Enabling
& Transboundary Cooperation
Integrated Water Resources Management
in the extended DRIN RIVER BASIN

GEF/UNDP/GWP-Med Project "Enabling Transboundary Cooperation and Integrated Water Resources Management in the Extended Drin River Basin

In the framework of the Memorandum of Understanding
for the Management of the Extended Transboundary Drin Basin

Pilot activity "Preparation of Wastewater Management Decision Support Tool"

Wastewater management solutions in the Shkodra city

Annex 5: Detailed concept solution for Jubice

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The Coordinated Action for the implementation of the Memorandum of Understanding for the management of the Drin basin (Drin CORDA) is supported by the GEF Drin Project. Thus, the latter constitutes an institutional project implemented by the United Nations Development Programme (UNDP) and executed by the Global Water Partnership (GWP) through GWP-Mediterranean (GWP-Med), in cooperation with the United Nations Economic Commission for Europe (UNECE). The Drin Core Group (DCG), being the multilateral body responsible for the implementation of the Memorandum of Understanding serves as the Steering Committee of the Project. GWP-Med serves as the Secretariat of the DCG.

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1 General

As an example of a WWTP solution for dispersed settlements surrounding Shkodra, the settlement Jubice was selected. According to the "Komuna Qendër, Rrethi Malësi e Madhe," Jubice's settlement has 572 inhabitants (2011).

2 Design paramatrs

Hydraulic and biological loading

The boundary conditions for dimensioning and budgeting of the facilities for collection and treatment of wastewater arise from establishing input quantities and composition of wastewater i.e., the required parameters the effluent must meet after the treatment.

Table 1: Overview of hydraulic loading for the settlement of Jubice

Project parameter	EM	Project value
Specific water consumption	l/dw/day	150
Daily water consumption	m3/day	88.5
Maximum flow per hour (Qmax)	m3/h	11.1

Hydraulic loading of a plant for wastewater treatment is defined as hydraulic loading during peak loadings. Since the sewage system is designed as separate and waterproof, the infiltration of stormwater and "other waters," which are estimated, is negligible.

For dimensioning a treatment plant, characteristic values that describe the loading of average municipal waters are used:
COD = 120 g/PE/d
BOD5 = 60 g/PE/d
Suspended solids = 70 g/PE/d
Total nitrogen = 11 g/PE/d
Total phosphorus = 2,5 g/PE/d

The above values are also in accordance with Austrian Standard ATV-DWK-A 198E.

Pursuant to the abovementioned, the biological loading of the Jubice WWTP (590 PE) has been calculated, as shown in the table below.

Table 2:Overview of biological loading for the settlement of Jubice

PARAMETER	Inflow loading with Q medium	
	in g/EP/day	u kg/day for 590 PE
Suspended Solids (SS)	70	41

Chemical Oxygen Demand (COD)	120	35
Biochemical Oxygen Demand (BOD5)	60	71
Total nitrogen (TN)	2.5	1
Total phosphorus (TP)	11	6

3 VARIANTS FOR WASTE WATER TREATMENT

General description of treatment technologies for agglomerations below 2.000 PE are presented in the Report, chapter 3.3.10.2.

3.1 VARIANT 1: CONSTRUCTED WETLAND

3.1.1 Basic dimensioning

Hydraulic parameters:
Estimated capacity: 590 ES
Daily quantity of waste waters: Votp = 88,5 m3/d
Maximum hourly flow: Qmax = 3.07 l/s

Loads:
BOD5: 35 kg/d
COD: 71 kg/d
SS : 41 kg/d
TN: 1 kg/d
TP: 6 kg/d

Process parameters:
Retention time in the sedimentation bank (Imhoff tank V = 60 m3) - 16 h
Retention time in a CW (beds) - 77 h
Total retention time - 94 h

CW dimensions take into account the amount of time necessary for the elimination of parameters (COD, BOD5, and SS). Usually, over three days are needed, under the condition that the CW is adequately maintained and that primary treatment is executed.

Primary treatment is taking place in the sedimentation tank. Due to the correct deposition of particles, sufficient time in the sedimentation tank must be ensured to achieve a 70% suspended matter reduction. In the sedimentation tank, decomposition of organic matter takes place, ensuring a parameter decrease of COD and BOD5 by 30%.

The total effective volume of the beds where wastewaters will stream represents the app. 30% of the total volume and amounts to 285 m3. The maximum inflow of water to the CW for 590 PE is 88,5 m3/day. Therefore, the CW's retention time is 77 h, and 16 hours in the sedimentation tank. Total retention time is 94 h (3,90 days), which is sufficient to ensure wastewater treatment that reaches the required limit values for wastewater emissions.

Waste water treatment is occurring in the following parts of a device in order of appearance:
Primary treatment – sedimentation tank;
Filtration bed (FB);
Purification bed (PB);
Polishing bed (PsB).

The dimensions of single beds are demonstrated in the table below.

Table 3: Dimension of beds

Beds	Width [m]	Length [m]	Depth* [m]	Area [m2]	Volume [m3]	Effective volume [m3]
FB	20	20	0,6	400	240	72
PB	20	40	0,7	800	560	168
PsB	15	20	0,5	300	150	45
TOTAL				1.500	950	285

*Net depth of the substrate.

Water tightness of the beds is ensured by non-permeable foil resistant to mechanical loads, UV light, air, and root growth. The thickness and type of foil are determined by the leading designer in the main project. To protect the foil from external influences, geotextile is put above and beneath the foil. The beds are filled with a substrate of different fractions (from 0.2 – 32 mm) and of different heights. Beds are usually planted with common reed (Phragmites australis) or other plants that grow well in wetlands. The density of plants should be at least 7 per m^2.

Filtration bed

Filtration bed (FB) is the first in the CW and, therefore, the most loaded. Its function is the retention (filtration) of suspended matters and others that have escaped the sedimentation tank. FB represents a sedimentation tank of nutritious and toxic matters, thus protecting the rest of the CW from being clogged. The water flow is horizontal and runs underground.

Purification bed

In purification beds (PB), an intensive degradation of waste matters is taking place. Plant activities assisted by diffusion are ensuring satisfactory levels of oxygen, thus securing an effective nitrification process and a decrease of ammonium nitrogen. The tasks of this bed are retention, accumulation, and later plant uptake of nutrients into plant and microbial biomass. The reduction of all human or animal bacteria occurs, including the reduction of pathogenic bacteria. The water flow is horizontal and runs gravitationally underground.

Polishing bed

The polishing bed (PsB) function is to bring the final stage of wastewater treatment to an end. Apart from further biological degradation of solute matters, this bed improves other parameters and reduces the rest of the microorganisms in the wastewater. The water flow is horizontal and runs gravitationally underground.

Recipient
Treated water from the constructed wetland runs into the environment or drainage ditch.

3.1.2 Investment costs

Table 4: Breakdown of investment costs for Variant 1 – constructed wetland

Part of the device	Indicator	Investment costs [EUR]
Concrete manhole with automatic coarse grid - construction works - machine works	$V = 7\ m^3$	10.000,00
Sedimentation tank (Imhoff tank) - construction works - machine works	$V = 60\ m^3$	14.480,00
Excavation of beds with preparatory works, laying of geotextile and impermeable foil - construction works - machine works	$A_{BU} = 1.500\ m^2$	50.760,00
Substrate input - construction works - machine works	$V = 950\ m^3$	29.970,00
Planting	10 plants/m^2	18.000,00
Distribution shaft (3 pieces) - construction works - machine works	DN 400 mm	825,00
Shaft for water level regulation (3 pieces) - construction works - machine works	DN 800 mm	1.980,00
Distribution and drainage perforated pipes	PE DN 110 mm	3.790,00
Landscaping and other costs	N = 590 PE	6.000,00
	TOTAL:	**135.805,00**
10% of unpredictable costs		**13.580,50**
	TOTAL:	**149.385,50**

3.1.3 Operation and maintenance costs

Table 5: Breakdown of operation and maintenance costs for Variant 1 - constructed wetland

Type of cost	Indicator	Cost of operation and maintenance [EUR/year]
Cost of sludge and waste deposition	151 m^3/year	3.014,90

Staff costs	80 h/year	800,00
	TOTAL:	**3.814,90**

Maintenance activities mostly enclose regular monitoring of the operation of a constructed wetland, occasional pumping of sludge from the sedimentation tank, cleaning of parts of the device with water, plant cutting, and landscaping.

3.2 VARIANT 2: EXTENDED AERATION

3.2.1 Basic dimensioning

Hydraulic parameters:

- Nominal capacity: 590 PE
- Daily quantity of waste waters: V_{otp} = 88,5 m^3/d
- Maximum hourly flow: Q_{max} = 3,07 l/s

Loads:

- BOD_5: 35 kg/d
- COD: 71 kg/d
- SS: 41 kg/d
- TN: 1 kg/d
- TP: 6 kg/d

Pre-treatment

Automatic coarse grid:

- Maximal flow: Q = 3,7 l/s
- Sieve hatch: d = 6 mm
- Channel width: b = 0.30 m
- Power installed: P = 1.5 kW
- Estimated daily waste: 0.207 m^3/d

Suitable deposition

Selected two storey precipitator dimensions:

- Outer diameter: DBBa = 3.7 m
- Inner diameter: BBi = 3.4 m
- Water depth: WT = 5.0 m
- Precipitator volume: V = 18 m^3
- Average surface load: q_{Amax} = 2 m/h
- Dunghill volume: V_t = 36 m^3

Biological treatment

- Volume load: BR = 0.22 kg BOD_5/(m^3 d)
- Dry matter concentration: TSS = 5.00 kg TS/m^3
- Specific excess sludge quantity: USB = 1.00 kg TS/kg BOD_5
- Sludge load: BTS = 0.05 kg BOD_5/(kg d)
- Required volume: V_{min} = 130 m^3
- Ratio of returned sludge at dry weather: R = 1
- Minimum retention time: t_{Rmin} = 12 h
- Selected dimensions of bio-aerial tank:
    - Outer diameter: D_{BBa} = 7.50 m
    - Inner diameter: D_{BBi} = 3.90 m
    - Water depth: W_T = 4.10 m
    - Volume: V_{BB} = 131.20 m^3

- Retention time: t_{Rmin} = 23 h
- Estimated values review:
    - BR = 0.248 kg $BOD_5/(m^3\ d)$
    - BTS = 0.050 kg BOD_5/(kg d)

Necessary oxygen quantity:
- Oxygen load: OB = 3.00 $kgO_2/kgBOD_5$
- Input depth: He = 3.77 m
- Specific oxygen transfer: fO_2 = 12.00 $gO_2/(Nm^3\ m)$
- Required hourly air quantity: QL = 135.00 m^3/h
- Pipe pressure loss: 150 mbar
- Pressure for blower dimensioning: 527 mbar

Blower piston:
- Nr of compressors: 2 pieces
- Input capacity per device: 102 m^3/h
- Power rated: 4 kW
- Pressure: 550 mbar

Mixers:
- Specific requested energy input: 3.00 W/m^3
- Requested energy input: 394 W
- Number of generators: 1 piece
- Rated power: 0.80 kW
- Mixer diameter: 2.0 m

Horizontal flow of additional precipitator
- Maximum surface load of sludge quantity: qSVmax = 450 $l/(m^2\ h)$
- Index of sludge volume: ISV = 100.0 ml/g
- Dried matter concentration: TSBB = 5.00 kg/m^3
- Parallel sludge volume: VSV = 500.00 ml/l
- Maximum surface load: qAmax = 1.40 m/h
- Average surface load: qAmax, pro = 0.47 m/h
- Required surface: Amin = 8.03 m^2
- Required diameter: DNBmin = 3.24 m
- Required total surface: ANBmin = 8.26 m^2
- Selected dimensions:
    - Selected diameter: DNB = 3.30 m
    - Total surface: ANBges = 8.55 m^2
    - Real surface load of sludge quantity: qSV = 434 $l/(m^2\ h)$
- Water depth calculation:
- Total height on 2/3 of flow length: HNB = 4.00 m
- Slope of the pool bottom: 3.80 n
- Minimal depth at pool edge: HR = 3.97 m
- Volume (with no entry part): VNB = 33.60 m^3
- Retention time: 4.60 h

Pumping station of returned sludge

- Maximum flow of returned sludge at dry weather: 7.23 m^3/h
- Required air quantity for mammoth pump: 6.21 m^3/h
- Actual pressure: 376.96 mbar
- Number of generators: 1 piece
- Air supply capacity per generator unit: 6.5 m^3/h
- Rated power: 0.3 kW
- Mixer pressure: 400.0 mbar
- Height of delivery for mammoth pump: 0.5 m

Excess sludge

Daily quantity of excess sludge (non thickened): 4.07 m^3/d

3.2.2 Investment costs

Table 6: Breakdown of investment costs for Variant 2 – extended aeration

Part of the device	Indicator	Investment costs [EUR]
Entry pumping station with automatic sieves - construction works - machine works	Q = 3,01 l/s	25.600,00 24.800,00
Two- storey precipitator (Emscher tank) - construction works - machine works	V = 54 m3	29.900,00 25.100,00
Aeration tank and additional thickener - construction works - machine works	V = cca 165 m^3	74.000,00 49.500,00
Power building	N = 590 PE	151.400,00
Measurement unit and electrical equipment	N = 590 PE	38.000,00
Landscaping and other costs	N = 590 PE	53.700,00
	TOTAL:	**472.000,00**

3.2.3 Operation and maintenance costs

Table 7: Breakdown of operation and maintenance costs for Variant 2 – extended aeration

Type of cost	Indicator	Operation and maintenance costs [EUR/year]
Energy costs	26 333 kWh/year	2.368
Costs of sludge and waste disposal	198 m^3/ year	3.960
Staff costs	1460 h/ year	14.600
	TOTAL:	**20.928**

4 SELECTION OF OPTIMAL VARIANT

The selection of an optimal variant will be elaborated by using multicriterial analysis. Basic aspects of defining the selection of optimal variant are:

- Technical aspects (ease of operation, the suitability of technology, ease of spare parts management, etc.),
- Environmental aspects (risk of odor, noise, the certainty of achieving targeted effluent quality),
- Financial aspect (investment costs, costs of operation, and maintenance).

All criteria (technical, environmental, and financial) have equal weight in the general evaluation.

4.1 TECHNICAL ASPECTS

Considering the described technical aspects of the device in previous chapters, the following comparison is made using criteria of ease of operation, the suitability of technology, ease of spare parts management, and required space for implementation. In the table below, technical aspects of variant solutions are compared.

Table 8: Technical aspects of single variant solutions

	Variant 1 **Constructed wetland**	**Variant 2** **Extended aeration**
Advantages	1. No energy and mechanical equipment is usually requested for operation 2. Energy built in plant biomass may be reused (briquettes, compost, animal feed, etc.) 3. The construction is simple and does not require large intervention to the environment 4. Maintenance is low-cost and simple 5. Multipurpose use of treated water is possible (watering, irrigation of green surfaces, firefighting, aquaculture…) 6. Fluctuation of water quantities caused by seasonal increase of population has no effect on operation	1. Minimal requirement for space; flexibility for drive 2. Independency from weather conditions 3. Construction of a septic tank for primary treatement is not necessary. 4. Sludge stabilisation is taking place in the same reactor (aeration tank)

Deficiencies	1. Larger need for land surface 2. Greater sensitivity for anaerobic conditions	1. Huge energy consumption 2. High level of mechanisation 3. Sludge treatment and disposal is necessary (but not sludge stabilisation)
Rank	**1**	**2**

Variant 2 is not suitable for the treatment plant of this size (590 PE) due to the complex drive and more complicated maintenance regime.

Taking into consideration technical aspects, Variant 1 – constructed wetland, is optimal.

4.2 ENVIRONMENTAL ASPECTS

Considering the described environmental aspects of the device in previous chapters, the following comparison is made using criteria of risk of odor, noise, the certainty of achieving targeted effluent quality, environmental impact in case of malfunction, etc. In the table below, the environmental aspects of variant solutions are compared.

Table 9: Environmental aspects of single variant solutions

	Variant 1 **Constructed wetland**	**Variant 2** **Extended aeration**
Advantages	1. Great treatment efficiency, 70 – 90% 2. In the decomposition, 10 - 20% of nutrients (phosphorus, nitrogen, carbon, etc.), heavy metals, pesticides and other toxic substances is taken up into plant biomass. At other devices, without additional chemicals they penetrate into the environment 3. No odours and insects develop because the water flows underground 4. Green areas contribute to urban surroundings biological diversity – representing sustainable ecosystems for birds and amphibians 5. Device improves the landscape in degraded areas	1. High treatment efficiency (BOD_5), 2. Possible biological removal of N and P 3. Low risk in emergence of odours and insects, degradation
Deficiencies		1. In the case of failure and repair of mechanical part of WWTP, microbial population needs a few days to recover; waste waters are released into the environment during this period
Rank	**1**	**2**

All analysed variants satisfy the treatment demands (achieving targeted effluent quality).

Taking into consideration environmental aspects, Variant 1 – constructed wetland, is optimal.

4.3 FINANCIAL ASPECTS

Financial aspects of variant solutions are considered through investment costs and operation/maintenance costs. The duration of cost observation is 30 years. For the calculation of net present value (NPV) of costs, the discount rate of 4% is used. Amortisation is calculated as follows:

- Construction works 50 years,
- Machine works 15 years.

Table 10: Economic aspects of single variant solutions

	Variant 1 Constructed wetland	**Variant 2 Extended aeration**
INVESTMENT COSTS (EUR)	- 159.945,50	- 472.000,00
INVESTMENT COSTS - RANKING	**1**	**2**
COST OF OPERATION AND MAINTENANCE (EUR/year)	- 5.914,00	- 20.928,00
COST OF OPERATION AND MAINTENANCE - RANKING	**1**	**2**
NPV OF INVESTMENT COSTS	- 165.386,00	- 420.600,00
NPV OF INVESTMENT COSTS AND REPLACEMENT OF EQUIPMENT	- 74.675,00[1.]	- 366.398,00[2.]
NPV OF THE REST OF THE VALUE	Not known	Not known
NPV TOTAL	- 224.060,00	- 838.398,00
NPV OF INVESTMENT AND COSTS – RANKING THE VARIANTS	**1**	**2**

1. Necessary replacement of substrate in the first bed every 10 years.

2. After 15 years, the replacement of hydro mechanical equipment is expected in the amount of minimum 60% of investment cost.

Comment: The price (market value) of plots (land) for waste water treatment plant is not taken into account.

From the table above it is evident that the Constructed wetland (Variant 1) is financially more reasonable and has minimal energy (drive) and maintenance (yearly) costs.

Taking into consideration economic aspect, Variant 1 – constructed wetland, is optimal.

Based on the analysis of costs for both variants for a period of 30 years, taking into account a 4% discount rate, it is estimated that the Variant 1 – Constructed wetland is most acceptable.

4.4 SELECTION OF OPTIMAL VARIANT

The selection of optimal variant is proposed using the multicriteria analysis. The results are demonstrated in the table below.

Table 11: The selection of optimal variant

	Variant 1 Constructed wetland	**Variant 2 Extended aeration**
TECHNICAL ASPECTS RANKING	1	2
ENVIRONMENTAL ASPECTS RANKING	1	2
FINANCIAL ASPECTS RANKING	1	2
SELECTION OF OPTIMAL VARIANT RANKING	**1**	**2**

The comparison of variant solutions for WWTP of Jubice, the constructed wetland (variant 1) has proved to be the optimal solution.

Using multicriteria analysis, Variant 1 is selected – Constructed wetland is the optimal solution for waste water treatment for the community of Jubice.

Figure 1: Positioning of the CW Jubice