchart of Madaba wastewater treatment plant. Treatment operations start with preliminary treatment including screens and grease removal units. The secondary treatment (activated sludge/extended aeration system) follows and consists of an aeration tank, two secondary clarifiers, and two polishing ponds. Reclaimed water is discharged to a near-by stream.

Sludge Treatment:

The sludge treatment units consist of two thickeners followed by drying beds series. Table (2) shows the design criteria for thickeners operated at the treatment plant compared to some typical design values.

Table (2): Design criteria for thickeners at Madaba treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	$kg/m^2.d$	107	24.4-34.2**
Disposed sludge from thickener	m^3/d kg solids /d	250-300 (TS=3%) 8,250	-
No. of units	-	2	-
Depth	m	4.5	-
Total surface area	m^2	77	241***

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

It can be noticed from table (2) above that the total surface area of the thickeners is not sufficient to handle the solids loading since the solids loading is relatively high compared to the typical values. In order to satisfy the typical design conditions, an area three times what is currently available is needed.

Table (3) below shows the actual and typical design for drying beds operated at the treatment plant compared to some typical values. It can be seen that the total area of the drying beds is sufficient to treat the disposed sludge quantities from the thickeners, an area of (18,720 m^2) is available while only (10,000 m^2) is required. The drying beds dimensions also fit into typical values.

Table (3): Actual and typical design for drying beds at Madaba treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	18,720	10,000 (0.16-0.23m^2/capita)
Number of units	-	156	-
Length	m	20	6-30
Width	m	6	6
Sludge depth	cm	35	20-30
Detention time	days	20-30	-
Aggregate layer depth	cm	90	23-30

* Source: WAJ documents and person in charge at the treatment plant.
* Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:

Table (4) below shows the liquid sludge and dewatered bio-solids generation rates at Madaba wastewater treatment plant. The treatment plant generates about (250-300m^3/day) of liquid sludge during the period (November to April) and only (5m^3/day) of dewatered bio-solids during the period (May to October). In other words, about (900m^3) of dewatered bio-solids is generated annually compared to (50,200m^3) of liquid sludge.

Table (4): Sludge/bio-solids generation at Madaba MWTP*.

Item	Liquid sludge	Dewatered bio-solids
Generation rate (m^3/day)	250-300	5
Generation period	Nov.-Apr.	May-Oct.
Total generated amounts (m^3/ year)	50,200	900

* Source: WAJ documents and person in charge at the treatment plant.

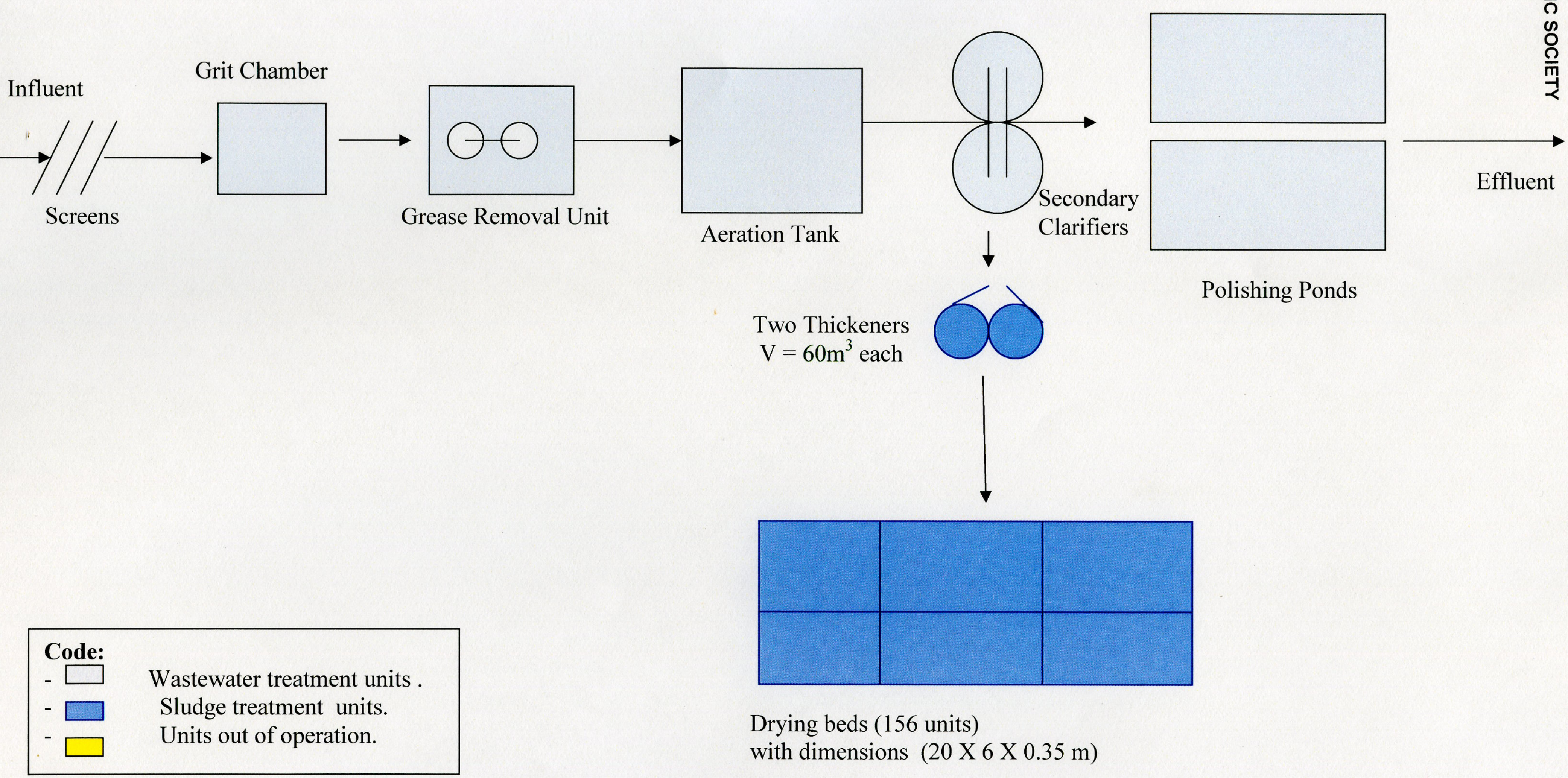


Figure (1): Madaba wastewater treatment plant / schematic flowchart.

Sludge Disposal and Entailed Costs:

Generated liquid sludge is currently disposed of at Ain Ghazal treatment plant, about (45) km away from the treatment plant, while dewatered bio-solids is usually accumulated within the premises of the treatment plant, then periodically hauled by private contractors to As-Samra treatment plant, about (60) km away from the plant. Table (5) shows annual estimated costs of transferring sludge/bio-solids to damping sites.

Table (5): Sludge/bio-solids estimated transfer costs for Madaba MWTP*.

Item	Liquid sludge	Dewatered bio-solids
Transfer costs (JD/m^3)	2	9
Total transfer costs (JD/year)	100,400	8,100
Total Transfer Cost: 108,500 (JD / year)		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:

There are no available data on the quality of generated sludge/bio-solids. It is not common to analyze for sludge samples at WAJ laboratories as the technical capabilities are not available. In view of this, no plans exist currently for utilizing bio-solids generated at the treatment plant.

3.2 Abu- Nuseir Treatment Plant

Abu-Nuseir wastewater treatment plant started operation in (1986) to serve the inhabitants of Abu-Nuseir new residential town. The operation system is of activated sludge type, and the inflow is mainly of domestic type as the plant is currently serving about (35,000) inhabitants. Table(6) shows the actual and design loads for Abu-Nuseir wastewater treatment plant at different operational years.

Table(6): Actual and design loads for Abu-Nuseir treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	1,977	2,215	2,265	2,300	4,000
BOD_5	mg/l	544	525	485	550	1,100
	kg/d	1,075	1,163	1,098	1,265	4,400
TSS	mg/l	547	551	509	-	1,000
	kg/d	1,081	1,220	1,153		4,000

*Source: WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (6) shows slight increase in hydraulic and organic loadings over the period (2002-2005), however, it can be noted that the treatment plant is currently operating at only (57%) of its hydraulic capacity and (29%)of its design organic load.

Wastewater Treatment :
Figure (2) shows a schematic flowchart of Abu-Nuseir wastewater treatment plant. Preliminary treatment consists of equalization basin, screens and grit removal, while primary treatment consists of primary sedimentation tank. Secondary treatment consists of two aeration tanks followed by two secondary sedimentation tanks. Rotating Biological Contactors (RBCs) are not currently utilized because of the low hydraulic loads coming to the plant. Reclaimed wastewater is currently utilized in irrigation and landscaping.

Sludge Treatment:
Sludge is only thickened at the treatment plant, there is one thickener as shown in figure(2) with a volume of (350m^3). Influent to the thickener is about (350 m^3/d). A filter press and an aerobic digester exist but are not set in operation because of high operational costs (as per the person in charge). Table (7) shows the actual and typical design for thickeners operated at Abu-Nuseir wastewater treatment plant.

Table (7): Actual and typical design for thickeners at Abu-Nuseir treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	kg/m^2.d	20	24.4-34.2**
Disposed sludge from thickener	m^3/d kg solids /d	80 2400	-
No. of units	-	1	-
Depth	m	3	-
Total surface area	m^2	117	82***
Detention time	hour	24	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

It can be shown from table(7) that the solids loading is less than recommended values, and the actual surface area satisfies what is needed, an area of (82 m^2) is recommended while (117 m^2) is available.

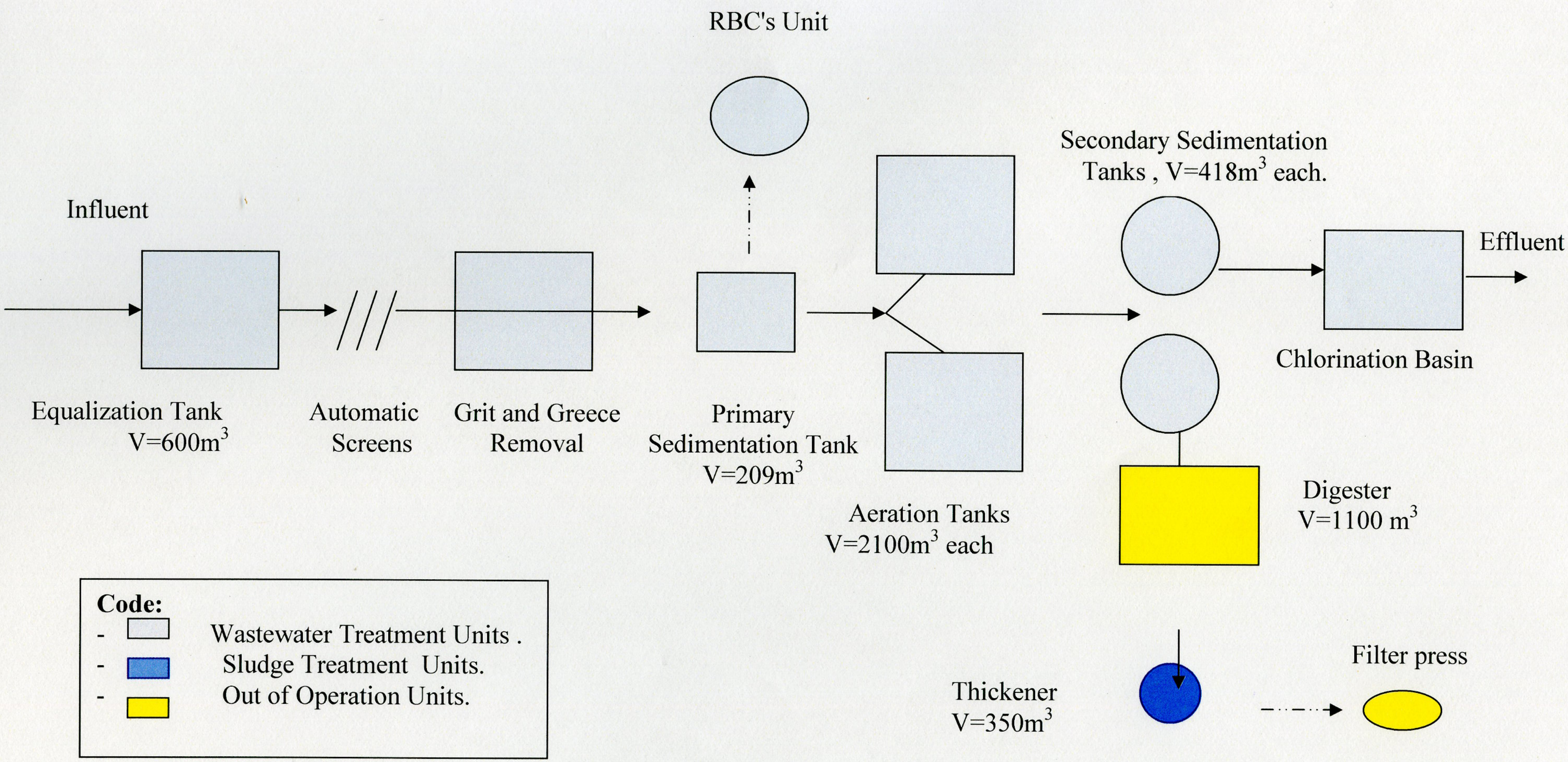
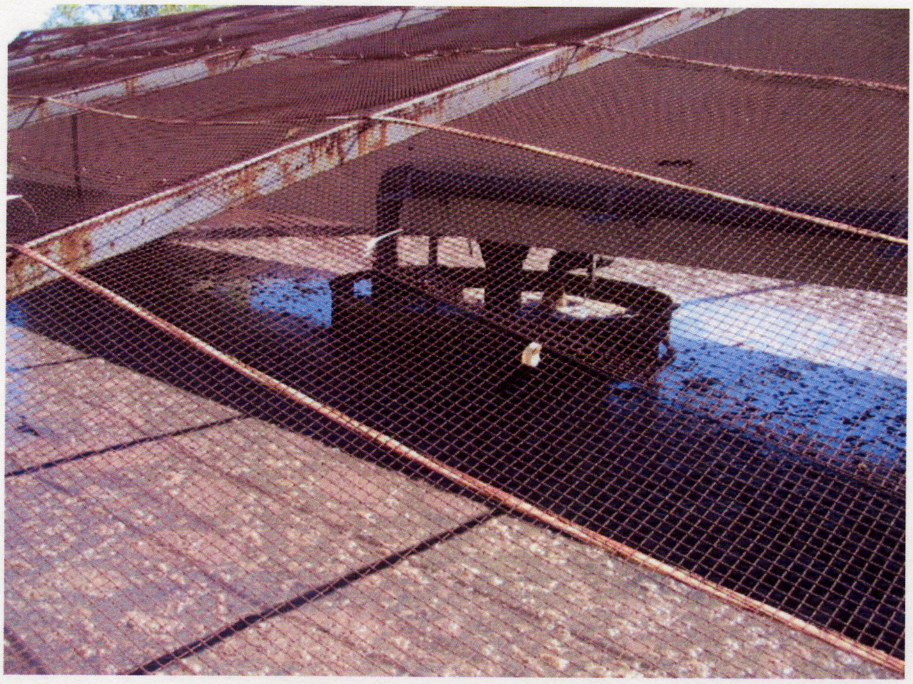
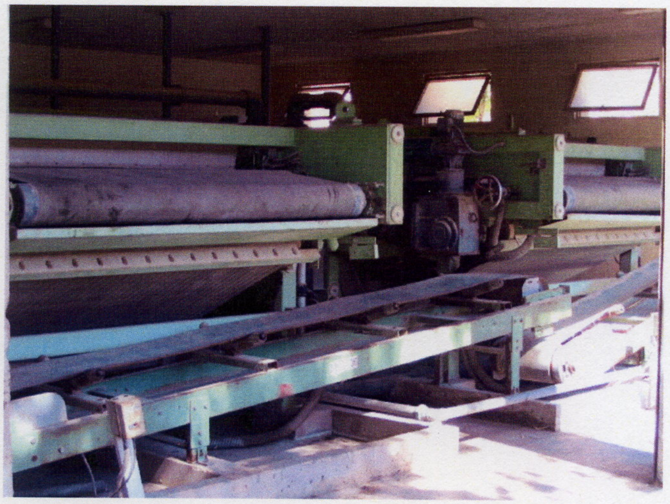


Figure (2): Abu Nuseir wastewater treatment plant / schematic flowchart.



Figure(3):Thickener at Abu-Nuseir MWTP.

a: Aerobic digester



b: Filter press

Figure(4):Unused aerobic digester and filter press at Abu-Nuseir MWTP.

Sludge Generation Rates:

Table(8) shows the liquid sludge generation at Abu-Nuseir wastewater treatment plant. Sludge is generated at a rate of ($80m^3/d$), the total amount generated per year is ($29,200m^3$).

Table (8): Liquid sludge generation at Abu-Nuseir MWTP*.

Item	Liquid Sludge
Generation rate (m^3/day)	80
Generation period	allover the year
Total generated amounts (m^3/ year)	29,200

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:

Liquid sludge is currently disposed of at Ain Ghazal treatment plant, about (25 km) away from the plant. Table (9) shows annual estimated costs of transferring sludge to Ain Ghazal.

Table (9): Sludge estimated transfer costs for Abu-Nuseir MWTP.

Item	Liquid Sludge
Transfer cost (JD/m^3)	0.55
Total transfer cost (JD/year)	16,060

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:
No data are available regarding the quality of generated sludge. During late eighties, generated bio-solids coming out of the filter press (was in operation at that time) were given to farmers in the area, but this was forbidden at that time by WAJ because of health concerns.

3.3 Fuheis Treatment Plant

Fuheis wastewater treatment plant started operation in (1997) , the operation system is of activated sludge type. The treatment plant serves about (23,000) inhabitants in addition to some industrial activities such as food factories (four factories) and olive mills. Table (10) below shows the actual and design loads for Fuheis wastewater treatment plant at different operational years.

Table(10): Actual and design loads for Fuheis treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	1,523	1,942	1,560	1,600	2,400
BOD_5	mg/l	679	604	595	600	1,000
	kg/d	1,034	1,173	928	960	2,400
TSS	mg/l	600	577	557	600	-
	kg/d	914	1,120	869	960	

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (10) shows that hydraulic and organic loads received by the treatment plant are still below design values, the treatment plant is operating at (67%) of its design hydraulic capacity and (40%) of its design organic loading.

Wastewater Treatment :
Figure (5) shows a schematic flowchart for Fuheis wastewater treatment plant, the treatment system consists of screens followed by equalization tank then grit removal channel. The biological treatment units follow consisting of two aeration basins and two settling tanks, then effluent goes into polishing lagoons (two lagoons). Final effluent is chlorinated before being discharged to a near-by stream.

Sludge Treatment:
The sludge treatment system consists of a thickener followed by drying beds series. Table (11) shows the actual and typical design for the thickener operated at Fuheis wastewater treatment plant.

Table (11): Design criteria for thickener at Fuheis treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	$kg/m^2.d$	34.2	24.4-34.2**
Disposed sludge from thickener	m^3/d	24	-
	kg solid /d	720	
No. of units	-	1	-
Depth	m	4	-
Total surface area	m^2	21	21***
Detention time	hour	24	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

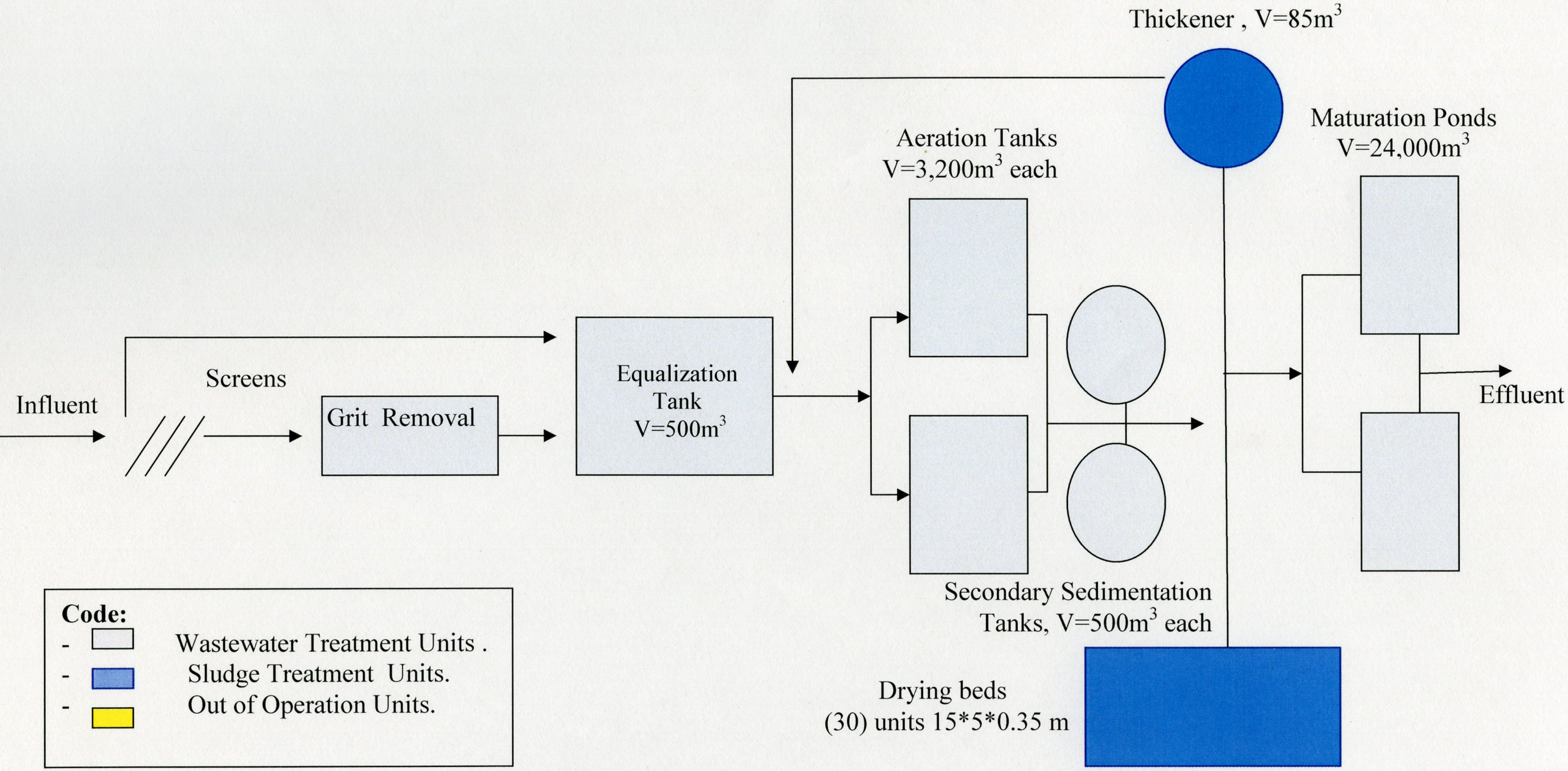


Figure (5): Fuheis wastewater treatment plant/schematic flowchart.

It can be shown from table (11) that the thickener is working under maximum solids loading values compared to typical ones. Moreover, available surface area is just equal to the typical values. This indicates that one thickener will not be sufficient to handle solids loading in the near future, taking into consideration the increasing loads coming to the treatment plant.

Table (12) shows the actual and typical design for drying beds operated at Fuheis wastewater treatment plant. It can be shown that the actual area of the drying beds is not sufficient to treat the generated sludge, the available area is (2,250 m^2) while an area of (4,600 m^2) is required.

Table (12): Actual and typical design for drying beds at Fuheis treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	2,250	4,600 (0.16-0.23m^2/capita)
Number of units	-	30	-
Length	m	15	6-30
Width	m	5	6
Sludge Depth	cm	35	20-30
Detention Time	days	30	-
Aggregate Layer Depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:

Table (13) shows the liquid sludge and dewatered bio-solids generation at Fuheis treatment plant. The plant generates about (24 m^3/day) of liquid sludge from October to May, and only (0.72 m^3/day) dewatered bio-solids from June to September. About (130m^3) of dewatered bio-solids is generated annually compared to (4,380 m^3) of liquid sludge.

Table (13): Sludge/bio-solids generation at Fuheis MWTP*.

Item	Liquid Sludge	Dewatered bio-solids
Generation rate (m^3/day)	24	0.72
Generation period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	4,380	130

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:
Generated liquid sludge is currently transferred to Ain Ghazal treatment plant while dewatered bio-solids is usually collected within the premises of the treatment plant then transferred by a private contractor to As-Samra treatment plant.

Table (14) shows sludge/bio-solids transfer costs. One cubic meter of liquid sludge costs (1.8 JD) while that cost is (7.0 JD) for dewatered bio-solids. The total annual transfer cost is about (8,800 JD).

Table (14): Sludge/bio-solids estimated transfer costs for Fuhais MWTP*.

Item	Liquid Sludge	Dewatered bio-solids
Transfer cost (JD/m^3)	1.8	7.0
Total transfer cost (JD/year)	7,880	910
Total Transfer Cost : 8,800(JD / year)		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge. In addition, generated bio-solids have not yet been utilized.

3.4 Salt Treatment Plant

Salt wastewater treatment plant stared operation in (1982) , the operation system is activated sludge. The plant is serving about (55,000) inhabitants living in Salt city in addition to some industrial activities such as drug factories, restaurants and a slaughterhouse. Table(15) shows the actual and design loads for Salt treatment plant at different operational years.

Table(15): Actual and design loads for Salt treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	3,898	4,248	4,431	5,200	7,600
BOD_5	mg/l	764	843	819	850	600
	kg/d	2,978	3,581	3,629	4,420	4,560
TSS	mg/l	822	811	843	880	600
	kg/d	3,204	3,445	3,735	4,576	4,560

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (15) shows an increase in hydraulic as well as organic and suspended solids loads over the years (2002-2005). The treatment plant is currently operating at (68%) of its hydraulic capacity and (97%) of its design organic load.

Wastewater Treatment :
Figure (6) shows the treatment processes at Salt treatment plant which consists of screening unit followed by grit removal channel and primary sedimentation tanks. The biological treatment units follow consisting of two aeration basins followed by three sedimentation tanks and polishing ponds. Reclaimed water is chlorinated before being discharged to Salt Wadi.

Sludge Treatment:
The sludge treatment system consists of two thickeners followed by drying beds series. Table (16) shows the design criteria for thickeners operated at Salt wastewater treatment plant.

Table (16): Design criteria for thickeners at Salt treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	$kg/m^2.d$	70	24.4-34.2**
Disposed sludge from thickener	m^3/d kg solid /d	100 3,000	-
No. of units	-	2	-
Depth	m	7	-
Total surface area	m^2	42.8	102***
Detention time	hour	24	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

Table (16) shows that the total surface area of the thickeners is not sufficient to handle solids loading, the actual area is only (42.8 m^2) while an area of (102 m^2) is required. Figure (7) shows the sludge thickener at Salt MWTP.

Table (17) shows the actual and typical design for drying beds operated at Salt treatment plant. There are (32) units, it can be noted that the total area of the beds is not sufficient, an area of (11,000 m^2) is required while the available area is only (6,400 m^2).

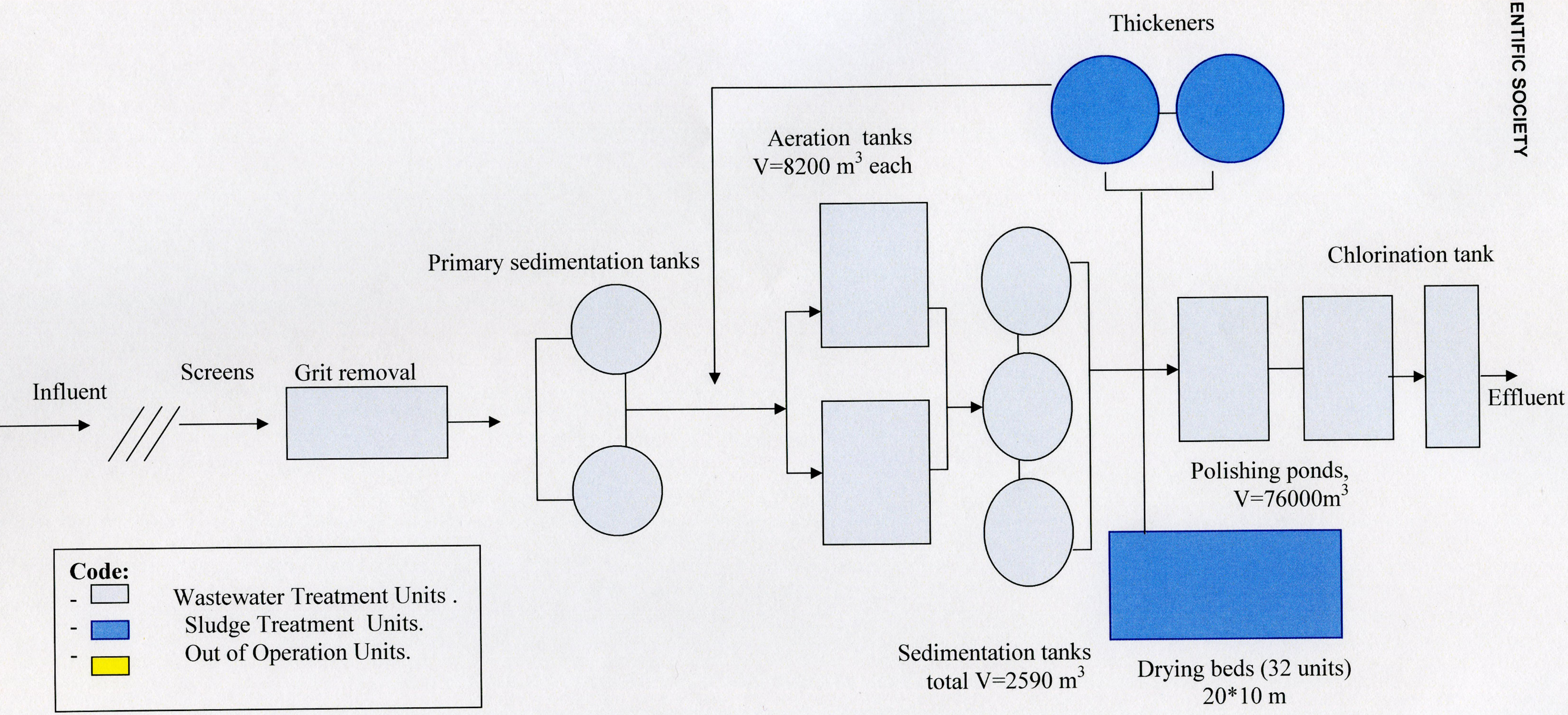


Figure (6): Salt wastewater treatment plant / schematic flowchart.

Figure (7): Sludge thickener at Salt treatment plant

Table (17): Actual and typical design for drying beds at Salt treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	6,400	11,000 (0.16-0.23m^2/capita)
Number of units	-	32	-
Length	m	20	6-30
Width	m	10	6
Sludge depth	cm	35	20-30
Detention time	day	15-20	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:

Table (18) below shows the liquid sludge and dewatered bio-solids generation at Salt wastewater treatment plant. The treatment plant generates about (100m^3/day) of liquid sludge during the period November to April, and (10m^3/day) of dewatered bio-solids and (50 m^3/day) of liquid sludge during the period May to October.

Table (18): Sludge/bio-solids generation at Salt MWTP*.

Item	Generation period	Generation rate (m^3/day)	Total Generated amount (m^3/ year)
Liquid sludge	Nov.-Apr. May-Oct.	100 50	27,375
Dewatered bio-solids	May-Oct.	10	1,825

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:

Liquid sludge is transferred daily to Ain Ghazal treatment plant while dewatered bio-solids is collected and transferred to As-Samra treatment plant. Table (19) shows the sludge/bio-solids transfer costs. One cubic meter of liquid sludge costs (1.8 JD) while for dewatered bio-solids the cost is (7.0 JD). The total annual transfer cost is (62,000 JD).

Table (19): Sludge/bio-solids estimated transfer costs for Salt MWTP*.

Item	Liquid Sludge	Dewatered bio-solids
Transfer cost (JD/m^3)	1.8	7.0
Total transfer cost (JD/year)	49,275	12,775
Total Transfer Cost : **62,000 (JD / year)**		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:

There are no available information about the quality of generated sludge/bio-solids, as mentioned earlier it is not common to analyze for sludge samples at WAJ laboratories. Bio-solids used to be utilized by farmers for agricultural purposes in the past but this is currently forbidden by WAJ.

3.5 Baq'a Treatment Plant

Baq'a wastewater treatment plant started operation in (1988) to serve (250,000) inhabitants living in Baq'a town, Baq'a camp, Saffot and part of Swaileh town. The operation system is trickling filters. Table (20) shows the actual and design loads for Baq'a wastewater treatment plant at different operational years.

Table(20): Actual and design loads for Baq'a treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	11,768	12,052	10,588	10,000	14,900
BOD_5	mg/l	965	986	975	900	800
	kg/d	11,356	11,883	10,323	9000	11,920
TSS	mg/l	930	985	907	-	-
	kg/d	10,944	11,871	9,603		

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (20) shows that the treatment plant is now operating at (67%) of its hydraulic capacity and (76%) of its design organic load.

Wastewater Treatment :
Figure (9) shows the wastewater treatment processes at Baq'a wastewater treatment plant. The operation system consists of screening unit, grit chamber, trickling filters, secondary clarifiers, and finally polishing ponds. Reclaimed water is discharged to a near-by stream.

Sludge Treatment:
The sludge treatment process at Baq'a wastewater treatment plant consists of only three thickeners (Figure (8)), two are usually in operation. There are no drying beds, hence only liquid sludge is generated allover the year.

Figure(8): Sludge thickeners at Baq'a wastewater treatment plant.

Sludge Generation Rates:
The sludge generation rate is about ($250 m^3$/day) resulting in a total amount of ($91,250\ m^3$) annually.

Sludge Disposal and Entailed Costs:
Generated liquid sludge is currently disposed of at Ain Ghazal treatment plant. With regard to transfer costs, one cubic meter of sludge costs (1.0 JD) making the total transfer costs about (91,000 JD/year).

Sludge Quality Monitoring & Utilization:
There are no available information regarding sludge quality, only sludge total solids is measured from time to time. Generated sludge has not been utilized yet.

3.6 Wadi Al-seir Treatment Plant

Wadi Al-seir wastewater treatment plant started operation in (1997), the operation system is aerated lagoons. The treatment plant serves the following towns: Wadi Al-seir, Hai Al-kursi, Wadi Zabda and part of Al-Husein medical city. Table(21) shows the actual and design loads for Wadi Al-seir wastewater treatment plant at different operational years.

Table(21): Actual and design loads for Wadi Al-seir treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	1,917	2,445	2,593	2,700	4,000
BOD_5	mg/l	658	538	661	600	670
	kg/d	1,261	1,315	1,714	1,620	2,680
TSS	mg/l	594	499	581	400	780
	kg/d	1,138	1,220	1,506	1,080	3,120

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table(21) shows an increase in hydraulic loads received by the plant which is still operating below the hydraulic capacity and the organic design loads.

Wastewater Treatment:
The operation system consists of three anaerobic ponds followed by two aerobic ponds and four maturation ponds. Reclaimed water is chlorinated before being discharged to a near-by stream. Figure(10) shows the treatment process at Wadi Al-seir wastewater treatment plant.

Sludge Generation Rates:

Since the start-up of the treatment plant, sludge accumulated at the maturation ponds was disposed of twice; the first was in (2003) and the second was in (2005), while anaerobic ponds were desluged only once during (2005). The previously disposed amounts were about ($960m^3$) from maturation ponds in addition to (3,000-4,000 m^3) disposed from anaerobic ponds. Costs entailed are about (13,000 JD). Desluged quantities were stored within the premises of the treatment plant (Figure (10)).

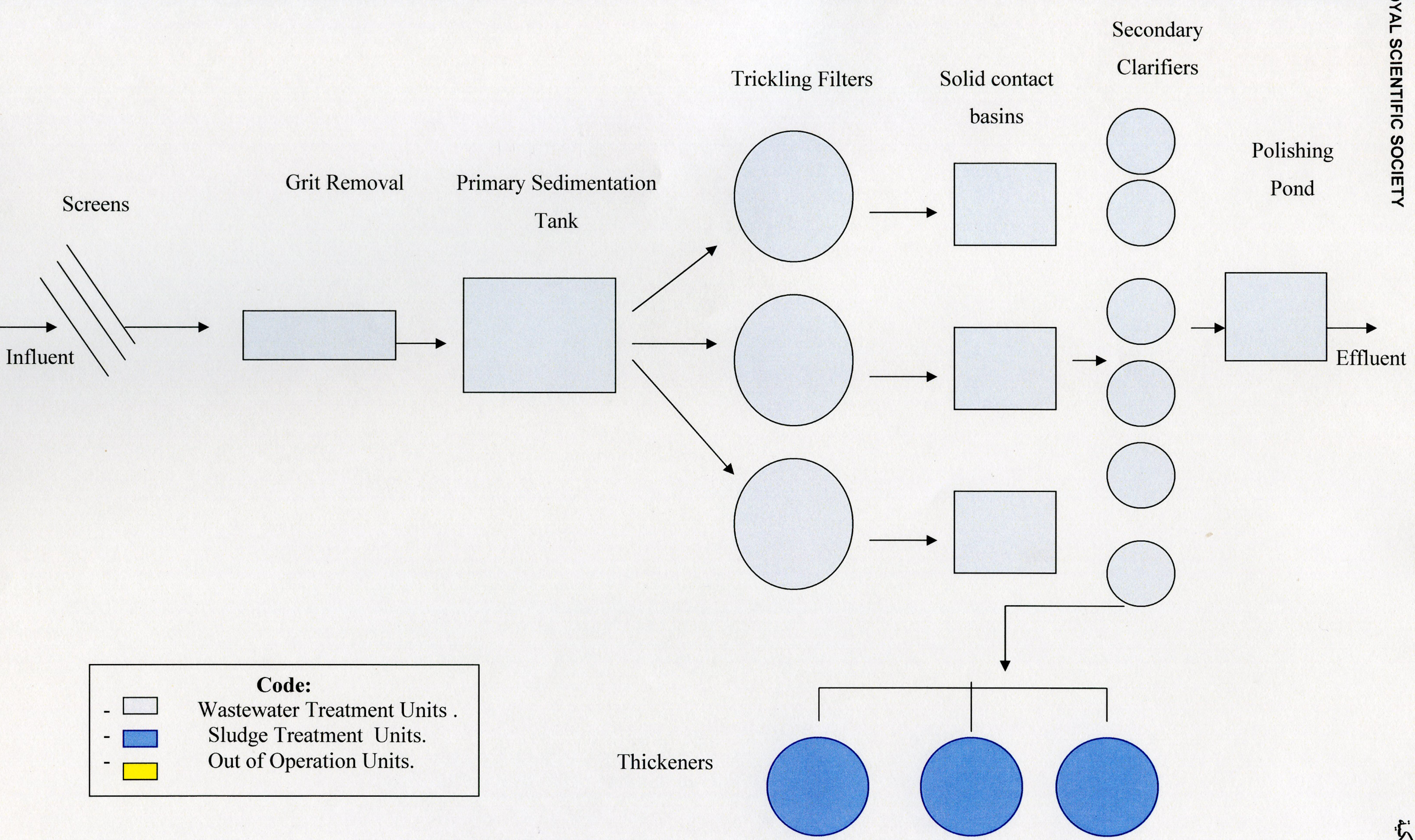


Figure (9): Baq'a wastewater treatment plant / schematic flowchart.

Figure (10): Accumulated disposed sludge at Wadi Al-seir treatment plant.

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge. In addition, generated sludge have not yet been utilized.

3.7 As-Samra Treatment Plant

As-Samra wastewater treatment plant is the largest treatment plant in Jordan, it started operation in (1986) to serve the cities of Amman , Zarqa , Al-Hashmia and Al-Rusaifa. The operation system is stabilization ponds. Table(22) shows the actual and design loads for As-Samra wastewater treatment plant at different operational years.

Organic as well as hydraulic loads coming to the plant grew rapidly over the period (2002-2005). The plant is now operating at (340%) of its hydraulic capacity and (400%)of its design organic load.

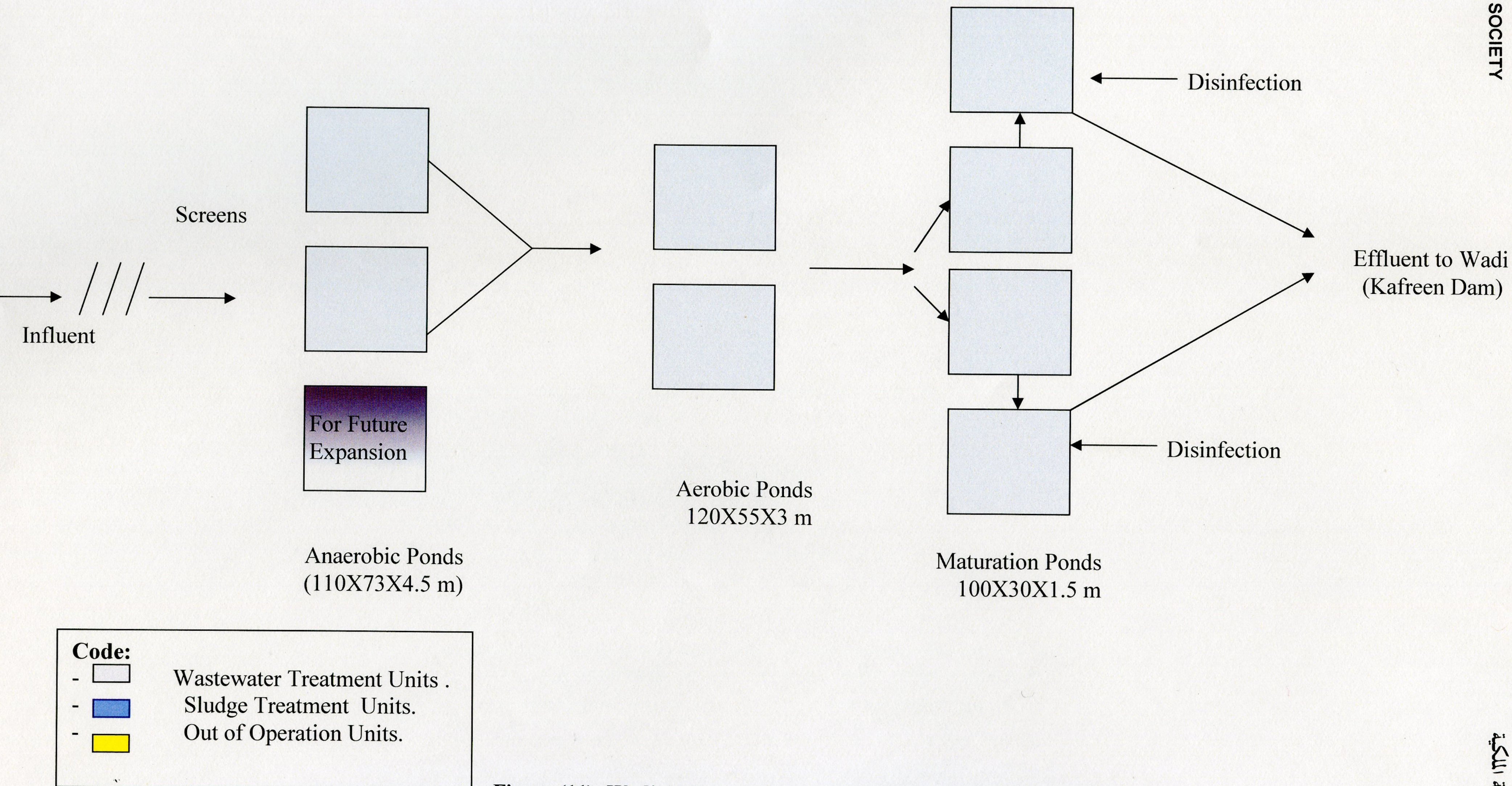


Figure (11): Wadi Al-Seir wastewater treatment plant / schematic flowchart.

Table(22): Actual and design loads for As-Samra treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	178,903	186,823	209,570	230,000	68,000
BOD_5	mg/l	709	693	603	650	526
	kg/d	126,842	129,468	126,371	149,500	35,768
TSS	mg/l	558	563	555	-	-
	kg/d	99,828	105,181	116,311		

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Wastewater Treatment :
Figure (12) shows wastewater treatment processes at As-Samra wastewater treatment plant, the treatment process consists of three stream-lines, each line consists of anaerobic ponds, facultative ponds and maturation ponds.

Sludge Generation Rates:
Because of the operation system type, there is no periodic sludge disposal. Two of the anaerobic ponds were desluged during (1996), the desluged amounts estimated at (250,000m^3) were stored at the plant site. In addition, there are also about (350,000 m^3) of dewatered bio-solids generated at other treatment plants and disposed within the plant premises as shown in figure (13) (as per the person in charge).

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge. In addition, generated sludge have not yet been utilized.

3.8 Wadi Arab Treatment Plant

Wadi Arab wastewater treatment plant started operation in (1999) to treat part of the wastewater generated from Irbid city, the treatment plant serves north west of Irbid villages and part of Irbid city with a total population of about (190,000) capita. Table(23) shows the actual and design loads for Wadi Arab wastewater treatment plant at different operational years.

Table(23): Actual and design loads for Wadi Arab treatment plant.

Parameter	Unit	Actual Load			Design Load**
		2002*	2004*	2005**	
Inflow	m^3/d	7,055	7,085	9,500	20,800
BOD_5	mg/l	836	690	850	612
	kg/d	5,898	4,888	8,075	12,730
TSS	mg/l	796	520	-	-
	kg/d	5,616	3,684		

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

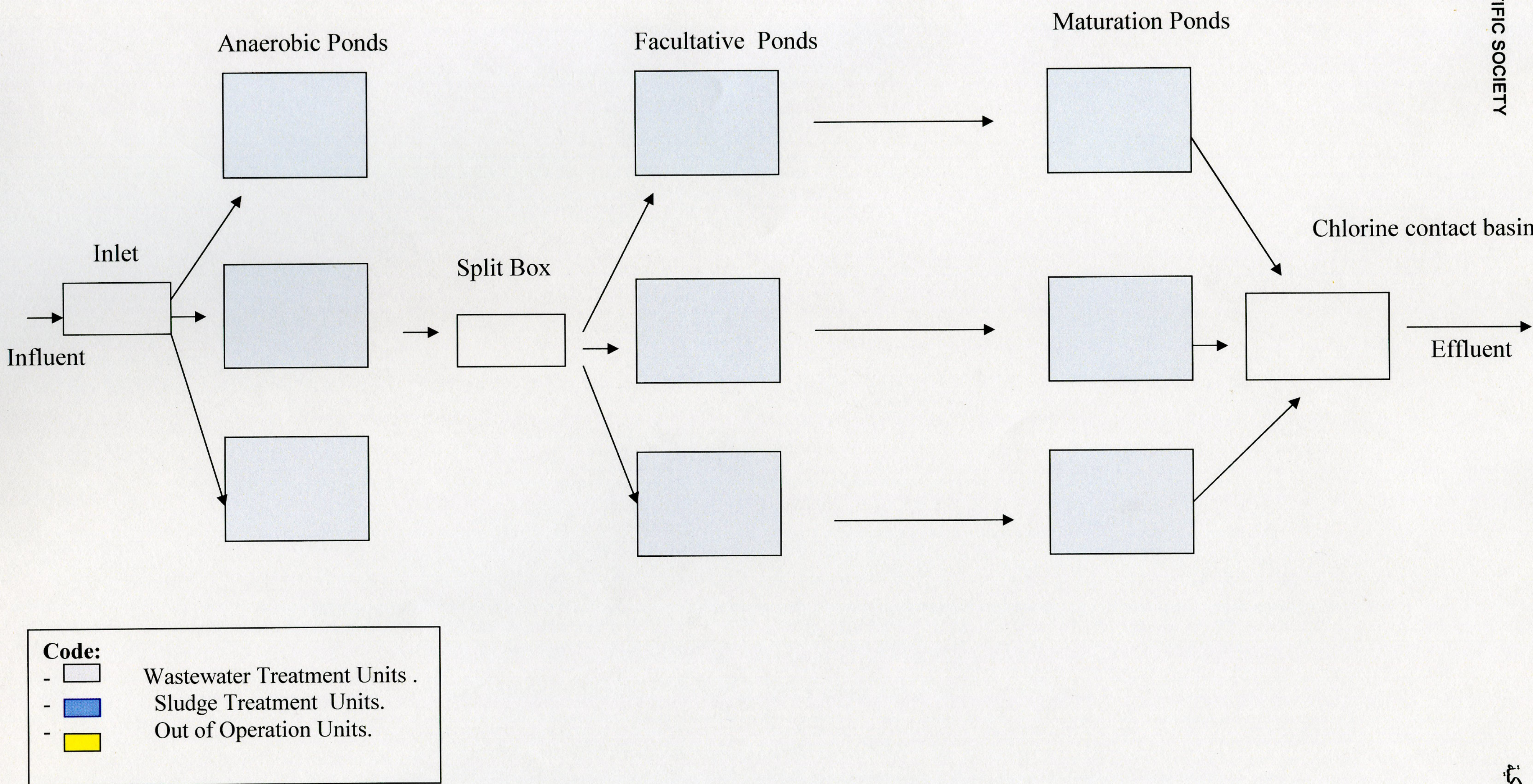


Figure (12): As-Samra wastewater treatment plant / schematic flowchart.

Figure (13): Disposal of sludge at As-Samra treatment plant.

Table (23) shows an increase in inflow and BOD_5 influent values over the years (2002 to 2005), the treatment plant is currently operating at (46%) of its hydraulic capacity, while the actual organic load is (63%) of the design value.

Wastewater Treatment :
Figure (14) shows wastewater treatment processes at Wadi Arab treatment plant, the operation system is activated sludge/extended aeration consisting of the following units respectively: screens, grit chamber, aeration basins, sedimentation tanks and finally a chlorination basin.

Sludge Treatment:
Sludge treatment processes at Wadi Arab wastewater treatment plant consist of a thickener, two sludge holding tanks and drying beds series. Table (24) shows the actual and typical design for the thickener operated at Wadi Arab wastewater treatment plant.

Table (24) shows that the total surface area of the thickener is not sufficient to handle solids loading, the available area is only (115 m^2) while an area of (174 m^2) is required. However, the two sludge holding tanks contribute in sludge thickening which makes the area of the thickener somehow sufficient.

Table (25) shows the actual and typical design for drying beds operated at Wadi Arab treatment plant. It can be shown that the total area of the drying beds is not sufficient to treat the disposed sludge from the thickener, the actual area is (10,950m^2) while an area of (38,000 m^2) is required.

Table (24): Design criteria for thickener at Wadi Arab treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	$kg/m^2.d$	44.3	24.4-34.2**
Disposed sludge from thickener	m^3/d kg solid /d	170 5100	-
No. of units	-	1	-
Volume	m^3	575	-
Depth	m	5	-
Total surface area	m^2	115	174***
Detention time	hour	48	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

Table (25): Actual and typical design for drying beds at Wadi Arab treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	10,950	38,000 (0.16-0.23m^2/capita)
Number of units	-	73	-
Length	m	25	6-30
Width	m	6	6
Sludge depth	cm	25	20-30
Aggregate layer depth	cm	-	23-30
Detention time	day	14	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:

Table (26) below shows the liquid sludge and dewatered bio-solids generation at Wadi Arab wastewater treatment plant. The treatment plant generates about (170m^3/day) of liquid sludge during the period November to April and (17m^3/day) dewatered bio-solids from May to October. About (3,100 m^3) of dewatered bio-solids is generated annually compared to (31,000m^3)of liquid sludge.

Table (26): Sludge/bio-solids generation at Wadi Arab MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Generation rate (m^3/day)	170	17
Generation period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	31,000	3,100

* Source: WAJ documents and person in charge at the treatment plant

Sludge Disposal and Entailed Costs:

Generated liquid sludge and dewatered bio-solids are currently disposed at Alakaider dumping site. Figure(15) shows accumulated dewatered bio-solids before being transferred to the dumping site.

Table (27) shows the sludge/bio-solids transfer costs. One cubic meter of liquid sludge costs (1.13 JD) while for dewatered bio-solids (1.88 JD). The total annual transfer cost is (40,800JD).

Table (27): Sludge/bio-solids estimated transfer costs for Wadi Arab MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Transfer cost (JD/m^3)	1.13	1.88
Total transfer cost (JD/year)	35,000	5,800
Total Transfer Cost: 40,800(JD / year)		

*Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge. In addition, generated sludge have not yet been utilized.

3.9 Central Irbid Treatment Plant

Central Irbid wastewater treatment started operation in (1986), the plant serves about (70,000) inhabitants living in Irbid city. Table (28) shows the actual and design loads for Central Irbid wastewater treatment plant at different operational years.

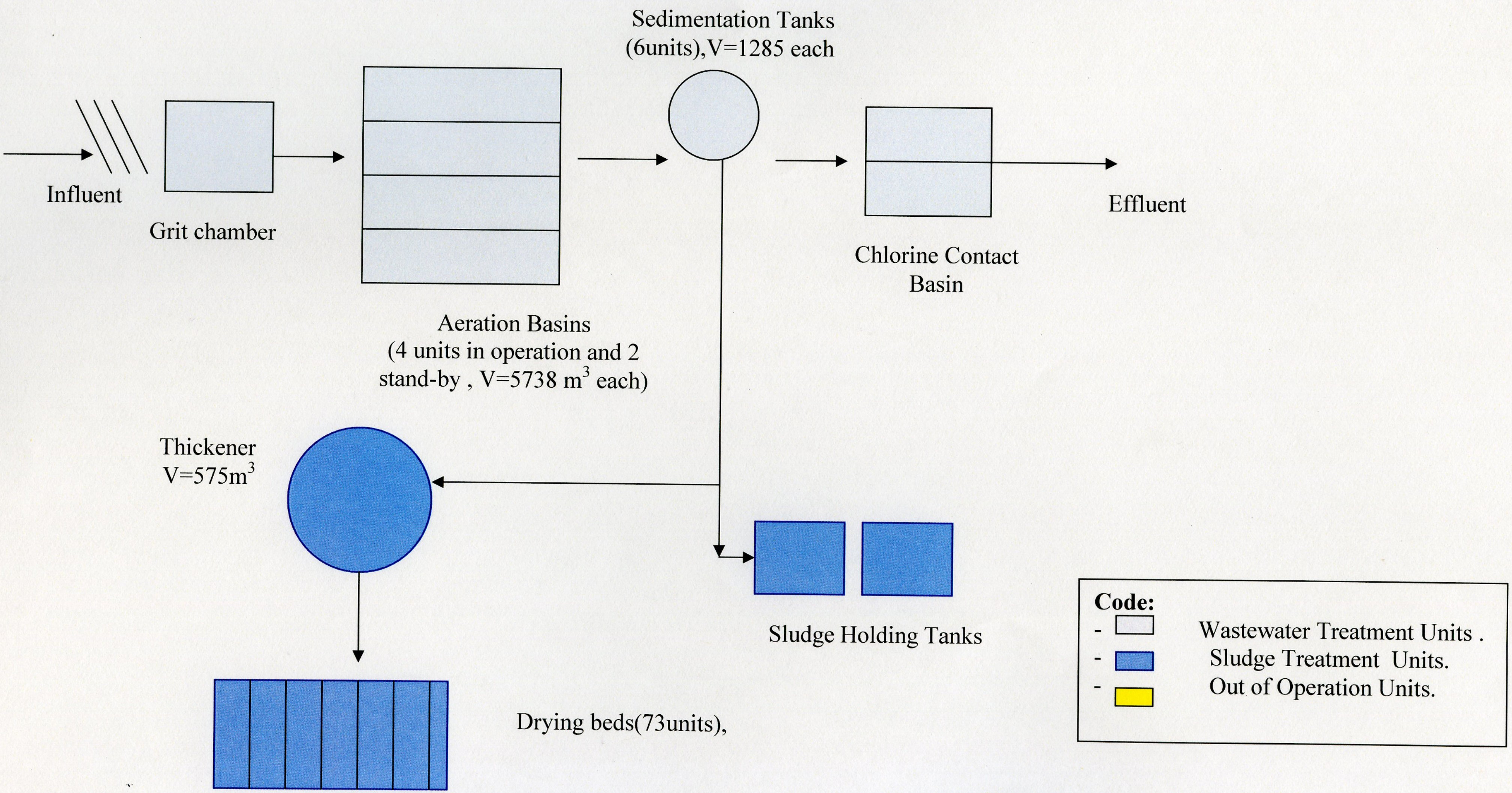


Figure (14): Wadi Arab wastewater treatment plant / schematic flowchart.

Figure (15): Sludge accumulation before disposal at Wadi Arab treatment plant.

Table(28): Actual and design loads for Central Irbid treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	7,121	8,103	7,776	6,500	11,023
BOD_5	mg/l	1,144	1,066	1,211	1,150	850
	kg/d	8,146	8,638	9,417	7,475	9,370
TSS	mg/l	1,092	1,073	1,008	-	-
	kg/d	7,776	8,694	7,838		

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (28) shows a decrease in both hydraulic and organic loads over the period (2002-2005), this is mainly due to diversion of part of the wastewater to Wadi Arab treatment plant. The plant is now operating at (59%) of its hydraulic capacity and (80 %) of its design organic load.

Wastewater Treatment:
Wastewater treatment units include: screening, grit removal channel, primary sedimentation tank, trickling filters (two units), aeration basins, secondary sedimentation tanks and finally a chlorination basin.

Sludge Treatment:
Sludge treatment processes consist of a thickener with a volume of (1,000 m^3), a sludge holding tank with a volume of (960 m^3), an anaerobic digester with a volume of (3,540 m^3) and a drying beds series. Table (29) shows the actual and typical design for thickener operated at Central Irbid wastewater treatment plant.

It can be shown in table (29) that the surface area of the thickener is sufficient, the available surface area is (250 m^3) while an area of (112 m^3) is required. Figure(17) shows the thickener at Central Irbid plant.

Table (29): Design criteria for thickeners at Central Irbid treatment plant.

Parameter	Unit	Actual Design	Typical Design
Solids loading	$kg/m^2.d$	13.2	24.4-34.2*
Disposed sludge from thickener	m^3/d kg solid /d	110 3,300	-
No. of units	-	1	-
Depth	m	4	-
Total surface area	m^2	250	112
Detention time	day	5	-

*Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

Table (30) shows the actual and typical design for drying beds at Central Irbid plant, there are nine units with a total surface area of (12,000 m^2), the surface area of the drying beds is not sufficient because the required area is (14,000m^2). Drying beds are shown in figure (18).

Table (30): Actual and typical design for drying beds at Central Irbid treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	12,000	14,000 (0.16-0.23m^2/capita)
Number of units	-	9	-
Sludge depth	cm	25	20-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:

Table (31) below shows the liquid sludge and dewatered bio-solids generation. The treatment plant generates about (110m^3/day)of liquid sludge during the period November to April and (14m^3/day) of dewatered bio-solids during May to October. About (2,500m^3) of dewatered bio-solids is generated annually compared to (20,000m^3) of liquid sludge.

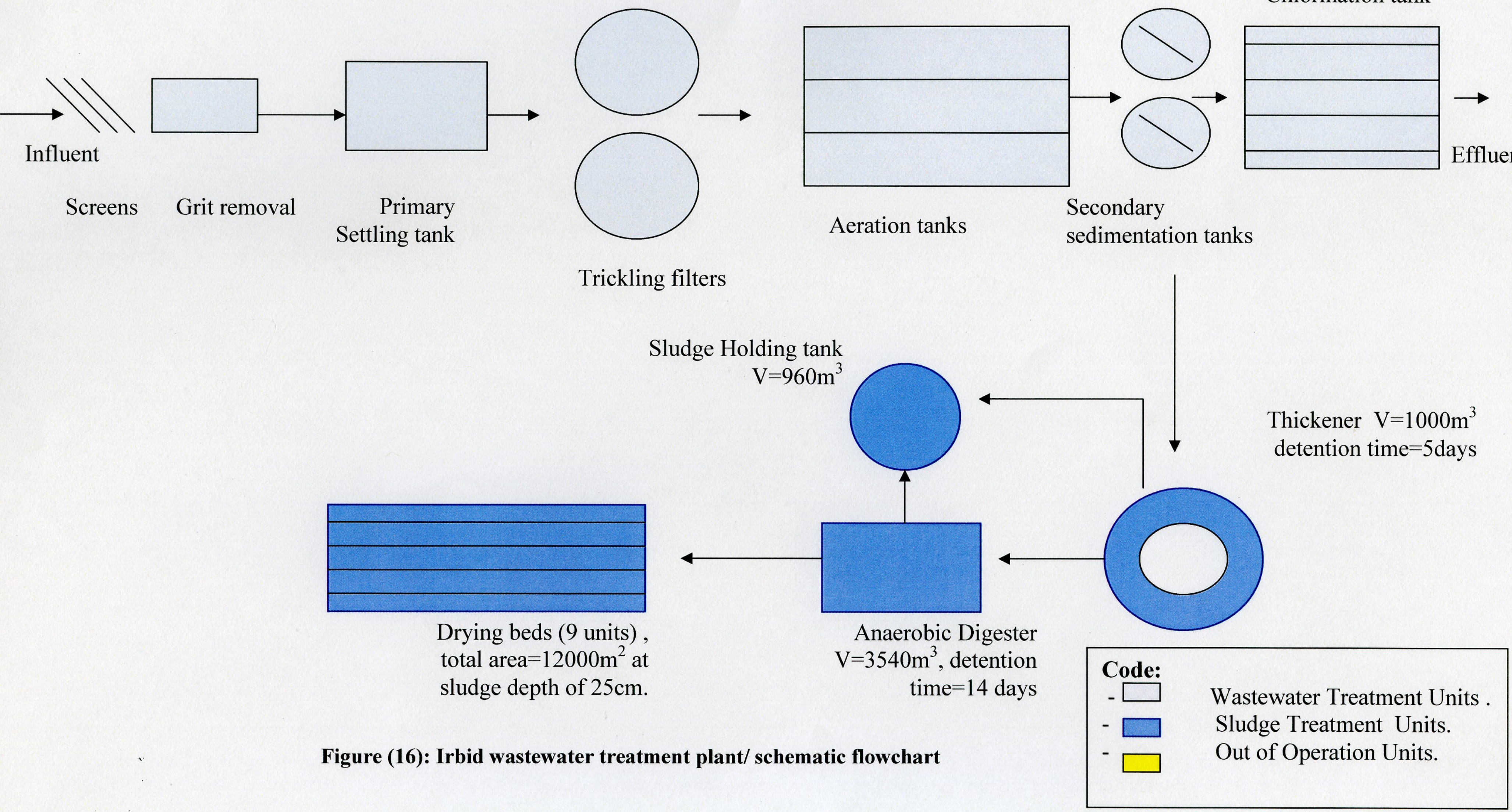


Figure (16): Irbid wastewater treatment plant/ schematic flowchart

Figure (17):Sludge thickener at Central Irbid treatment plant.

Figure (18): Drying beds at Central Irbid treatment plant.

Table (31): Sludge/bio-solids generation at Central Irbid MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Generation rate (m^3/day)	110	14
Generation period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	20,000	2,500

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:

Generated liquid and dewatered bio-solids are currently disposed of at Alakaider dumping site. Table (32) shows sludge/bio-solids transfer costs. One cubic meter of liquid sludge costs (7.8 JD) while for dewatered bio-solids the cost is (1.25 JD) . The total transfer cost is (159,000 JD) annually.

Table (32): Sludge/bio-solids estimated transfer costs for Central Irbid MWTP*.

Item	Liquid Sludge	Dewatered bio-solids
Transfer cost (JD/m3)	7.8	1.25
Total transfer cost (JD/year)	156,000	3,000
Total Transfer Cost : 159,000 (JD / year)		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:

There are no available information about the quality of generated sludge. In addition, generated sludge have not yet been utilized.

3.10 Wadi Hassan Treatment Plant

Wadi Hassan wastewater treatment plant started operation in (2001), the operation system is activated sludge–oxidation ditch. The treatment plant serves about (40,000) inhabitants living in Al-Husun camp and the villages of Kitm, Shatana and Alnuaimah. Table(33) shows the actual and design loads for Wadi Hassan wastewater treatment plant at different operational years.

Table(33): Actual and design loads for Wadi Hassan treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	423	725	1,061	1,100	1,600
BOD_5	mg/l	859	802	836	850	600
	kg/d	363	581	887	935	960
TSS	mg/l	724	765	748	900	-
	kg/d	306	555	794	990	

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (33) shows an increase in hydraulic as well as organic loadings over the years (2002 to 2005). The plant is now operating at (69%) of its hydraulic capacity and (97%) of its design organic load.

Wastewater Treatment:
Wastewater treatment at Wadi Hassan plant includes: screening, grit removal, aeration basins, sedimentation tanks, polishing ponds and finally chlorination basin. Reclaimed water is utilized for on-site agricultural purposes.

Sludge Treatment:
Sludge treatment process consists of a thickener with a volume of ($350m^3$) and a series of drying beds with a total surface area of ($2,400m^2$). Table (34) shows the actual and typical design for thickener operated at Wadi Hassan wastewater treatment plant. Table (34) shows that the solids loading to the thickener is within the design range and that the available surface area is sufficient, the actual area is ($64\ m^2$) while an area of only ($40m^2$) is required. Table (35) shows the actual and typical design for drying beds operated at Wadi Hassan treatment plant. It can be shown that the drying beds surface area is not sufficient, the actual area is only ($2,400m^2$) while an area of ($8,000\ m^2$) is required.

Table (34): Design criteria for thickener at Wadi Hassan treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	$kg/m^2.d$	18.75	24.4-34.2**
Disposed sludge from thickener	m^3/d kg solid /d	40 1,200	-
No. of units	-	1	-
Depth	m	5.5	-
Total surface area	m^2	64	40***
Detention time	hour	24	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

Figures (20)&(21) show drying beds and sludge accumulation at Wadi Hassan treatment plant.

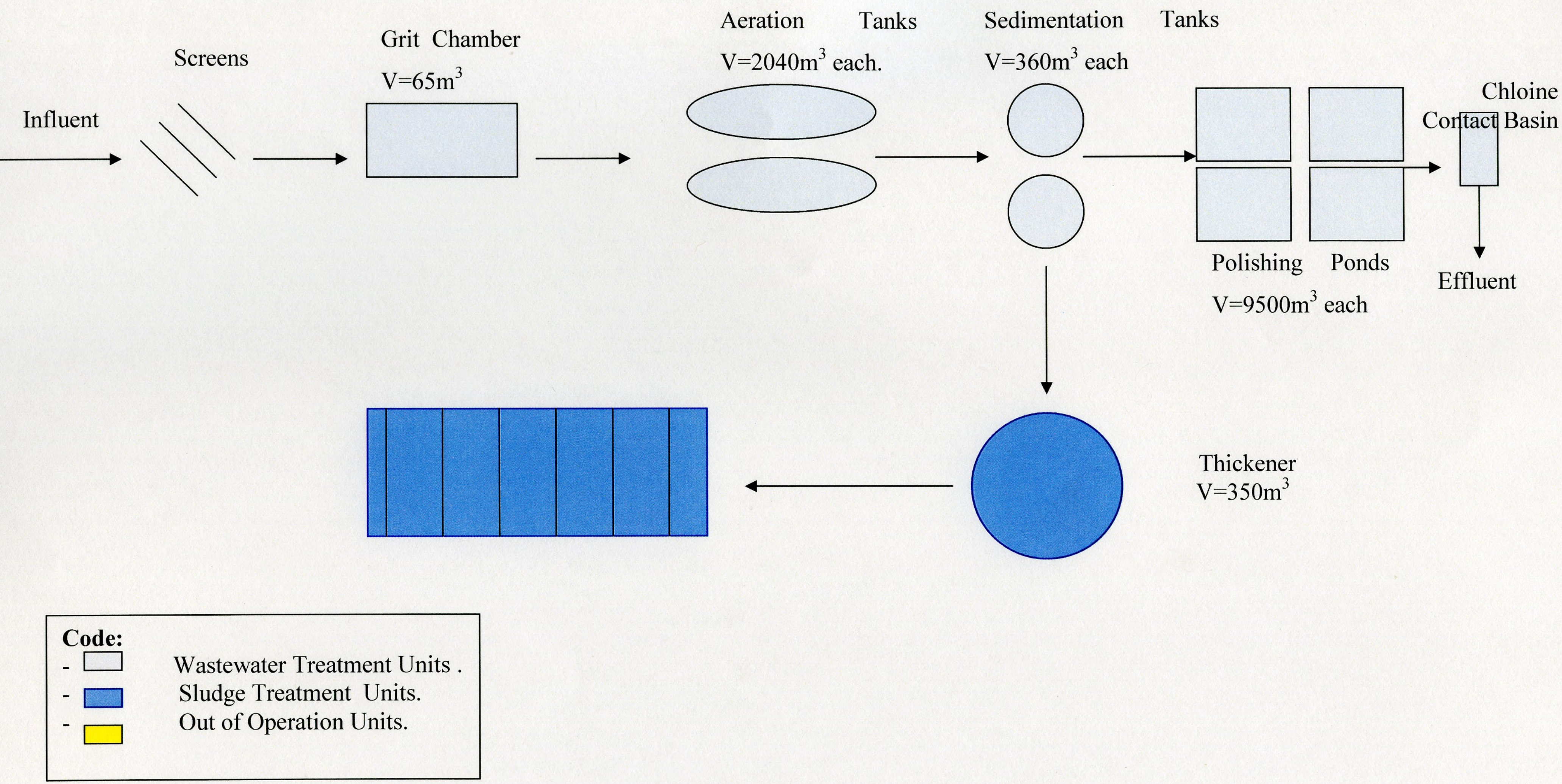


Figure (19): Wadi Hassan wastewater treatment plant/ schematic flowchart

Figure (20): Drying beds at Wadi Hassan treatment plant.

Table (35): Actual and typical design for drying beds at Wadi Hassan treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	2,400	8,000 (0.16-0.23m^2/capita)
Number of units	-	16	-
Length	m	25	6-30
Width	m	6	6
Sludge depth	cm	25	20-30
Detention time	days	11-14	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,199 .

Sludge Generation Rates:

Table (36) shows the liquid sludge and dewatered bio-solids generation at Wadi Hassan treatment plant. The treatment plant generates about (40 m^3/day)of liquid sludge during the period November to April and (4 m^3/day) of dewatered bio-solids during the period May to October.

Figure (21): Sludge accumulation before disposal at Wadi Hassan treatment plant.

Table (36): Sludge/bio-solids generation at Wadi Hassan MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Generation rate (m^3/day)	40	4
Generation period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	7,300	730

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:

Generated liquid sludge and dewatered bio-solids are currently disposed of at Alakaider damping site. Table (37) shows sludge/bio-solids transfer cost, one cubic meter of liquid sludge costs (0.75 JD) while (1.1 JD) for dewatered bio-solids. The total annual transfer cost is (6,300 JD).

Table (37): Sludge/bio-solids estimated transfer costs for Wadi Hassan MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Transfer cost (JD/m3)	0.75	1.1
Total transfer cost (JD/year)	5,500	800
Total Transfer Cost: 6,300(JD / year)		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:
There is no available data about the quality of generated sludge/bio-solids. Only solids content of sludge coming out of the thickener is measured from time to time.

Small amount of bio-solids is being utilized for an applied research carried out by RSS aiming at studying the feasibility of utilizing bio-solids and impacts on soil fertility and crop production.

3.10 Ramtha Treatment Plant

Ramtha wastewater treatment plant started operation in (1987), the operation system was of stabilization ponds type, this was shifted later in (2004) to activated sludge system. The treatment plant serves about (40,000) inhabitants living in Ramtha city. Table(38) shows the actual and design loads for Ramtha wastewater treatment plant at different operational years.

Table(38): Actual and design loads for Ramtha treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	2,301	3,072	3,035	3,300	5,400
BOD_5	mg/l	852	696	801	950	950
	kg/d	1,960	2,138	2,431	3,135	5,130
TSS	mg/l	597	549	614	700	-
	kg/d	1,374	1,686	1,863	2,310	

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (38) shows an increase in hydraulic, organic and solids loads coming to the plant over the period (2002-2005). The treatment plant is currently operating at (61%) of the hydraulic capacity and (61%) of the design organic load.

Wastewater Treatment:
Figure (22) shows wastewater treatment processes at Ramtha wastewater treatment plant, the treatment process consists of two parallel lines, each line consists of screens, grit removal, aeration basin and sedimentation tank. The final effluent is further treated in polishing ponds and finally pass through a rock filter. Treated effluent is chlorinated and currently reused for on-site agricultural purposes.

Sludge Treatment:
The sludge treatment system consists of two thickeners followed by drying beds series. Table (39) shows the actual and typical design for thickeners operated at Ramtha wastewater treatment plant.

Table (39): Design criteria for thickeners at Ramtha treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	$kg/m^2.d$	6.63	24.4-34.2**
Disposed sludge from thickener	m^3/d kg solid /d	27 810	-
No. of units	-	2	-
Depth	m	4.5	-
Total surface area	m^2	122	27***
Detention time	hour	12-24	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

It can be shown in table (39) that the total surface area of the thickeners is sufficient to handle solids loading, the actual area is (122 m^2) while an area of only (27 m^2) is required.

Table (40) shows the actual and typical design for drying beds, it can be shown that the total area of the drying beds is sufficient to treat the disposed sludge from thickeners, the actual area is (17,100 m^2) while only (8,000 m^2) area is required.

Table (40): Actual and typical design for drying beds at Ramtha treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	17,100	8,000 (0.16-0.23m^2/capita)
Number of units	-	114	-
Length	m	25	6-30
Width	m	6	6
Sludge depth	cm	35	20-30
Detention time	days	30	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:

Table (41) shows the liquid sludge and dewatered bio-solids generation at Ramtha treatment plant .The plant generates about (27 m^3/day)of liquid sludge during the period November to April and (5 m^3/day) dewatered bio-solids within the period May to October. About (900 m^3) of dewatered bio-solids is generated annually compared to (5,000 m^3)of liquid sludge.

Table (41): Sludge/bio-solids generation at Ramtha MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Generation rate (m^3/day)	27	5
Generation period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	5,000	900

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:
Generated liquid sludge and dewatered bio-solids is currently disposed of at Alakaider damping site (Figure(23)).

Table (42) shows the sludge/bio-solids transfer cost. One cubic meter of liquid sludge costs (1.6 JD) while the cost is (1.15 JD) for dewatered bio-solids. The total annual transfer cost is (9,000 JD).

Table (42): Sludge/bio-solids estimated transfer costs for Ramtha MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Transfer cost (JD/m3)	1.6	1.15
Total transfer cost (JD/year)	8,000	1,000
Total Transfer Cost : 9,000 (JD / year)		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge/bio-solids. No previous or present utilization practices exist.

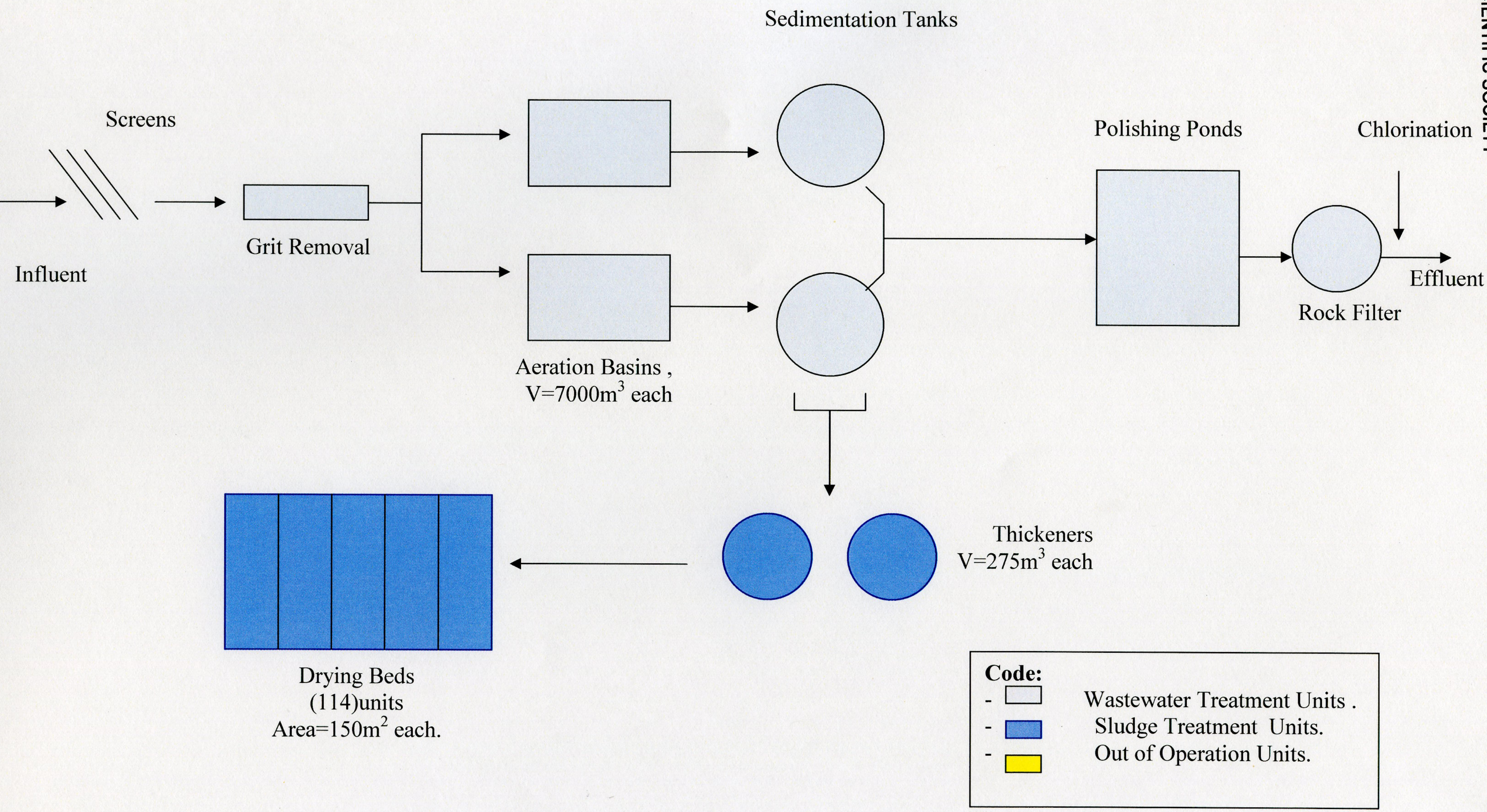


Figure (22): Ramtha wastewater treatment plant / schematic flowchart.

Figure (23): Dewatered sludge disposal at Ramtha treatment plant.

3.12 Jerash Treatment Plant

Jerash wastewater treatment plant started operation in (1985), the operation system is activated sludge /extended aeration. The treatment plant serves about (75,000) inhabitants living in Jerash city, Soof city, Soof camp, Moqbelah and Deer Al-lyat towns. Table (43) shows the actual and design loads for Jerash treatment plant at different operational years.

Table(43): Actual and design loads for Jerash treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	2,913	4,359	3,441	3,600	3,250
BOD_5	mg/l	1,219	1,106	1,084	1,500	600
	kg/d	3,551	4,821	3,730	5,400	1,950
TSS	mg/l	1,281	1,047	898	1,150	761
	kg/d	3,731	4,564	3,090	4,140	2,473

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (43) shows an increase in hydraulic, organic and solids loads over the period (2002-2005). The treatment plant is now operating at (110%) of its hydraulic capacity and (277%) of the design organic load.

Wastewater Treatment:

Figure (24) shows the treatment processes at Jerash wastewater treatment plant which consists of the following units: screens, grit chamber, oil removal unit, aeration tanks, secondary clarifiers and finally polishing ponds.

Sludge Treatment:

The sludge treatment processes at Jerash wastewater treatment plant consist of a thickener and drying beds. Table (44) shows the characteristics of the thickener operated at Jerash wastewater treatment plant.

Table (44): Design criteria for thickener at Jerash treatment plant.

Parameter	Unit	Actual Design*	Typical Design
Solids loading	$kg/m^2.d$	62.5	24.4-34.2**
Disposed sludge from thickener	m^3/d kg solid /d	100 3000	-
No. of units	-	1	-
Depth	m	5	-
Total surface area	m^2	48	88***
Detention time	hour	60	-

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.
*** : Calculated (based on typical solids loading).

It can be shown from table (44) that the surface area of the thickener is not sufficient, the actual area is (48 m^2) while an area of (88 m^2) is required.

Table (45) shows the characteristics of drying beds at Jearsh plant compared to typical design, it can be shown that the total area of the drying beds is not sufficient, an area of (15,000 m^2) is required while the actual area is only (3,600m^2). Also the sludge depth applied to the drying beds is higher than recommended values. Figure (25) shows the drying beds at Jerash wastewater treatment plant .

Table (45): Actual and typical design for drying beds at Jerash treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	3,600	15,000 (0.16-0.23m^2/capita)
Number of units	-	30	-
Length	m	20	6-30
Width	m	6	6
Sludge depth	cm	40	20-30
Detention time	days	15-20	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:

Table (46) shows liquid sludge and dewatered bio-solids generation at Jerash treatment plant.The plant generates about (100 m^3/day) of liquid sludge during the period November to April and (50 m^3) during May to October in addition to (3 m^3/day) of dewatered bio-solids during May to October.

Table (46): Sludge/bio-solids generation at Jerash MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Generation rate (m^3/day)	100 (winter) 50 (summer)	3
Generation period	Nov.-Apr. May-Oct.	May-Oct.
Total generated amount (m^3/ year)	27,400	600

* Source: WAJ documents and person in charge at the treatment plant.

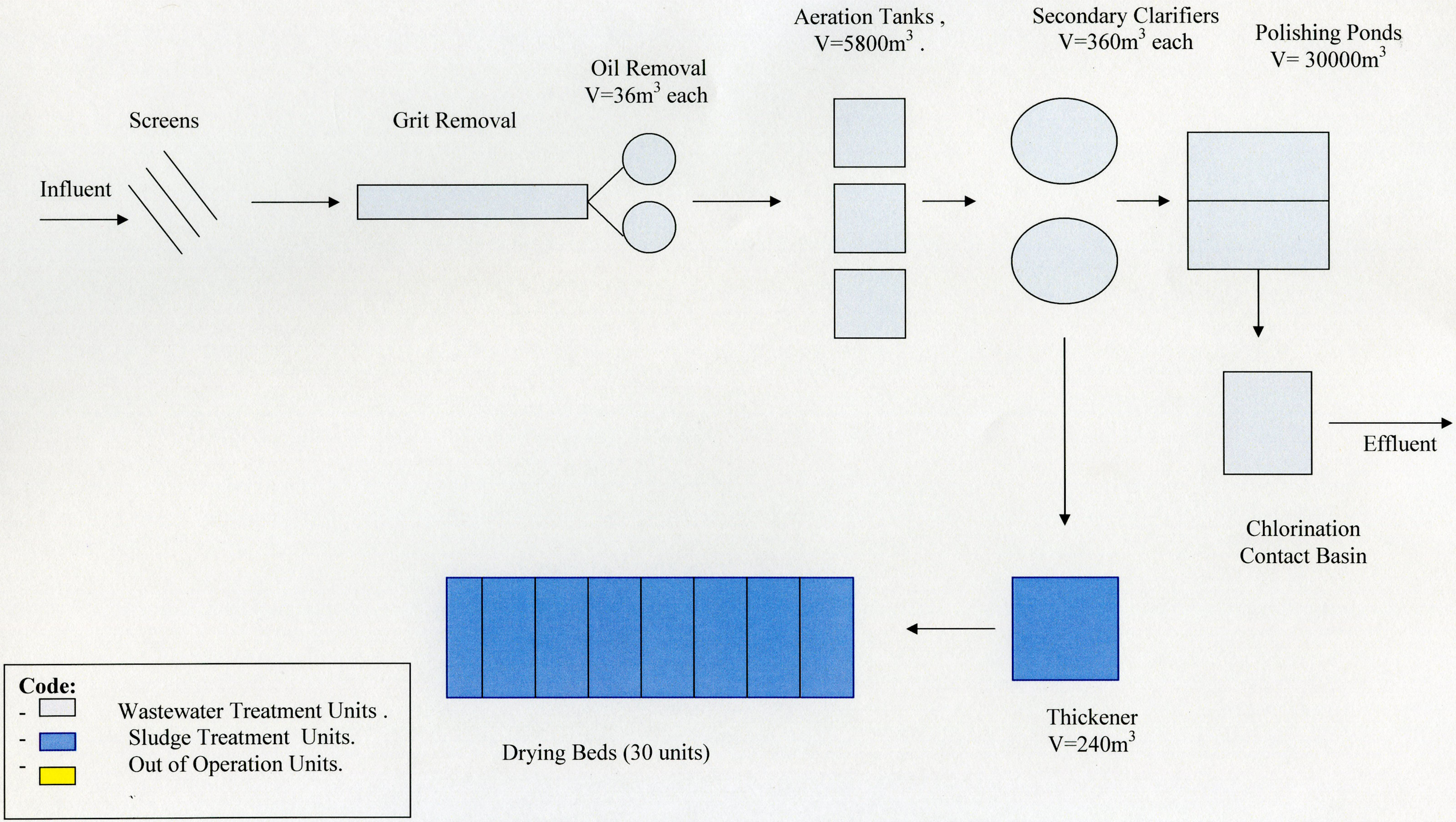


Figure (24): Jerash wastewater treatment plant / schematic flowchart.

Figure (25):Drying beds at Jerash treatment plant

Sludge Disposal and Entailed Costs:

Generated sludge/bio-solids are currently disposed of at Alakaider damping site. Table (47) shows sludge transfer cost, one cubic meter of liquid sludge costs (1.1JD) while (2.0 JD) for dewatered bio-solids. The total annual transfer cost is (31,300JD).

Table (47): Sludge/bio-solids estimated transfer costs for Jerash MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Transfer cost (JD/m3)	1.1	2.0
Total transfer cost (JD/year)	30,100	1,200
Total Transfer Cost: 31,300(JD / year)		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:
Only the total solids of liquid sludge coming to the thickener is measured from time to time at Jerash treatment plant. No previous or present utilization practices exist.

3.13 Kufranjeh Treatment Plant

Kufranjeh wastewater treatment plant started operation in (1990), the operation system is trickling filters. The plant serves about (45,000) inhabitants living in Ain-Janna , Ajloun city, Kufranjeh and Annjarah. Table(48) shows the actual and design loads for Kufranjeh wastewater treatment plant at different operational years.

Table(48): Actual and design loads for Kufranjeh treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	2,222	2,787	2,403	2,550	1,800
BOD_5	mg/l	1,195	1,076	1,134	1,150	850
	kg/d	2,655	2,999	2,725	2,932	1,530
TSS	mg/l	804	748	891	-	-
	kg/d	1,787	2,085	2,141		

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (48) shows an increase in hydraulic, organic and solids loads over the period (2002-2005). The treatment plant is currently operating at (141%) of its hydraulic capacity and (191%) of its design organic load.

Wastewater Treatment:
Figure (26) shows the wastewater treatment processes at Kufranjeh treatment plant which consists of : screening, imhoff tank which works as a precipitation and digestion tank, first stage trickling filters and sedimentation tank followed by the second stage trickling filter and sedimentation tank. Reclaimed water is chlorinated before being discharged to an adjacent stream.

Sludge Treatment:
Sludge generated at the first and second treatment stages is returned back to the imhoff tank where it is thickened and digested then transferred to the drying beds.

Table (49) shows the actual and typical design for drying beds operated at Kufranjeh treatment plant. It can be seen that the total area of the drying beds is not sufficient to treat the disposed sludge from the imhoff tank, an area of (3,000 m^2) is available while the required area is (9,000 m^2). Due to the shortage in drying beds capacity, the operators apply sludge at relatively high depth (50cm) to the drying beds.

Sludge Generation Rates:

Table (50) shows the liquid sludge and dewatered bio-solids generation at Kufranjeh treatment plant. The treatment plant generates about (60 m^3/day) of liquid sludge during the period November to April and (3.5 m^3/day) dewatered bio-solids during May to October.

Table (49): Actual and typical design for drying beds at Kufranjeh treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	3,000	9,000 (0.16-0.23m^2/capita)
Number of units	-	6	-
Length	m	83	6-30
Width	m	6	6
Sludge depth	cm	50	20-30
Detention time	days	30	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Table (50): Sludge/bio-solids generation at Kufranjeh MWTP*.

Item	Liquid Sludge	Dewatered bio-solids
Generation rate (m^3/day)	60	3.5
Generation period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	11,000	700

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:

Generated liquid sludge and dewatered bio-solids is currently disposed of at Alakaider damping site. Figure (27) shows the removal process of dewatered bio-solids from drying beds prior to transfer to Alakaider.

Table (51) shows sludge/bio-solids transfer cost. One cubic meter of liquid sludge costs (2.1 JD) while the cost for dewatered bio-solids is (2.85 JD). The total annual transfer cost is (24,800 JD).

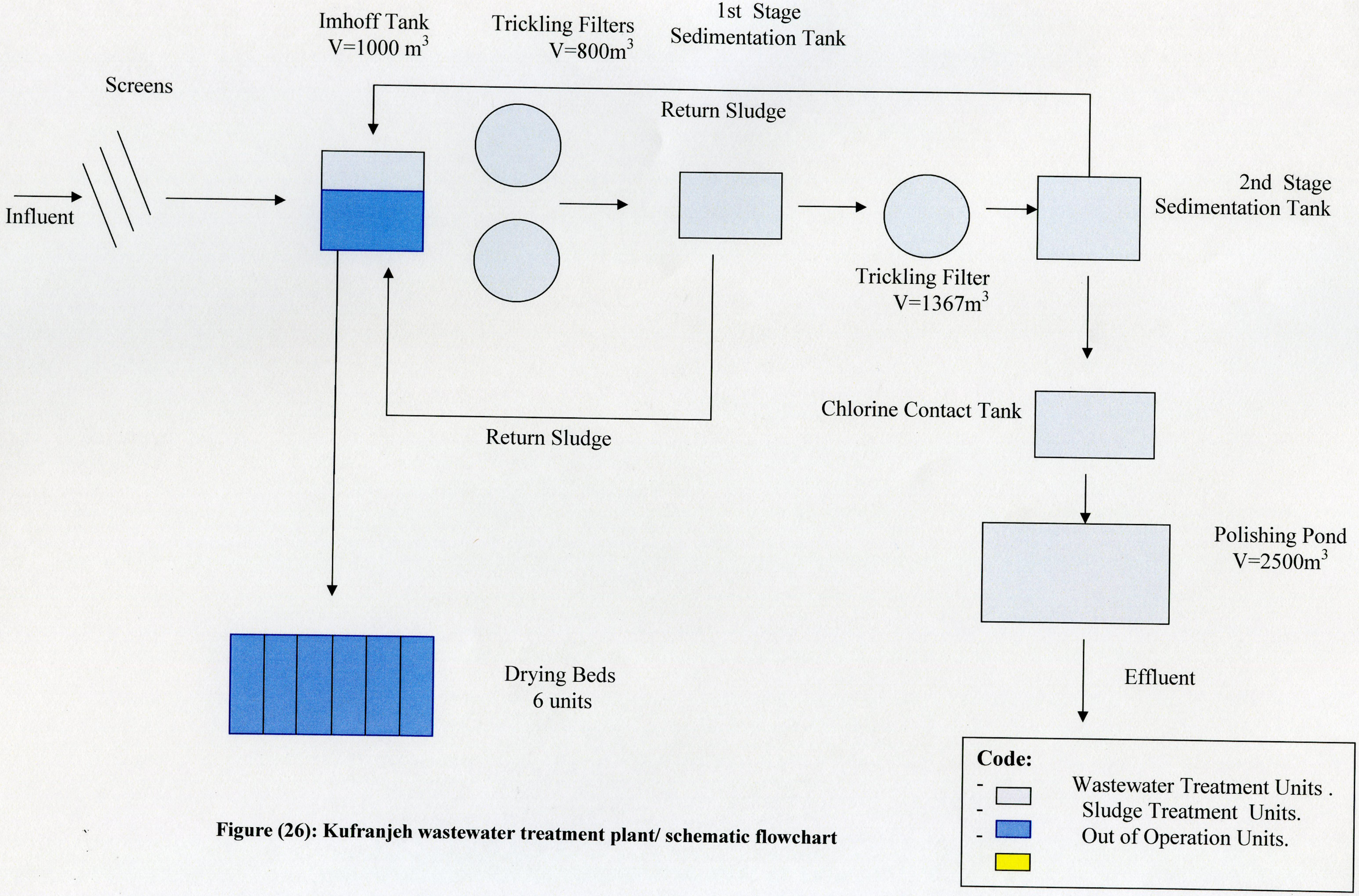


Figure (26): Kufranjeh wastewater treatment plant/ schematic flowchart

Figure (27): Dewatered sludge disposal at Kufranjeh treatment plant.

Table (51): Sludge/bio-solids estimated transfer costs for Kufranjeh MWTP*.

Item	Liquid Sludge	Dewatered bio-solids
Transfer cost (JD/m^3)	2.1	2.85
Total transfer cost (JD/year)	23,000	2,000
Total Transfer Cost: 24,800(JD / year)		

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge. In addition, generated sludge have not yet been utilized.

3.14 Mafraq Treatment Plant

Mafraq wastewater treatment plant started operation in (1988). The operation system is waste stabilization ponds consisting of two lines, each line consists of an anaerobic pond, three facultative ponds and two maturation ponds. Mafraq treatment plant serves a population of (30,000-35,000) inhabitants living in Mafraq city. Table(52) shows the actual and design loads for Mafraq wastewater treatment plant at different operational years.

Table(52): Actual and design loads for Mafraq treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	1,805	2,189	2,003	1,800	1,800
BOD_5	mg/l	696	733	589	500	845
	kg/d	1,256	1,604	1,180	900	1,521
TSS	mg/l	571	1,103	866	350	920
	kg/d	1,030	2,414	1,735	630	1,656

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

The plant is currently operating at (100%) of its hydraulic capacity and (59%) of the design organic load.

Wastewater Treatment:
Figure (28) shows wastewater treatment processes at Mafraq wastewater treatment plant, the treatment process consists of two parallel lines, each line consists of an anaerobic pond ,three facultative ponds and two maturation ponds.

Sludge Generation Rates:
Anaerobic ponds were desluged in 1996 and 2005, the sludge amounts are estimated at (5,000m^3). These were buried within the premises of the treatment plant.. Desludging costs were estimated at (55,000 JD).

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge. In addition, generated sludge have not yet been utilized.

3.15 Karak Treatment Plant

Karak treatment plant started operation in (1988), the operation system is trickling filter. The treatment plant serves a population of (60,000) inhabitants living in Karak, Al-Thalaja and Al-Marj cities. Table(53) shows the actual and design loads for Karak wastewater treatment plant at different operational years.

Table(53): Actual and design loads for Karak treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	1,478	1,574	1,639	1,700	785
BOD_5	mg/l	708	697	685	700	800
	kg/d	1,046	1,097	1,123	1,190	628
TSS	mg/l	608	490	574	750	800
	kg/d	899	771	941	1,275	628

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (53) shows an increase in influent, organic and solid loads, the treatment plant is currently operating at (216%) of the hydraulic capacity and (190%) of the design organic load.

Wastewater Treatment:
Figure (29) shows a schematic flowchart of Karak wastewater treatment plant. Wastewater treatment operations starts with mechanical treatment including screens followed by imhoff tank, biological treatment takes place in two trickling filters followed by a secondary clarifier and polishing ponds.

Sludge Treatment:
The sludge treatment system consists of drying beds. Table (54) shows the actual and typical design for drying beds. It can be shown that the total area of the drying beds is not sufficient to treat the generated sludge, the actual area is (864 m^2) while an area of (12,000 m^2) is required.

Table (54): Actual and typical design for drying beds at Karak treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	864	12,000 (0.16-0.23m^2/capita)
Number of units	-	12	-
Length	m	12	6-30
Width	m	6	6
Sludge depth	cm	-	20-30
Detention time	days	15-20	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:
Table (55) shows the liquid sludge and dewatered bio-solids generation at Karak wastewater treatment plant. The treatment plant generates about (5.5m^3/day) of liquid sludge during the period November to April and (2.7m^3/day) dewatered bio-solids during May to October. About (500m^3) of dewatered bio-solids is generated annually compared to (1,000m^3) of liquid sludge.

Table (55): Sludge/bio-solids generation at Karak MWTP*.

Item	Liquid Sludge	Dewatered bio-solids
Generation Rate (m^3/day)	5.5	2.7
Generation Period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	1000	500

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:
Generated liquid sludge is currently disposed of at Al-Lajoon treatment plant while dewatered bio-solids at Karak landfill. Total transfer costs are estimated at only about (1,070 JD/year) since WAJ vehicles are utilized for this purpose.

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge/bio-solids and no periodic monitoring or present utilization practices exist.

3.16 Tafilah Treatment Plant

Tafilah wastewater treatment plant started operation in (1989), the operation system is trickling filter. The treatment plant serves a population of (11,000) inhabitants living in Tafilah, Wadi-Ziad and Al-Qaser towns. Table(56) shows the actual and design loads for Tafilah wastewater treatment plant at different operational years.

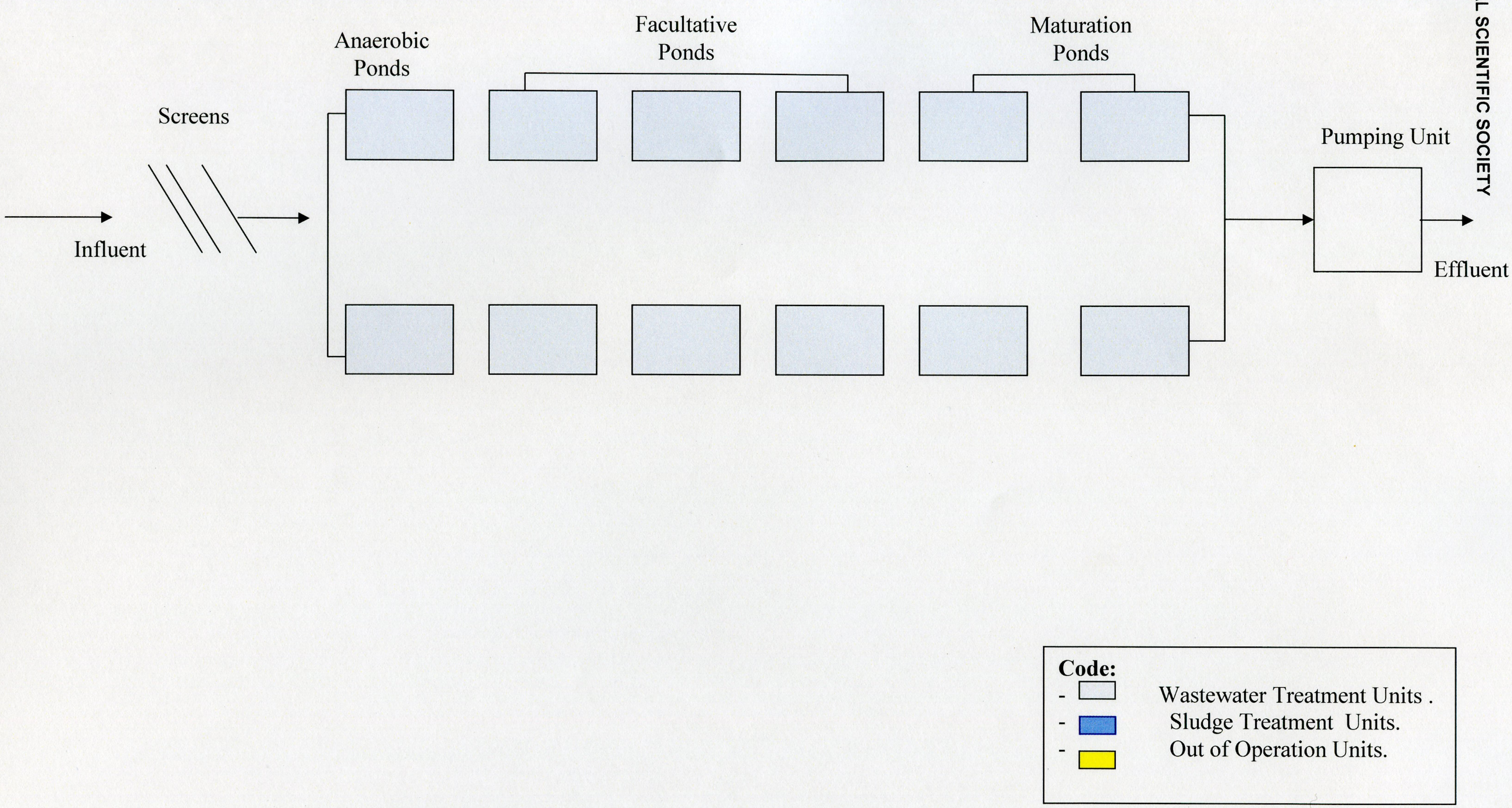


Figure (28): Mafraq Wastewater treatment plant/ schematic flowchart

Table(56): Actual and design loads for Tafilah treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	740	844	970	1,000	1,600
BOD_5	mg/l	671	683	683	800	1,650
	kg/d	497	575	662	800	2,640
TSS	mg/l	606	583	567	750	1,650
	kg/d	448	492	550	750	2,640

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (53) shows an increase in influent , organic and solid loads , the treatment plant is currently operating at (62%) of the hydraulic capacity and (30%) of the design organic load.

Wastewater Treatment:
Figure (30) shows a schematic flowchart of Tafilah wastewater treatment plant. Wastewater treatment operations starts with mechanical treatment including screens followed by imhoff tank, biological treatment takes place in two trickling filters followed by a secondary clarifier and polishing ponds.

Sludge Treatment:
The sludge treatment system consists of drying beds. Table (57) shows the actual and typical design for drying beds operated at Tafilah treatment plant. It can be seen that the total area of the drying beds is sufficient to treat the generated sludge, the actual area is (2,520 m^2) while an area of (2,200 m^2) is required.

Sludge Generation Rates:
Table (58) shows the liquid sludge and dewatered bio-solids generation at Tafilah wastewater treatment plant. The treatment plant generates about (5.8 m^3/day) of liquid sludge during the period November to April and (2.7m^3/day) dewatered bio-solids during May to October. A total of (500m^3) of dewatered bio-solids is generated annually compared to (1,050 m^3) of liquid sludge.

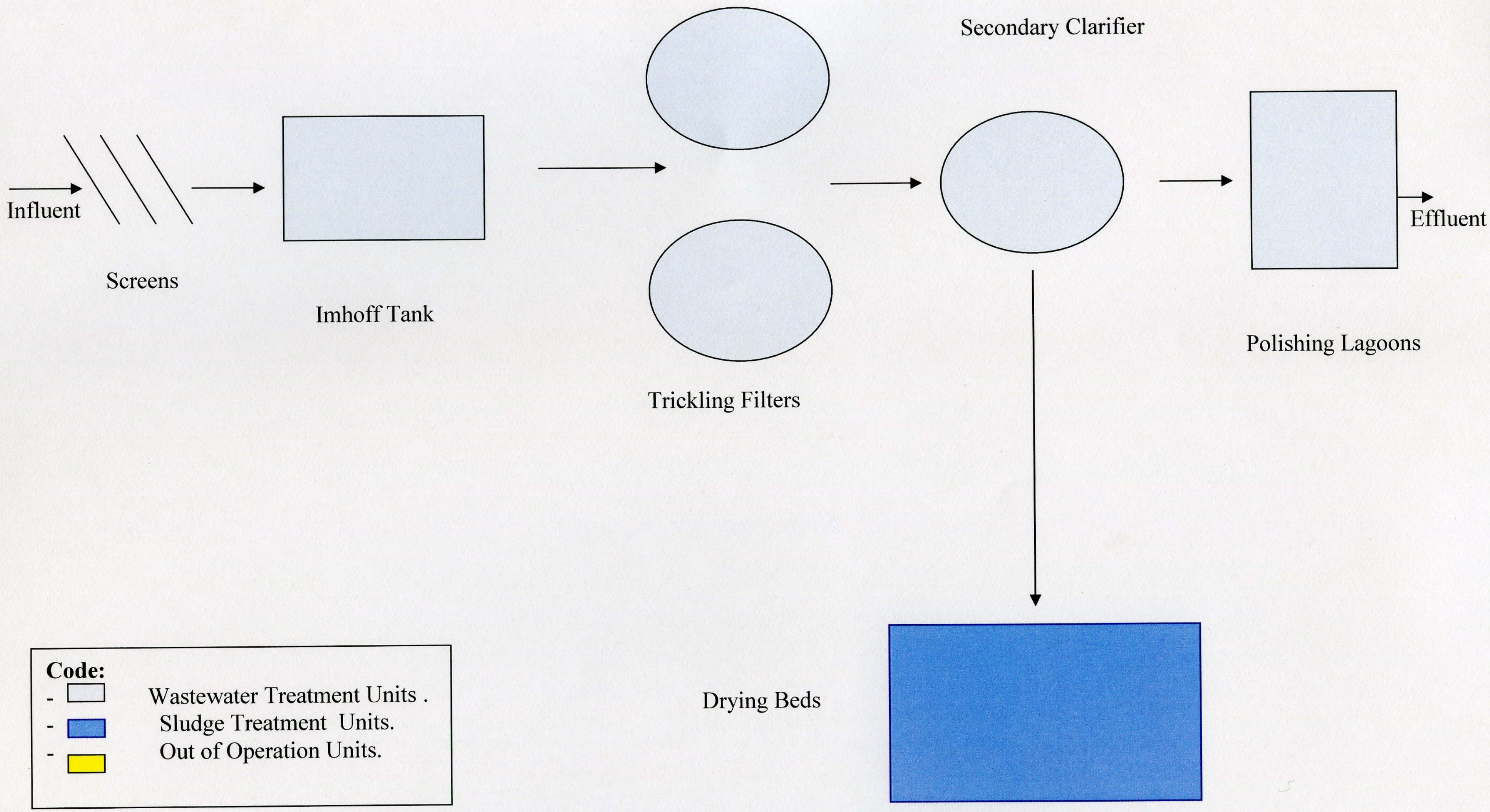


Figure (29): Karak wastewater treatment plant/ schematic flowchart

Table (57): Actual and typical design for drying beds at Tafilah treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	2,520	2,200 ($0.16-0.23m^2$/capita)
Number of units	-	21	-
Length	m	20	6-30
Width	m	6	6
Sludge depth	cm	-	20-30
Detention time	days	20	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Table (58): Sludge/bio-solids generation at Tafilah MWTP*.

Item	Liquid Sludge	Dewatered Bio-solids
Generation rate (m^3/day)	5.8	2.7
Generation period	Nov.-Apr.	May-Oct.
Total generated amount (m^3/ year)	1,050	500

* Source: WAJ documents and person in charge at the treatment plant.

Sludge Disposal and Entailed Costs:
Generated liquid and dewatered sludge are currently disposed of at Jarf Al-Daraweesh dumping site utilizing WAJ vehicles.

Sludge Quality Monitoring & Utilization:
There are no available information about the quality of generated sludge/bio-solids and no periodic monitoring or present utilization practices exist.

3.17 Ma'an Treatment Plant

Ma'an wastewater treatment plant started operation in (1990), the operation system is waste stabilization ponds. The treatment plant serves a population of (30,000) inhabitants. Table(59) shows the actual and design loads for Ma'an wastewater treatment plant at different operational years.

Table(59): Actual and design loads for Ma'an treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	2,155	2,,119	2,370	2,500	1,200
BOD_5	mg/l	735	607	688	700	600
	kg/d	1,584	1,286	1,630	1,750	720
TSS	mg/l	1,128	800	820	700	-
	kg/d	2,431	1,695	1,943	1,750	

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (59) shows an increase in influent and organic loads, the treatment plant is currently operating at (208%) of the hydraulic capacity and (243%)of the design organic load.

Wastewater Treatment:
Figure (31) shows a schematic flowchart of Ma'an wastewater treatment plant. Wastewater treatment operations starts with mechanical treatment including screens, biological treatment takes place at anaerobic, aerobic and maturation ponds.

Sludge Generation Rates:
Anaerobic ponds are usually desludged every five years. Previously generated sludge amounts are estimated at (7,000m^3).

Sludge Disposal and Entailed Costs:
The cost of ponds desludging and sludge transfer every five years is estimated at about (75,000JD) .

Sludge Quality Monitoring & Utilization:
There are no available data about the quality of generated sludge. In addition, generated quantities have not been utilized for beneficial uses.

3.18 Aqaba Treatment Plant

Aqaba wastewater treatment plant started operation in (1987), the operation system is waste stabilization ponds, the treatment plant serves a population of (100,000) inhabitants. Table(60) shows the actual and design loads for Aqaba wastewater treatment plant at different operational years.

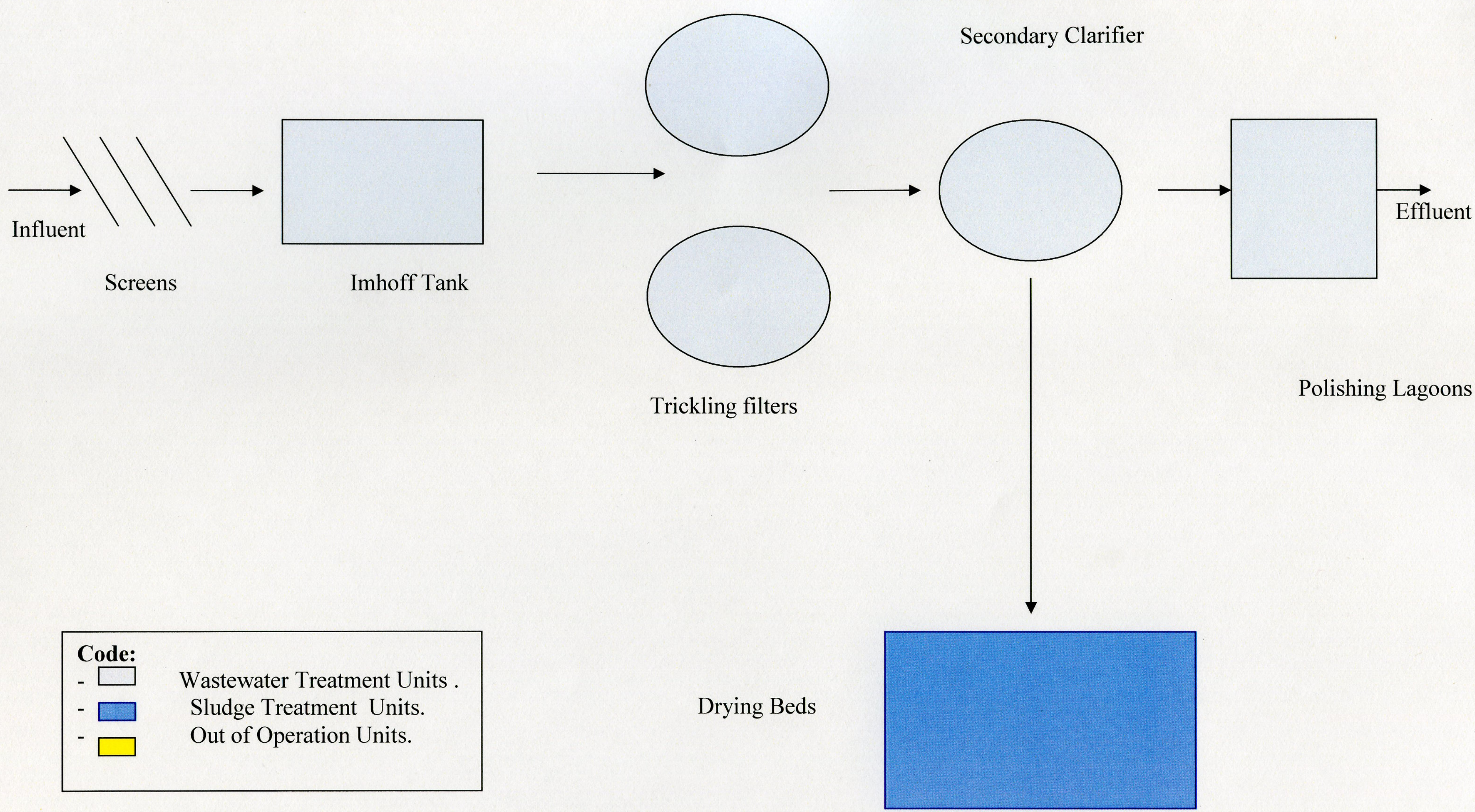


Figure (30): Tafilah wastewater treatment plant/ schematic flowchart

Table(60): Actual and design loads for Aqaba treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	9,329	10,332	10,332	10,000	12,000
BOD_5	mg/l	410	475	435	380	440
	kg/d	3,825	4,908	4,494	3,800	5,280
TSS	mg/l	298	246	267	440	220
	kg/d	2,775	2,542	2,759	4,400	2,640

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (60) shows an increase in influent and organic loads over the period (2002-2005), the treatment plant is currently operating at (83%) of the hydraulic capacity and (72%) of the design organic load.

It should be noted here that WAJ, with the technical and financial support of USAID, had upgraded the treatment plant by adding a new mechanical treatment line as shown in Figure (32). The new treatment train started operation in late 2005.

Sludge Treatment:
The sludge treatment system for the new treatment line consists of drying beds. Table (61) shows the actual and typical design for drying beds operated at Aqaba wastewater treatment plant. It can be shown that the available area is (7,680 m^2) while an area of (10,000 m^2) is required.

Sludge Generation Rates (new treatment line):
Liquid sludge is being recycled to the system during winter, dewatered bio-solids is generated at a rate of (100 m^3/day).

Sludge Quality Monitoring & Utilization:
There are no available data about the quality of generated sludge. In addition, generated quantities have not been utilized for beneficial uses.

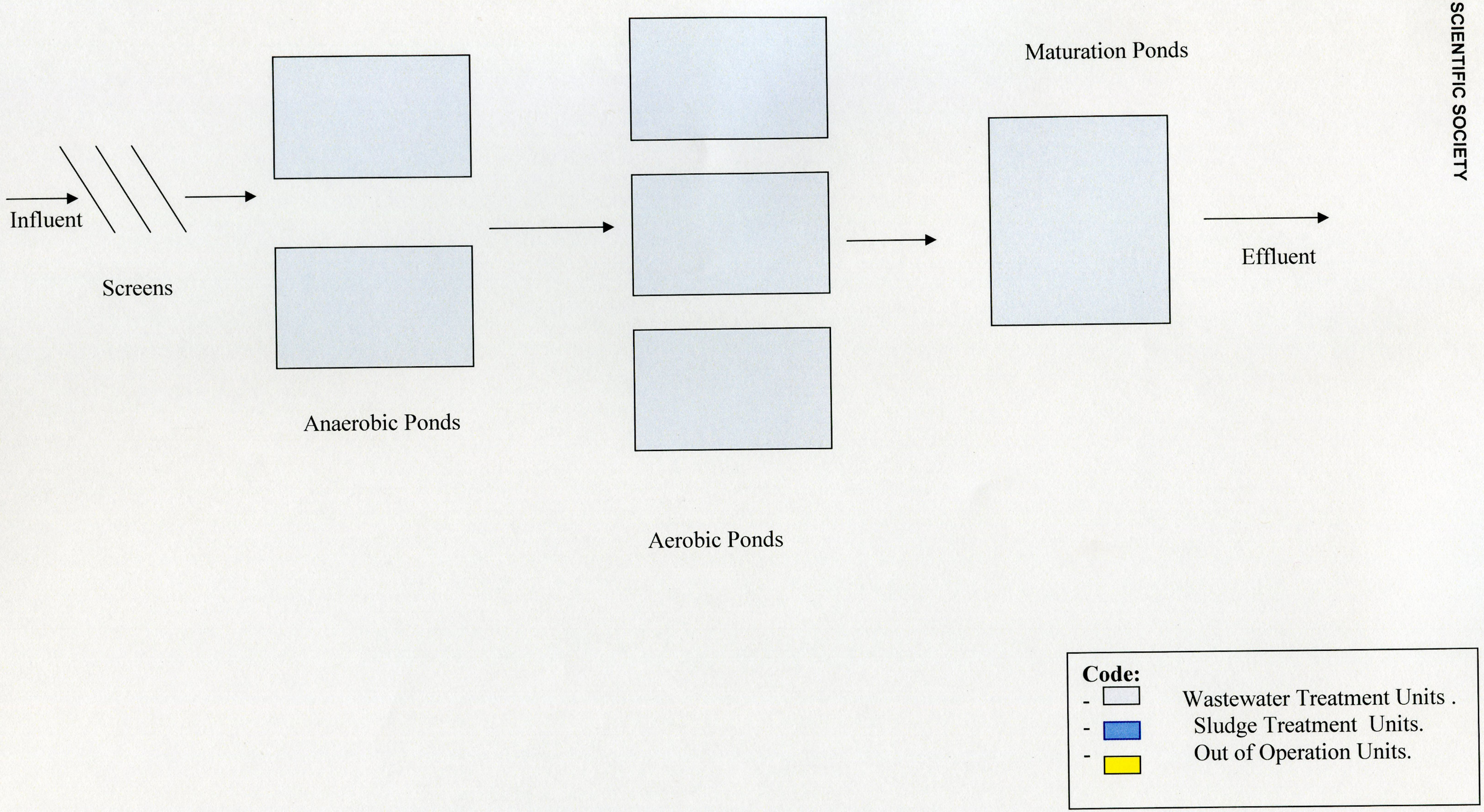


Figure (31): Ma'an wastewater treatment plant / schematic flowchart.

Table (61): Actual and typical design for drying beds at Aqaba treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	7,680	10,000 (0.16-0.23m^2/capita)
Number of units	-	64	-
Length	m	30	6-30
Width	m	4	6
Sludge depth	cm	30	20-30
Detention time	days	30	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

3.19 Wadi Mousa Treatment Plant

Wadi Mousa wastewater treatment plant started operation in (2000), the operation syste m is activated sludge-extended aeration, the treatment plant serves a population of (10,000) inhabitants. Table (62) shows the actual and design loads for Wadi Mousa wastewater treatment plant at different operational years.

Table(62): Actual and design loads for Wadi Mousa treatment plant.

Parameter	Unit	Actual Load				Design Load**
		2002*	2003*	2004*	2005**	
Inflow	m^3/d	866	900	1,391	1,200	3,400
BOD_5	mg/l	701	527	484	614	1,700
	kg/d	607	474	673	737	5,780
TSS	mg/l	1,221	772	902	972	1,700
	kg/d	1,057	695	1,255	1,166	5,780

*Source : WAJ, Wastewater Operating Systems Directory annual report, 2004.
**Source: WAJ documents and person in charge at the treatment plant.

Table (62) shows an increase in influent and organic loads over the period (2002-2005), the treatment plant is currently operating at (35%) of the hydraulic capacity and (12%) of the design organic load.

Wastewater Treatment :
Figure (33) shows a schematic flowchart of Wadi Mousa wastewater treatment plant. Wastewater treatment operations starts with preliminary treatment

including screens followed by grit removal unit. Secondary treatment takes place at aeration tanks followed by secondary clarifiers and polishing ponds.

Sludge Treatment:
The sludge treatment system consists of two holding tanks (746 m^3 each) and drying beds. Table (63) shows the actual and typical design for drying beds operated at Wadi Mousa wastewater treatment plant. It can be shown that the total area of the drying beds is sufficient to treat the generated sludge, the actual area is (5,600 m^2) while an area of (2,000 m^2) is required.

Table (63): Actual and typical design for drying beds at Wadi Mousa treatment plant.

Parameter	Unit	Actual Design*	Typical Design**
Total area	m^2	5,600	2,000 (0.16-0.23m^2/capita)
Number of units	-	16	-
Length	m	35	6-30
Width	m	10	6
Sludge depth	cm	-	20-30
Detention time	days	60	-
Aggregate layer depth	cm	-	23-30

* Source: WAJ documents and person in charge at the treatment plant.
** Source: Metcalf &Eddy, third edition,1991.

Sludge Generation Rates:
Liquid sludge generated during winter at Wadi Mousa treatment plant is recycled to the system, in summer dewatered bio-solids is generated at a rate of (5 m^3/day). Dewatered bio-solids are being accumulated at an open storage area within the premises of the treatment plant.

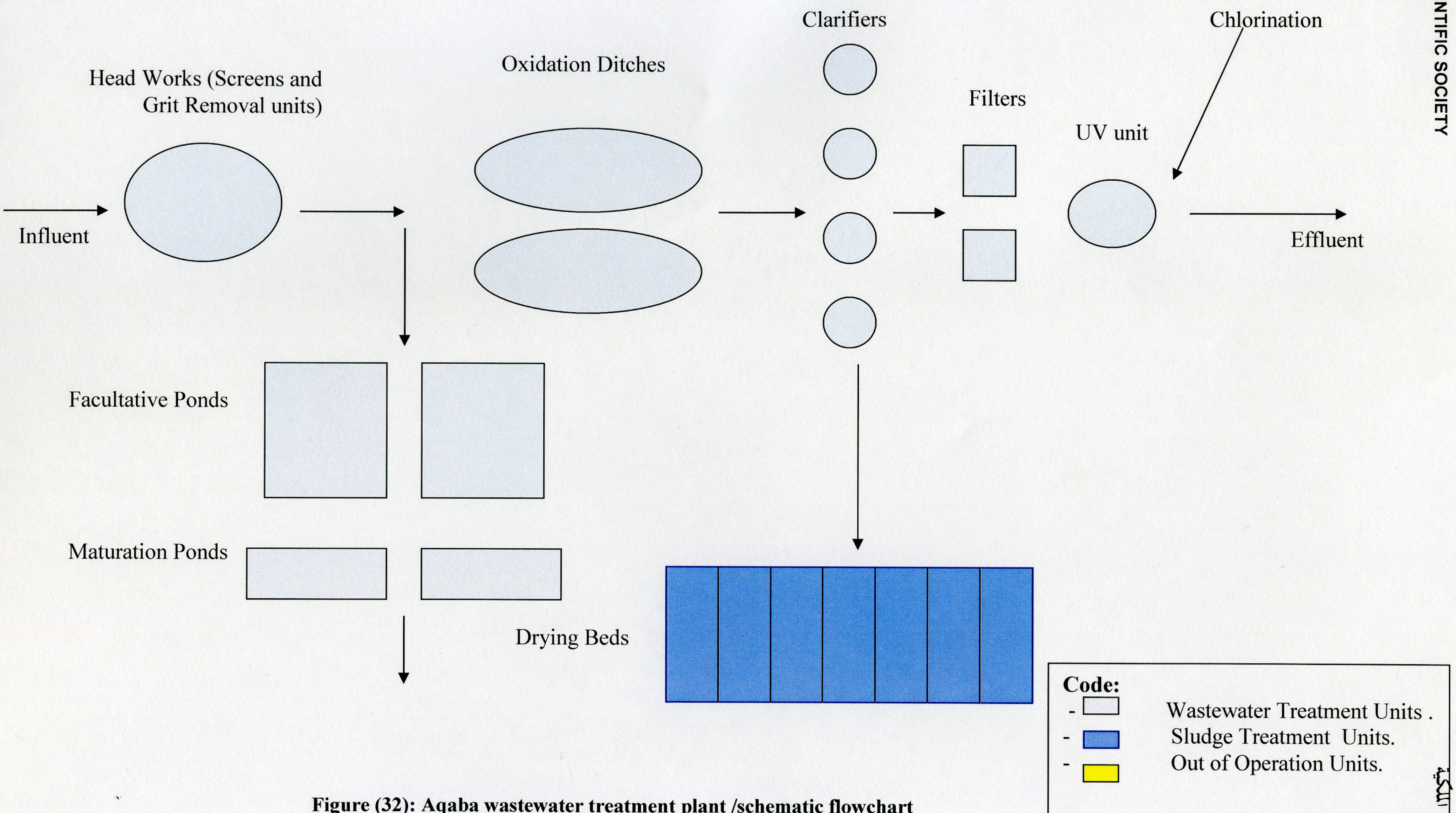


Figure (32): Aqaba wastewater treatment plant /schematic flowchart

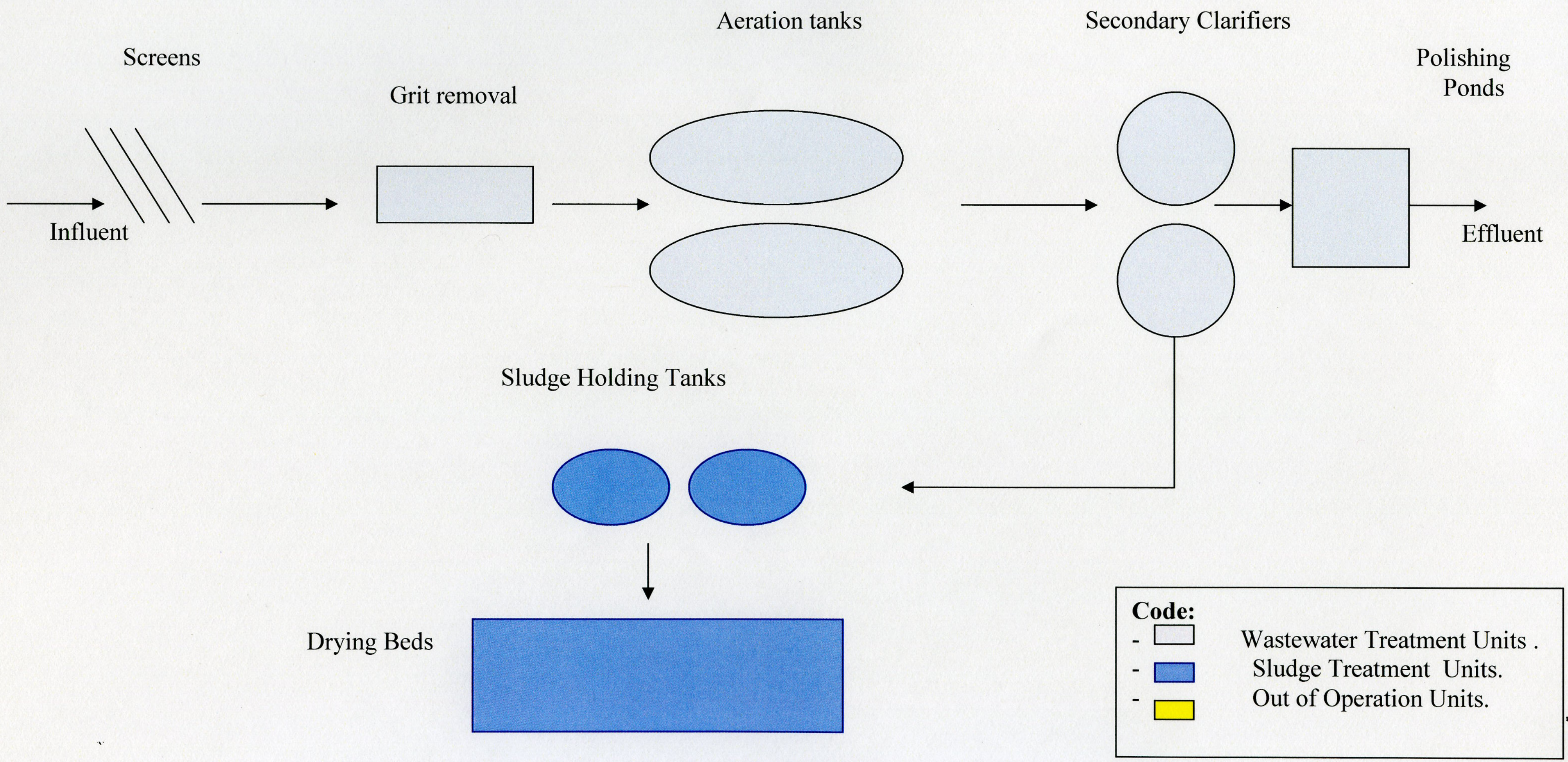


Figure (33): Wadi Mousa wastewater treatment plant/ schematic flowchart

4. SUMMARY

The previous section described current status of sludge/bio-solids at the designated treatment plants. The following summarizes the current management practices including treatment, handling and disposal of bio-solids:

- At treatment plants where waste stabilization ponds are utilized for wastewater treatment (Wadi Al-Seir, As-Samra, Mafraq, Ma'an and Aqaba treatment plants) the generally adopted practice is that every 5-8 years of operation, the anaerobic lagoons are desludged for operational purposes (like the effective depth of the lagoon becomes relatively low). Generated sludge is either piled in an open area or buried within the premises of the treatment plant.

- At mechanical treatment plants where sludge is only thickened and not dried utilizing drying beds (Abu-Nuseir and Baq'a treatment plants) relatively large quantities of liquid sludge are generated on daily basis. Cost of transferring sludge at both sites represents more than (17 %) of the total transfer costs for all designated treatment plants.

- At mechanical treatment plants where sludge is being thickened and dried utilizing drying beds (Madaba, Salt, Fuheis, Wadi Arab, Central Irbid, Wadi Hassan, Ramtha, Jerash, Kufranja, Karak, Tafilah and Wadi Mousa treatment plants) the operators usually do not utilize drying beds during the period (Nov.-Apr.) regardless of the weather conditions.

- Generated sludge/bio-solids is not usually analyzed for at WAJ laboratories.

- Sludge treatment processes at the designated treatment plants are not being dealt with based on the typical design and/or operational criteria. These are usually operated based on operational constraints (like keeping bio-solids for 3-4 weeks in drying beds regardless of its quality).

- Most of the bio-solids generated quantities are currently of liquid sludge. Only about 5% (volume basis) is generated in a dewatered phase.

- Sludge thickeners capacity at Madaba, Salt, Wadi Arab and Jerash treatment plants is not sufficient to handle sludge quantities.

- Drying beds capacity at Fuheis, Salt, Jerash, Kufranja and Karak treatment plants is not sufficient to handle sludge quantities.

5. CONCLUSIONS

The following major findings can be concluded from the field surveys that covered the nineteen domestic wastewater treatment plants operated by the Ministry of Water & Irrigation MWI/Water Authority of Jordan WAJ :

- Hydraulic and organic loads received by domestic wastewater treatment plants in Jordan are increasing continuously leading to an increase in generated sludge/bio-solids quantities. Considerable number of treatment plants are currently overloaded either hydraulically or organically.

- Thickening and natural drying (utilizing drying beds) are the most predominant sludge treatment processes in Jordan.

- The solids loadings for thickeners at some treatment plants exceed typical design values, hence thickeners capacity needs to be upgraded.

- Drying beds capacity at some treatment plants needs to be increased to properly handle the increasing sludge quantities.

- About (300,000 m^3) of liquid sludge as well as (15,000 m^3) of dewatered bio-solids are generated annually at the designated treatment plants.

- The total annual transfer cost of sludge/bio-solids to dumping sites is currently exceeding (750,000 JD). Most of the cost is attributed to hauling liquid sludge. This cost is expected to increase dramatically because of the current high oil prices.

- There are no available systematic data for generated sludge/bio-solids quality. Only solids content for sludge coming out of the thickeners is measured from time to time at some treatment plants.

- Almost all generated sludge and bio-solids quantities at the designated treatment plants are usually disposed of at near-by dumping sites, i.e. there are no beneficial usages for sludge and bio-solids in Jordan.

6. RECOMMENDATIONS

The following are recommended in order to improve the current status of sludge/bio-solids management in Jordan, and to build on and sustain work and activities related to bio-solids:

- **An operational manual** needs to be developed to tackle **Best Management Practices** of bio-solids handling, treatment, testing and reuse for agricultural land application in Jordan. The manual will greatly help improving the management practices at municipal wastewater treatment plants operated by the public and private sectors in the country. This could be one of the **potential future activities** to be conducted by RSS with the technical and financial support of IALC/University of Arizona.

- A definite strategy for the beneficial uses of bio-solids, particularly for agricultural land application, should be developed. This should take into consideration the following aspects among other issues: upgrading the current Jordanian Standard (JS: 1145/1996) for the reuse of bio-solids in agriculture; application procedures and rates that are suitable to local conditions; and potential locations for land application.

- The current Jordanian Standard (JS: 1145/1996) for the reuse of bio-solids in agriculture need to be modified taking into consideration the data and information collected throughout implementing relevant activities during the period (2003-2006) by RSS.

- The capacity of WAJ laboratories needs to be upgraded in order to better analyze and assess generated sludge/bio-solids quality for different beneficial uses.

- Since transfer costs of liquid sludge contribute the largest portion of the total transfer costs, it is highly recommended to adopt dewatering and/or drying techniques at **all** domestic wastewater treatment plants in order to reduce the volume of generated quantities and hauling costs accordingly.

- A continuous monitoring and assessment schemes of sludge/bio-solids physical, chemical and microbial properties need to be adopted and implemented.

- Outreach programs need to be designed and implemented to indicate the potential beneficial uses of bio-solids and proper handling practices of sludge. Such programs shall target different stakeholders including farmers, labors, and dumping sites and landfills operators.

- The capacity for some governmental stakeholders (e.g. Ministry of Health, Ministry of Environment) needs to be enhanced to help set and implement policies/strategies/action plans for bio-solids beneficial uses.

- Surveys need to be conducted to identify suitable locations close to different treatment plants where sludge/bio-solids can be land applied, taking into consideration public health and environmental requirements.

- Some of the sludge treatment processes that are out of operation currently at some treatment plants need to be put in operation (particularly digesters, filter presses, drying beds and others). This will help enhancing bio-solids quality, reducing generated amounts and handling costs.

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ANNEX (1)

Checklist

MWTPs Checklist

Plant name : Position :

Persons in charge

1- position Tel.

2- position Tel.

Communities served :

- Inhabitants
- No. of connections
- Industrial and commercial establishments
- Cities/Towns

Hydraulic and organic loads:

Actual :
-
-
-

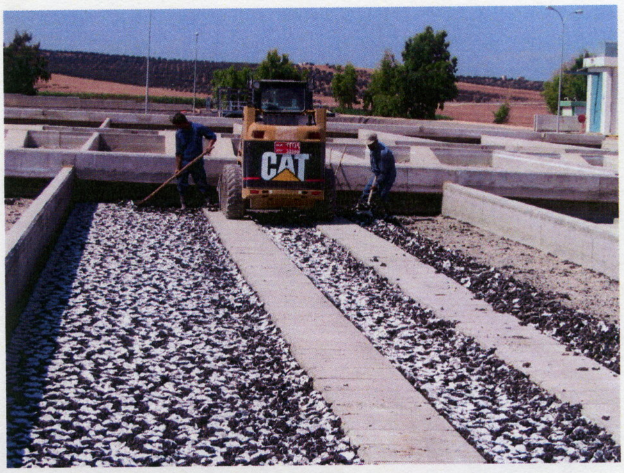
Design :
-
-
-

Wastewater treatment operations & processes (A schematic flowchart may be included):

Sludge treatment operations & processes (A schematic flowchart may be included):

Generated sludge / bio-solids amounts:
Available data on sludge/bio-solids quality before and after treatment:
Periodic analysis of sludge/bio-solids (if any):
Sludge/bio-solids disposal sites, methods and costs:
Past and current sludge/bio-solids utilization practices (if any) :

ANNEX(2)
Photos Taken During the Survey



Drying Beds

Bio-solids Accumulation

Bio-solids Collection & Disposal