REPUBLIC OF MOLDOVA

APA CANAL CHISINAU

CHISINAU WATER SUPPLY & SEWAGE TREATMENT - FEASIBILITY STUDY

Contract No: C21156/ECWC-2010-01-01

Water Production - FINAL

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seureca A Subsidiary of VEOLIA ENVIRONNEMENT

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LIST OF ABBREVIATIONS AND ACRONYMS

CAPEX	Capital Expenses
DAF	Dissolved Air Floatation
EU	European Union
HDPE	High-density polyethylene
H_2S	Hydrogen Sulphide
NH_4	Ammonium
NO_2	Nitrite
NTU	Turbidity unit
O_2	Oxygen
O&M	Operation and Maintenance
OPEX	Operational Expenses
PAC	Powder Activated Carbon
PIP	Priority Investment Program
SAN	Water Treatment Plant in Vadul Lui Voda
SCADA	Supervisory Control And Data Acquisition
SO_4	Sulphate
STA	Water Treatment Plant in Chisinau
TDS	Total Dissolved Solids
THM	Trihalomethane
WTP	Water Treatment Plant

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WATER PRODUCTION STRATEGY

1.1. BACKGROUND

1.1.1. PRODUCTION DEMAND ASSESSMENT

The following table presents the findings of the water production demand assessment study:

Table 1: Water production demand (in m^3/d)

		2010	2011	2012	2013	2014	2015	2020	2025	2030	2035
Potable water	***Production: Annual Average***	208 861	204 761	201 549	198 394	195 298	190 810	174 413	159 611	147 837	139 471
	Peak vol water into supply		252 982	249 256	245 589	241 980	236 980	219 547	202 822	189 049	180 101
	Required production capacity Potable water			284 864	280 673	276 549	270 834	250 911	231 796	216 056	205 830
Technical water	***Production: Annual Average***	7 120	7 001	6 880	6 760	6 640	6 510	5 972	5 458	4 955	4 457
	Peak vol water into supply		8 965	8 816	8 667	8 520	8 361	7 728	7 129	6 545	5 970
	Required production capacity Potable water			10 075	9 906	9 737	9 556	8 832	8 147	7 480	6 823
TOTAL	***Production: Annual Average***	215 981	211 762	208 428	205 153	201 938	197 320	180 384	165 068	152 792	143 929
	Peak vol water into supply		261 946	258 072	254 256	250 500	245 341	227 275	209 951	195 593	186 072
	Required production capacity Potable water			294 939	290 579	286 285	280 390	259 743	239 944	223 535	212 653
	Extra capacity : 3 715 m3/d			298 654	294 294	**290 000**	284 105	263 458	243 659	227 250	216 368

The total targeted production capacity shall be **290 000 m^3/d**, in 2014, including 9 700 m^3/d of "technical water" for industrial uses. The necessary investment in the various production sites are defined according to this figure.

It must be noticed that the production demand is expected to decrease afterward.

1.1.2. RAW WATER SOURCES – RAW WATER QUALITY

Two sources of water are currently used for drinking water production:

- The river Nistru
- Ground water

The water from the river Nistru accounts for more than 90 % of the total.

1.1.2.1. Quality of raw water from the Nistru

The quality of the Nistru water is quite good for drinking water production:

- The turbidity is low: from 1.5 NTU in winter to maximum 30 NTU in summer or during floods. Higher figures can be met for several hours (e.g. after a storm).
- There is no significant algae bloom – the organic matter concentration is always low (less than 3 mgO_2/L).

- Temperature varies from 1 °C in winter to 25 °C in summer. pH is always around 8.0
- Ammonia concentration is always low, with maximum figures around 0.8 mg/L
- For the other parameters (iron, manganese, heavy metals, micro pollutants, etc.), the quality of the river meet the standards for drinking water.

However, the river Nistru is vulnerable to accidental industrial pollution.

Then, the production plant shall include the following stages: clarification (removal of turbidity), and disinfection; in addition, some provisions against accidental pollution shall be included.

1.1.2.2. Quality of water from the wells

The quality of the water from the wells fields operated by APA CANAL is poor; depending on the fields, it is featured by high concentrations in:

- H_2S
- Ammonia
- Total dissolved solid,
- Sulphate

All these parameters lust be treated for drinking water production. However, it is conceivable to supply ***temporarily*** in case of emergency water with concentration in TDS, ammonia and sulphate above the standards.

Hence, if the water from the wells is used, a full treatment must be implemented for normal periods use, and at least a treatment of H_2S for emergency situation.

1.1.3. STANDARDS FOR DRINKING WATER

The targeted quality of treated water uses for the assessment of the investments is defined in the **Moldovan Standard**.

For long term investment, the EU norms, where they are more stringent than Moldovan standard, are considered.

1.1.4. OVERVIEW OF THE EXISTING FACILITIES

Currently, the water is produced in several sites:

- The treatment plant of Vadul Lui Voda, treating the water from the Nistru
- The main water treatment plant (« STA »), also supplied with raw water from the Nistru
- Wells fields for the remote villages, not connected to the city networks

The Vadul Lui Voda WTP was built in the sixties; its design capacity was 50 000 m^3/d, but the actual current production is around 25 000 m^3/d.

The main water treatment plant (STA) has been built in three phases (1972, 1977 and 1981). The current average production is around 200 000 m^3/d, for an initial design capacity of 350 000 m^3/d.

No significant investment has been made on the two plants since the construction of the third phase of the main plant, with the consequence that the two plants are today in a very bad condition and should be completely rehabilitated or reconstructed.

The total production of the well fields accounts for less than 5 % of the produced water. These fields are not operated at their maximum capacity, because of their bad conditions or because of poor water quality and lack of appropriate treatment. A part of the wells was built in 2008, as an emergency provision during an accidental industrial pollution of the Nistru, which had obliged to shut down the two surface water treatment plants.

1.2. PRODUCTION SCHEME

The production site of Vadul Lui Voda (SAN) will be decommissioned: as this plant takes its water from the Nistru, like the main site, it cannot be considered as a backup facility in case of accidental pollution. In the other hand, it will be more cost efficient to keep in the future one production site only for the Nistru water, instead of the two existing ones. Finally, the whole area supplied by SAN can easily be connected to the main network. Only the raw water pumping station located at SAN, and feeding STA, will be kept in operation.

Then the definition of the production scheme boils down to split the treatment capacities between the STA and the wells fields.

Given the poor quality of the ground water in most of the wells fields, the production of drinking water from these sources will require the implementation of treatment facilities.

However, when the quality issues concerns ammonia and salinity only, which, at the concentrations met in the wells, are harmful for the health only on long term, it can be contemplated to use this water without any treatment for limited periods of time, in case of accidental pollution of the Nistru, as an emergency and provisory supply only. In addition, other sources (Fantani artesiane, new wells fields near the STA) can be mobilized or developed for the emergency plan.

The marginal unit cost of treatment (CAPEX and OPEX) will be higher for the wells fields, with relatively low production capacity, than for the STA. But, in the other hand, if the wells are included in an emergency supply plan, they must be kept permanently in operation, at least for a part of the total capacity.

Depending on the strategic choices concerning the emergency plan, there are three options for the splitting of the production between STA and the wells:

Option 1: the ground water is mobilized at maximum capacity (with reasonable cost) for the emergency supply; Ialoveni is operated at high capacity for the routine supply, what requires the construction of a medium size treatment plant. The rest is produced at STA.

Option 2: Ialoveni is operated at a low capacity, compatible with the rapid implementation of a *package treatment plant*. The other wells fields are not mobilized; either for the emergency plan, and decommissioned.

Option 3: the ground water is mobilized at maximum capacity (with reasonable cost) for the emergency supply; during the normal periods, Ialoveni is operated at a low capacity, compatible with the implementation of a package treatment plant.

The following table summarize the treatment capacity (for normal situation) and the hydraulic capacity (for emergency situation, with distribution of raw water partially treated only):

Table 2: Options for treatment capacities

Future Required Capacity (horizon 2014)		Option 1	Option 2	Option 3
Balişevschi	m^3/d	850	0	850
Ghidighici	m^3/d	790	0	790
Petricani	m^3/d	1 130	0	1 130
Sîngera	m^3/d	0	0	0
sat. Ghidighici	m^3/d	0	0	0
Vatra	m^3/d	0	0	0
Goianul Nou	m^3/d	0	0	0
Ialoveni	m^3/d	15 000	5 000	5 000
SAN	m^3/d	0	0	0
STA : potable water	m^3/d	262 493	275 263	273 493
STA : technical water	m^3/d	9 737	9 737	9 737
TOTAL	m^3/d	**290 000**	**290 000**	**290 000**

In addition, as part of the emergency supply plan, for option 1 & 3, the *hydraulic* capacity of the wells fields shall be increased as shown in the following table:

Table 3: required hydraulic capacities for emergency plan

Future Required Capacity (emergency plan)		Current Capacity	Possible Additional Capacity	Total
Balişevschi	m^3/d	1 900	6 600	8 500
Ghidighici	m^3/d	4 400	3 500	7 900
Petricani	m^3/d	0	11 300	11 300
Goianul Nou	m^3/d	0	0	0
Ialoveni	m^3/d	3 120	17 780	20 900
New well field near STA	m^3/d	0	15 000	15 000
TOTAL	m^3/d	**9 420**	**54 180**	**63 600**

During emergency situation (pollution of the Nistru), the production of STA will be reduced to 200 000 m^3/d, by using at their maximum capacities the other sources, for option 1 & 3 – and 275 000 m^3/d for option 2. .

Then, the necessary investments *for the treatment facilities* are listed below:

- **Option 1**:
  - Rehabilitation of STA for a peak design capacity of **263 000 m^3/d**
  - Construction of a treatment plant at Ialoveni
    - treatment of ammonia, turbidity and H_2S for a capacity of **15 000 m^3/d;**
    - aeration and chlorination for **20 900 m^3/d.**
  - Construction of a disinfection at Petricani (for **11 300 m^3/d**)
  - Construction of a treatment plant at Ghidighici (aeration and chlorination, for **7 900 m^3/d**)
  - Construction of a treatment plant at Balişevschi
    - aeration, filtration, chlorination for **850 m^3/d**
    - aeration and disinfection for **8500 m^3/d**
  - Rehabilitation and extension of the wells fields
  - Construction of a Powder Activated Carbon facility in STA to be used in case of accidental pollution of the Nistru, for a production capacity of 200 000 m^3/d.

- **Option 2**:
  - Rehabilitation of STA for a peak design capacity of **275 000 m^3/d**
  - Construction of a treatment plant at Ialoveni for a capacity of **5 000 m^3/d**: treatment of ammonia, turbidity and H_2S
  - Construction of a Powder Activated Carbon facility in STA to be used in case of accidental pollution of the Nistru, for a production capacity of 275 000 m^3/d.

- **Option 3**:
  - Rehabilitation of STA for a peak design capacity of **274 000 m^3/d**
  - Construction of a treatment plant at Ialoveni
    - treatment of ammonia, turbidity and H_2S for a capacity of **5 000 m^3/d**:
    - aeration and chlorination for **20 900 m^3/d.**
  - Construction of a treatment plant at Petricani (disinfection for **11 300 m^3/d**)
  - Construction of a treatment plant at Ghidighici (aeration and chlorination for **7 900 m^3/d**)
  - Construction of a treatment plant at Balişevschi
    - aeration, filtration, chlorination for **850 m^3/d**
    - aeration and disinfection for **8500 m^3/d**
  - Rehabilitation and extension of the wells fields
  - Construction of a Powder Activated Carbon facility in STA to be used in case of accidental pollution of the Nistru, for a production capacity of 200 000 m^3/d.

2. INVESTMENT PLAN FOR WATER PRODUCTION PLANTS

2.1. Reconstruction of the main treatment plant (STA)

2.1.1. General investment strategy

Currently, the quantity of water produced by the main plant is sufficient to cater for the demand, and the quality complies with the Moldovan norms of quality. However, several important issues are met:

- The treatment is difficult during the critical periods (very cold water, flooding, etc.)
- The existing design obliges the use of a strong prechlorination, which is costly and not permitted by the EU regulation, for health reasons.
- The plant is vulnerable to accidental pollution of the Nistru
- The operation is hard and staff demanding (manual desludging of the settlers; manual control of the filters); basic safety standards are not met.
- The loss of water for filters backwashing is very high compared to international standards for this kind of plants.
- Most of the equipment is worn out; more and more frequent stops for breakdown and repair can be expected – civil work is locally in very bad condition – basic renovation works are necessary.

Then, the investments to be made on the water production can be driven by the following different objectives:

- Objective 1: improve the efficiency of the treatment – decrease the chlorine demand for prechlorination
- Objective 2: improve the technological reliability of the operation –
- Objective 3: upgrade the plant to make it able to cope with accidental pollution of the Nistru
- Objective 4: make the O&M less staff demanding, less hard, safer and more reliable

According to these objectives, the investment program can be split in sub projects and staggered:

- retrofitting of the coagulation / flocculation / settling
- overhauling of the filters
- implementation of a powder activated carbon injection
- reconstruction of chemical preparation and dosing
- upgrading of instrumentation and control system

These subprojects are more or less independent the ones from the others.

2.1.2. RETROFITTING OF COAGULATION / FLOCCULATION / SETTLING

2.1.2.1. Expected benefits

The upgrading of the coagulation/flocculation/settling stage is a mandatory investment to be implemented *before* the overhauling of the filters as, in the current situation, the poor performances of the settling are balanced by the under-loading of the filters.

This subproject will allow meeting the following objectives:

- Increase the quality of settled water – then getting an easier operation of the filters
- Decrease (and even almost stop) the continuous chlorine injection at prechlorination
- Cancel the hard and unsafe operation of manual desludging.

2.1.2.2. Current situation:

Coagulation in carried out in two tanks, fitted with baffles to generate static mixing. There are followed by contact tanks.

Then the flow is distributed on 16 settlers through metal sheet troughs and weirs; these equipments are totally corroded. Each settler includes a static flocculation zone and a settling zone.

The flocculation zones have a surface of 12 x 19.5 m, and a water of depth of 4.5 m. The coagulated water is distributed through drilled pipes laid on the bottom of the tanks. Each flocculation corridor of 6 m width is split into three successive compartments, with baffle walls. There is no mechanical stirring.

The settling zones have a surface of 12 x 63 m (756 m²), and a water depth of 4.5 m. The settled water is collected through drilled pipes (also totally corroded).

The settlers are totally covered with a thick concrete roof.

Photo 1: Settlers inlet troughs

One additional settler is used for treating dirty backwash water from the filters, for the production of technological water.

The sludge is collected three or four times a year. There are two procedures for collecting the sludge:

- In summer, the settler is emptied; an operator goes inside the tank and removes the sludge through the drilled pipes with the help of pressurized water
- In the other seasons, the draw off of the sludge is helped by injection of compressed air, but this method is not efficient at all.

Before the summer cleaning, the thickness of the layer of sludge can reach 50 cm.

2.1.2.3. Retrofitting works:

The upgrading of the settling is a priority project, because it is a mandatory condition for optimizing the chemical consumption (decrease of pre chlorination) and rehabilitating the filters.

In order to get an efficient settling, the following modifications must be implemented:

- Mechanical flash mixing for coagulation
- Efficient sludge removal device in the settlers.

Considering 3 % of water losses for filters backwashing, and 3 % of water losses for settlers desludging (conservative figures in both cases), the rehabilitation of STA shall be designed according to the water balance shown in the following table:

Table 4: water balance at STA

Water Balance inside STA		Option 1	Option 2	Option 3
STA: potable water	m^3/d	262 494	275 264	272 494
STA: technical water	m^3/d	9 737	9 737	9 737
Settled water inlet to filters	m^3/d	270 368	283 522	280 668
Filters backwash water	m^3/d	7 481	7 845	7 766
Additional technical water (settled water)	m^3/d	2 256	1 892	1 971
Total settled water	m^3/d	272 624	285 413	282 639
Total settled water	m^3/h	11 359	11 892	11 777
Raw water to STA	m^3/d	280 803	293 976	291 118

The basic design of the rehabilitation works is presented hereunder for option 2 (it can be very easily adapted to options 1 or 3).

***Flash mixing*:**

A retention time of minimum 60 seconds is necessary for a good and complete coagulation. Then, two tanks of 102 m^3 each must be created, in two parallel lines.

A part of the existing mixing tanks can be reused for the implementation of these flash mixing tanks. The water depth is 4.4 m, with 30 cm of additional free board.

One tank only would be too big, and the side/depth ratio would not be optimum; then, it is recommended to implement two successive tanks per line, of 50 m^3 each (side: 3.5 m x 3.5 m; depth 4.2 m).

Each tank will be fitted with one vertical flash mixer. The power of the mixers is calculated on the base of a velocity gradient (G) of 300 s^{-1}.

Mixing power = 2 x 4.7 kWatt / line.

***Flocculation zone*:**

For each 6 m width corridor, the total volume of the existing flocculation tank is around 330 m^3.

For low temperatures and low turbidity, a minimum retention time in the flocculation tank of 20 minutes is recommended. The renovation of **14 corridors** minimum will be necessary to insure the correct flocculation time.

To improve the efficiency of the flocculation, mechanical stirring must be implemented. The best solution would be to remove the existing baffle walls, and install two vertical stirrers per corridor.

***Settling zone*:**

There are several technical options for rehabilitating the settling zone:

***Solution 1: rehabilitation according to the initial design, with implementation of a bottom sludge scrapping*.**

In this case, a maximum surface loading of 1.25 m/h can be considered as design criteria. Then, a total of 9 900 m² shall be rehabilitated, corresponding to a minimum of 14 settlers (i.e. 28 corridors).

The flocculation zone upstream each corridor could be reduced to 165 m2 – only one mixer would be implemented per corridor.

The main difficulty would be the design of the bottom scrapper. It is probably not feasible to scrap the sludge on the whole length of the settling zone (54 m) unto a hopper ; then, at least two (or even three) successive scrappers should be implemented, the first one scrapping the first third of the settler (where most of the sludge would settle), and the second one the two others.

In addition, hoppers shall be built at the end of the scrapped zones. As it is not recommended to break the existing raft, these hoppers could only be created by filling the bottom of the settlers with concrete. The implementation of the final sludge extraction pipes (from the hoppers) would also be difficult; it would probably be necessary to install submersible sludge pumps.

Another technical solution would be to implement a V shaped bottom, and to pump the sludge all over the length of the settler with a submersible pump carried by the travelling bridge.

In all the case, the upgrading of the existing settlers with keeping the principle of static settling will require important modification of the civil work: the removal of the existing roof, the complete reshaping of the bottom, the creation of new sludge channels of pipes. Hence, this solution is very dependent on the actual condition of the concrete, which can be investigated only with accurate and deep tests.

Solution 2: implementation of lamellae in the existing settlers

The use of lamellae would allow the concentration of the sludge on a part only of the existing settler, and then simplify the issue of sludge scrapping.

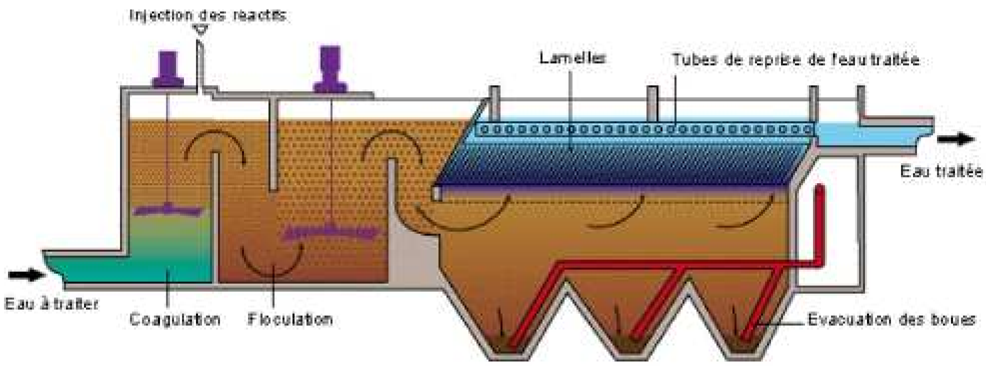
The limiting factor for the design of lamellae clarifiers will be the sludge withdrawing system. The total available water depth (around 4.3 m) is not enough to implement a moving scrapper with hoppers. The only possible system would consist in a set of drilled pipes laid in the bottom of longitudinal V shaped concrete corridors. To get a uniform desludging (and avoid sludge accumulation at the end of the pipes), the length of these pipes must be limited to about **6 meters**.

Then, the unitary surface of the settler will be limited to 36 m², and the implementation of lamellae would require the retrofitting of **18 corridors** (in this case, the flocculation tank shall also be rebuilt for 18 tanks – with two mixers per corridor).

A typical design would be based on the following dimensions:

- Length of the lamellae: 1.0 m – number of lamellae modules: 133 – total length of the lamellae pack: 5.5 m.
- Hazen velocity on the total projected surface of the lamellae: 1.0 m/h
- 6 settled water collecting pipes per corridor – diameter: 300 mm
- Number of sludge pipes: 4 – diameter: 200 mm – each pipe would be fitted with an automatic pneumatic valve.

The following sketch shows the principle of a lamellae settler; in the case of STA, the sludge hoppers would be replaced by longitudinal V shaped corridor, fitted with drilled pipes:



This solution is a good trade-off between the complexity of the construction and the number of tanks to be rehabilitated. However, the following point must be noticed:

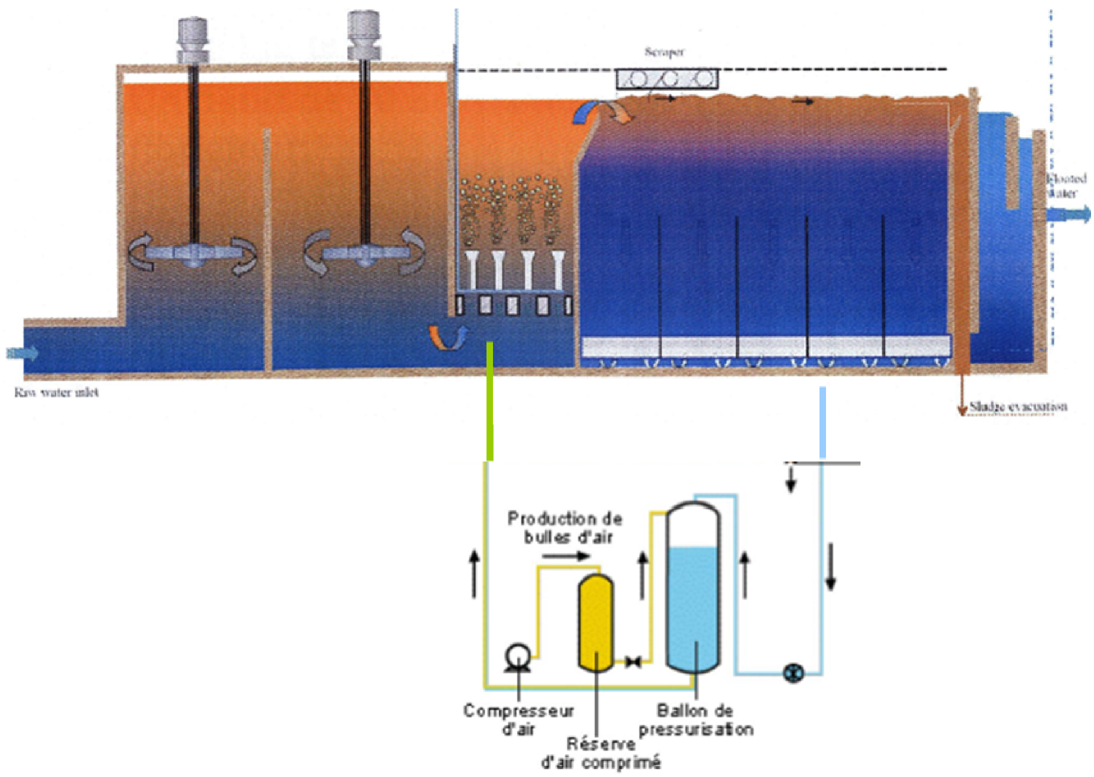
- It requires a complete reshaping of the bottom of the settlers – the feasibility and the exact final cost of this operation is very difficult to assess at this stage of the study.
- The detailed design of the sludge pipe shall be very carefully carried out, especially the diameter of the holes, which shall not be uniform along the pipe (otherwise, sludge accumulation could occur at the head of the pipes).
- The lamellae pack would be supported by reinforced concrete walls to be build inside the existing ones – so that the structural design can be independent from the existing concrete structures.

Solution 3: implementation of dissolved air floatation (DAF) in the existing settlers

This solution would present the advantage of entailing very little modification of the existing civil work, and being almost independent from the bottom conditions – the idea would be to recover the sludge on the surface instead of scrapping the bottom.

With an optimized hydraulic design, the surface loading can be designed up to 25 m/h (even 30 m/h in some cases). As the length of the settling zone is limited to 6 m (for a proper and safe surface scrapping), it would be necessary to retrofit **14** of the existing 6m-width corridors. Then, each floatator will have a settling surface of 36 m², and the total hydraulic loading will be limited to 23.2 m/h for option 1, 24.3 m/h for option 2 and 24.1 m/h for option 3.

Figure 2: principle of Dissolved Air Floatation



The implementation of the 14 floatators tanks will require the following works, for each compartment:

- Rearrangement of the flocculation zones – implementation of 2 mechanical mixers per zones
- Construction of new baffle walls
- Implementation of recycled water plus air diffusers in the mixing zone
- Implementation of surface scrappers
- Implementation of bottom drilled pipes for settled water recovery
- Construction of a sludge compartment, fitted with a sludge submersible pump
- Construction of a shelter above the tank, to house the air compressor and the recycling pump
- Connection of the settled water pipe to the existing outlet trough

Other works:

In addition, the following works must be done on the settling stage:

- Replacement of the inlet distribution troughs (steel troughs, which are corroded)
- Rehabilitation or replacement of interconnecting pipes – between coagulation and flocculation, between settlers and filters

2.1.2.4. Conclusion of settlers renovation

The investment costs of both solutions are very similar; the operation cost of floatation is higher, due to a higher energy consumption. Therefore, the lamellae settling would be preferable.

However, the technical feasibility of a bottom desludging system must be confirmed by detailed investigation before selecting this solution.

The best would probably to launch a tender on a “turn key” basis, and to let open the final choice of the process to the Contractor – with a cost comparison system taking into account the CAPEX and the OPEX. This procedure would require that an access is given to the tenderers to some empty settlers, in order to give them the possibility of carrying out detailed investigation on the conditions of the bottom.

2.1.3. RENOVATION AND OVERHAULING OF THE FILTERS:

2.1.3.1. Expected benefits

The overhauling of the filters will result in an increase of treated water quality and steadiness, and in a decrease of water consumption for backwashing. In addition, a better water distribution on the filters and the implementation of an efficient control system make able to use a part of the filters only; that will decrease the maintenance and equipment renewal costs.

2.1.3.2. Current situation

The filters battery includes 20 dual rapid dual media filters. The heights and the nature of the media seem to depend on the filter. Some filters are filled with zeolith and activated carbon, some other with sand and activated carbon, some with a mix of sand and zeolith, and activated carbon. The total height of media varies between 180 and 210 cm.

The surface of the filters also varies, probably due to inaccurate construction; the average is 112 m² for the filters 1 to 10, and 117 m² for filters 11 to 20. The total filtration surface is then around 2 290 m². With the current production of approximately 200 000 m², this gives a surface loading of 4.0 m/h, which is very low, given the height of media.

The activated carbon has never been regenerated; so it is probably completely saturated. Actually, the use of activated carbon in a dual media filters is questionable: in the conditions of Chisinau, the activated carbon would have a physical *adsorption* effect only (no significant biological activity, because of the strong prechlorination); then, it would required frequent and expensive regeneration. Hence, it is recommended to cancel the activated carbon filtration, and to replace it by injection of powder activated carbon (see below) in the coagulation tank, in case of accidental pollution of the Nistru only (analysis show that there is no permanent pollution of the raw water by micro pollutant – the only problem in the current situation being the formation of THM due to prechlorination).

There is no equal distribution upstream the filters: they are all hydraulically connected. The filters control is fully manual; an operator has to check every 30 minutes the filtrated water flow on each filter, and adjust manually the water distribution with the outlet valve.

The drainage system is made of drilled pipes (in cast iron or in HDPE, depending on the filters), or in porous concrete slabs.

The backwash is made with water only; this method is not efficient and results in a high consumption of filtrated water (4 to 8 % - even up to 15 % during critical periods, when two backwashes per day are necessary for each filter). Filtration cycle life varies between 40 hours when the raw water quality is good and 12 hours when the water is difficult to treat. There are two backwash pumps, having each a capacity of 6 250 m3/h. The actual backwash flow is estimated at approximately 4 500 m^3/h; this low flow would be due to a defect of the inlet valves, which cannot be fully open anymore.

The civil works seem to be in relative good conditions, given the age of the structures; only several cracks and missing tiles are visible. The roof of the filters room is leaking.

Photo 2: filters

There is a provision to inject coagulant at the inlet of the filters. This is used only when the water is difficult to treat, because of low temperature or during flooding periods.

2.1.3.3. Overhauling works:

Redesign of the filters:

The implementation of an efficient backwash system and the improvement of the global hydraulic scheme would allow the increase of the surface loading on the filters.

With a total media depth of 180 cm, for instance, a maximum loading of 17 m/h could be accepted, with a targeted turbidity of 0.5 NTU for the filtrated water.

To keep some safety margin, a good trade off could be to overhaul **10 filters of 117 m²**, giving an hydraulic loading of 9,6 m/h to 10.5 m/h, depending on the option.

Table 1: Design characteristics for each option

	Capacity	Number of filters	Height of sand	Filtration velocity
Option 1	263 000 m^3/d	10	121 cm	9.63 m/h
Option 2	~~277~~ 275 000 m^3/d	10	125 cm	10.14 m/h
Option 3	274 000 m^3/d	10	125 cm	10.03 m/h

Required characteristic of the sand: effective size 1.0 mm; uniformity coefficient < 1.5

The sand layer will be supported by a gravel layer of 10 cm.

The ten filters to be renovated could be selected after a comprehensive assessment of the status of the civil work. The other ones would be decommissioned.

In order to get a good repartition of the settled water flow over the filters (independent from the degree of clogging of each filter, and on the inlet flow), a weir should normally be implemented at the inlet of each filter. This is difficult to carry out, and would entail deep modifications of the civil works; however, it is possible to decrease the water level upstream the filter with a proper regulation of the filtrated water valves (see below), in order to get a weir at the level of the inlet troughs.

***Implementation of a new underdrain system*:**

The breaking of the old drainage porous slabs is one major problem. The slabs have been progressively replaced by drilled pipes. However, 5 filters still have this old underdrain system.

The drilled pipes also tend to break.

In addition, the increase of the hydraulic loading on the filters will require the implementation of an efficient underdrain system to get good filtrated water distribution.

Two kinds of technologies can be regarded:

- Construction of a nozzled false floor
- Implementation of prefabricated system in stainless steel (e.g.: TRITON from Johnson - http://www.johnsonscreens.com/content/triton-underdrain-system-7)

The prefabricated system solution will be more expensive, but present the great advantage of being almost independent from the existing civil work, whereas the construction of the false floor would require sealing and grouting of the supporting posts in the existing raft.

The following sketch shows the principle of the TRITON underdrain system:

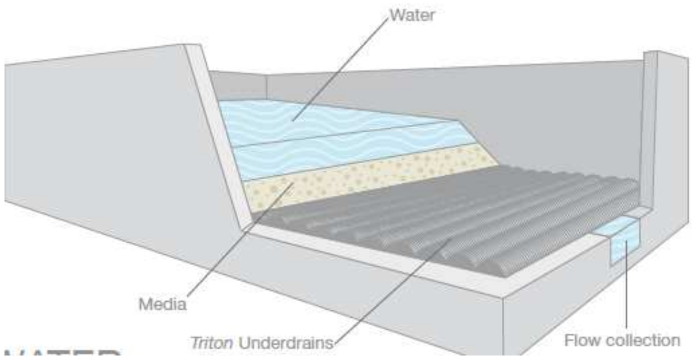
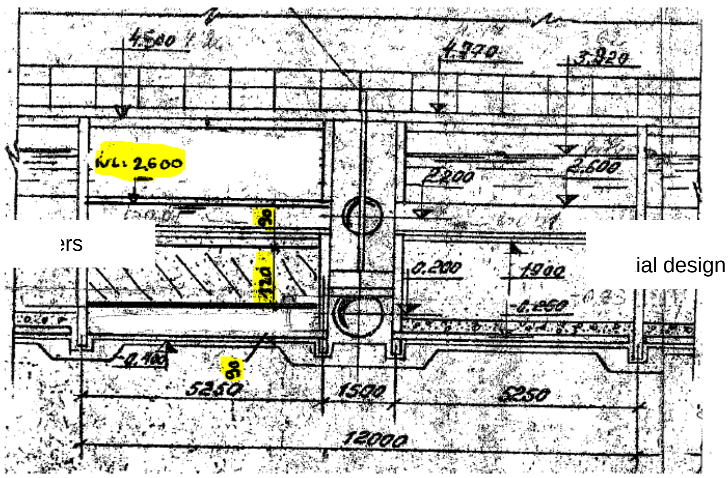


Figure 3: TRITON underdrain system

The levels in the retrofitted filters will be modified; the following sketch compares the new level with the ions of the initial design:



design

Implementation of air + water backwash system

The implementation of a combined air and water backwashing would allow an important savings in backwash water, and improve the quality of the backwash and thus the filtration cycle life. However, this modification is not mandatory and can be postponed.

The initial design of the piping makes difficult the connection of an air pipe at the outlet of the filter; the injection of air could disturb the backwash water flow; then, it is recommended to implement an air injection grid in the filtration media, and to supply it with air from the top of the filter.

Air backwash would be performed at 50 $m^3/m^2/h$ – requiring the installation of two blowers (one in duty, one in stand-by) of 5,750 Nm^3/h capacity – with around 350 to 400 mb of backpressure.

Implementation of an automatic filter control system

The level above the filter will be set just under the level of the distribution troughs, in order to get a weir and a good water distribution over the filters.

In each filter, a level measurement will be implemented – for instance with an ultrasonic sensor. This measurement will control the opening of the filtrated water outlet valve, to balance the progressive clogging of the filtration media.

Replacement of equipment

The following equipment must be replaced:

- Settled water inlet valve
- Backwash inlet valve
- Backwash water outlet valve
- Filtrated water outlet valves
- Filter control panels

Renovation of the civil work

In most of the filters, the civil work seems to be in rather good conditions.

This should be confirmed by a detailed investigation to be carried out during the preparation of the Tender Documents for the renovation contract. It is reasonable to assume that at least ten filters will be is such condition that an extension of their life for several tenths of years is possible with superficial renovation work only.

Then, the renovation works would basically include:

- Replacement of missing tiles
- Fixing of the roof

- Treatment of superficial cracks, on case they exist on the filters selected for rehabilitation.

Not renovated filters

The ten other filters, which will not be renovated, could be kept in working conditions as stand-by facility.

2.1.4. IMPLEMENTATION OF A CONTACT TANK FOR FINAL DISINFECTION

The historical treated water analysis shows that the residual concentration of ammonia is sometime not negligible (up to 0.7 mg/L); this results in a high chlorine demand, with a significant reaction time. Beside, some other parameters may create a slow chlorine demand.

This contact time is also required for a full and reliable disinfection.

Then, the residual free chlorine can only be safely controlled with a sufficient retention time between chlorine injection point and the residual chlorine analysis point. A standard value of 30 minutes can be considered.

This entails a contact capacity 5700 m^3.

2.1.5. IMPLEMENTATION OF POWDER ACTIVATED CARBON INJECTION

The existing layer of activated carbon on the filters cannot be considered as a reliable barrier for micropollutants. Grain activated carbon requires frequent regeneration, because of progressive saturation.

As activated carbon shall be used for emergency purpose only (with the hypothesis of a progressive stop of the continuous prechlorination), it would be more efficient to consider powder activated carbon, to be temporarily injected in the coagulation tanks in case of pollution, than continuous filtration on grain activated carbon.

A maximum dosing rate of 25 mg/L can be considered for the design of the PAC facilities, corresponding to 300 kg/hour of PAC to be injected.

The PAC plant would include:

- A storage silo (6 Tonnes capacity)
- A PAC slurry preparation tank, with a dosing screw and a mixer
- Two PAC slurry dosing pumps (capacity: 2,000 L/ h each)
- Safety system to avoid fire or explosion of the dry PAC

2.1.6. Renovation of the chemical storage, preparation and dosing plant:

The following chemicals are used in the plant:

- Coagulant: aluminium sulphate or aluminium hydroxide chloride
- Floculant: polyacridamine
- Disinfection: gas chlorine, to be replaced within the emergency investment program by sodium hydroxide.

The aluminium sulphate is delivered under powder form; this powder is dissolved in a storage tank, and then, the concentrated solution is transferred to a dilution tank, where water is added, and from the dilution tank to a dosing tank. It is injected by dosing pumps.

The same facilities are used for aluminium hydroxide chloride.

The whole system is old and degraded. A lot of abandoned equipment are still in place and make the operation unsafe and hard.

A complete reengineering of the coagulant storage, dilution and dosing should be done; this would include:

- Dismantling of all equipment
- Deep renovation of civil work
- Supply of new transfer pumps pipes and fitting
- Supply of new dilution pipes and fitting
- Supply of new dosing pumps
- Automation of the whole system

2.1.7. Upgrading of the control system

There is a lack of instrumentation and control within the plant, compared to modern international practices.

When the main rehabilitation works (settlers, filters, chemical plant) have been implemented, a upgrading of the instrumentation and control will be possible and relevant.

The benefits would be to make the operation less staff demanding and more reliable, and to upgrade the operational data recording.

The following on-line instrumentation should be implemented:

- On raw water: turbiditimeter, pH meter, temperature
- On settled water: turbiditimeter
- On treated water: turbiditimeter, pH meter, residual chlorine

- On each filter: water level upstream
- Water level in the backwash water tank

A specific SCADA system, dedicated to the treatment plant only (separated from the network control) would be preferable. Some automation sequences or loops must be implemented

- Settlers desludging: automatic sequence based on frequency / timers.
- Filters backwashing
- Coagulant dosing controlled by raw water flow and turbidity
- Chlorine doses for final disinfection controlled by residual chlorine concentration

2.1.8. Other replacements – long term investments

In addition to the investment described above, the full replacement of the electrical plant must be planned in the coming years.

The retrofitting of the existing settlers is a provisory solution; it will most probably be necessary to built new settlers within 15 or 20 years – depending on the actual condition of the existing civil works.

2.2. Water treatment for the wells fields

2.2.1. General

In option 1 & 3, the wells will be used:

- For water supply in normal situation
- As part of the emergency plan

In order to minimize the investment (at least for the priority investment plan), it is proposed to accept temporary non compliance of water quality during emergency. This would concern mainly the TDS and the sulphate concentrations, which haven't any immediate effect on health.

Then, the following strategy is proposed:

- Full treatment of H_2S and NH_4 for permanent supply
- Dilution of the water in the reservoirs for permanent supply, in order to meet the standard for TDS and SO_4
- Partial treatment only of NH_4 and H_2S (by aeration and chlorination) for the emergency supply

- No treatment of TDS and SO_4 for the emergency supply

Then, the following facilities are proposed:

- Aeration for the emergency flow capacity
- Biological treatment of NH_4 and H_2S for the normal supply flow only
- Disinfection with break-point chlorine injection, based on emergency supply and average concentration of NH_4 and H_2S.

2.2.2. PROCESS DESIGN PARAMETERS

2.2.2.1. Proposed treatment process

In most of the wells, the pH of the water is comprised between 7.5 and 7.8.

In this range of pH, the percentage of sulphide which is as H_2S is low (30 % to 10 % only). From 70 % to 90 % of the sulphide is present as HS^-, which is very soluble. Hence, an acidification of the raw water is necessary before the aeration, in order to get a good efficiency of the stripping. A pH of 6.5 to 6.8 can be targeted.

The stripping of the H_2S will raise again the pH, making it compatible with a biological oxidation of the NH_4 (which requires a pH higher than 7.0). If not, some lime could be added.

In the other hand, the aeration stage will bring the dissolved oxygen concentration to the saturation.

Biological nitrification of NH_4 will be carried out in a sand filter. The nitrification of 1 mg of NH_4 requires 4.2 mg of oxygen. Considering a water temperature of 10 ℃, the saturation concentration is around 10.2 mg/L. Hence, a maximum of 2.4 mg/L of dissolved NH_4 can be biologically treated in the filter.

For a full biological treatment of NH_4, a contact time of 10 minutes minimum is required in the filter. Surface loading will be limited to 6.5 m/h.

When the NH_4 concentration is above the maximum treatable figure (2.4 mg/L), the remaining concentration will be removed by beak-point chlorination. The remaining H_2S, if any, will also be oxidized with chlorine.

2.2.2.2. Remarks on Nisporeni plant

An experimental plant has been implemented in Nisporeni, treating a water with quality problems similar to those of Ialoveni and Ghidghici.

In Nisporeni, The raw water contents:

- Up to 15 mg/L of H_2S
- Around 4 to 6 mg/L of NH_4

- 1.5 mg/L of fluoride

The turbidity is 2 to 4 NTU.

pH is comprised between 7.5 and 8.0

Instead of stripping the H_2S, which would require an acidification, the treatment is based on a *biological oxidation*.

The process line includes:

- A biological reactors, fitted with a plastic packing and forced aeration (one reactor per stream)
- A coagulation by injection of $Al_2(SO_4)_3$
- Settling tanks (2 tanks per stream – diameter is around 4 m)
- Rapid filtration on synthetic floating media bed (polystyrene) - 4 filters per stream
- Final disinfection with sodium hypochlorite.

The plant has been commissioned in July 2011.

Some analytical results were available; they show that:

- The biological oxidation of ammonia is very efficient; but results in some non compliance in nitrite (NO_2) concentration.
- The seeding of the H_2S oxidizing biomass is very slow – more than one month was necessary to reach a complete removal of H_2S in the biological tank.
- Turbidity of the treated water is little bit high compared to usual standard (1.5 to 2.0 NTU, for a usual target value of 0.5 NTU).

***Comment on the process*:**

The biological treatment of H_2S and NH_4 with attached growth should work well and is a good option compared to chemical treatments (saving in operation costs and oxidation of H_2S, avoiding strong smelling).

However, the implementation of a settling stage between the biological reactor and the filters is questionable. Given the raw water turbidity and the expected production of sulfur, it is probably not necessary. Direct filtration (with injection of coagulant) should be enough.

In the other hand, there is no real benefit in using floating synthetic media in the filters, compared to a traditional sand filtration. The reasons evoked would be a safe in energy consumption for backwashing.

***Conclusion on Nisporeni plant*:**

In its current configuration, this process would be more expensive than conventional ones, at least for the low H_2S concentrations met at Ialoveni and in the other wells fields of Chisinau (around 2.5 mg/L compared to more than 10 mg/L at Nisporeni). However, a simplified design (biological tank directly followed by sand filtration) could be contemplated.

At this stage of the feasibility study, the assessment of the investments and O&M costs is based on a conventional treatment line (acidification – stripping,- sand filtration).

2.2.3. PLANTS DESCRIPTION:

2.2.3.1. Ialoveni:

For option 2 & 3, a package plant of 5000 m^3/d shall be implemented at Ialoveni; for option 1, the plant shall have a capacity of 15 000 m^3/d.

Option 1: 15 000 m^3/d

Acid injection will require a storage tank of 2.5 m^3, to be installed in a retention bund.

Then, aeration can be achieved in a saturation tower fitted with proper packing, or through a set of vertical sprinklers.

Photo 3: example of aeration with vertical sprinklers

Rapid sand filtration will require the construction of a battery of 4 filters, with a unitary surface of 27 m². These filters will be built in reinforced concrete, and the battery will include a machine room for backwashing (air and water).

Then the treated water will be stored in a 500 m^3 tank; in which sodium hypochlorite or pure chlorine will be injected.

Option 2 & 3: 5000 m^3/d

For option 2 & 3, a package plant can be implemented, including:

- Aeration tower
- Rapid sand filtration in pressure filters (5 filters – diameter: 3.02 m)
- Final storage and chlorination

2.2.3.2. Other plants:

Packages plants similar to the one of Ialoveni option 2 & 3 will be required for Balişevschi, Ghidighici and Petricani

2.2.4. SUMMARY OF WELLS PLANTS MAIN CHARACTERISTICS

The following table summarize the main characteristics of the required plants for the wells fields:

Table 5: Characteristics of the required plants at the well fields for the free options

		Ialoveni			Blisevschi	Ghidigici	Petrucani
		option 1	option 3	option 2	option 1&3	option 1&3	option 1&3
NH4 max	mg/l	2.72	2.72	2.72	1.67	0.8	0.86
NH4 average	mg/l	1.51	1.51	1.51	0.64	0.32	0.67
H2S max	mg/l	2.08	2.08	2.08	2.08	2.08	1.4
H2S average	mg/l	1.5	1.5	1.5	1.38	1.62	0.9
capacity full treatment	m3/d	15 000	5 000	5 000	850	790	1 130
emergency total	m3/d	19 200	19 200	0	9 800	11 420	9 960
aeration + Cl2 only	m3/d	4 200	14 200	0	8 950	10 630	8 830
Aeration							
O2 consumption for ammonia	mg/L	*11.42*	*11.42*	*11.42*	7.01	3.36	3.61
acidification (H2SO4)	mg/L	*10.00*	*10.00*	*10.00*	*10.00*	*10.00*	*10.00*
lime injection	mg/L	*5.00*	*5.00*	*5.00*	*5.00*	*5.00*	*5.00*
Filtration							
contact time	min	10	10	10	10	10	10
volume of media	m3	107	36	36	6	6	8
total filter surface	m²	107	36	36	6	6	8
height of media	m	1.00	1.00	1.00	1.00	1.00	1.00
number of filters	u	4	5	5	1	1	2
unitary surface	m²	27	7	7	6	6	4
filters diameter (pressure filters only)	m		3.02	3.02	2.78	2.68	2.27
Disinfection							
chlorination for normal prod. (max)	mg/L	12.9	12.9	12.9	1.5	1.5	1.5
capacity chlorination normal prod	kg/h	8.06	2.69	2.69	0.05	0.05	0.07
chlorination for emergency	mg/L	15.08	15.08	15.08	7.88	5.8	7.16
capacity chlorination emergency	kg/h	3	12	0	3	3	3
total chlorination installed capacity	kg/h	10.70	14.75	2.69	3.27	2.81	3.04

2.3. ASSESSMENT OF COSTS

2.3.1. PRIORITY INVESTMENT PLANT (PIP)

The CAPEX assessment of the Priority Investment Plan is summarized on the following table:

Table 6: summary of investment costs - PIP

	Electro-mechanical	civil work	engineering costs	total costs
STA:				
Overhauling of coagulation	224 400 €	994 166 €	60 928 €	1 279 494 €
Retrofitting of settlers	3 588 200 €	1 098 347 €	234 327 €	4 920 874 €
Overhauling of filters	3 874 000 €	698 775 €	228 639 €	4 801 414 €
Electricity	990 000 €		49 500 €	1 039 500 €
Chemical plant	704 000 €	358 519 €	53 126 €	1 115 645 €
Total PIP STA				**13 156 927 €**
Additional cost for filters air backwash	455 400 €		22 770 €	478 170 €
Ialoveni option 1	540 256 €	573 289 €	55 677 €	1 169 223 €
Ialoveni option 2	433 755 €	88 000 €	26 088 €	547 843 €
Ialoveni option 3	512 503 €	154 000 €	33 325 €	699 828 €
Ghidighici	127 751 €	53 000 €	9 038 €	189 789 €
Petricani	171 592 €	53 000 €	11 230 €	235 822 €
Balişevschi	124 974 €	53 000 €	8 899 €	186 873 €
Total wells treatment option 1				**1 781 706 €**
Total wells treatment option 2				**547 843 €**
Total wells treatment option 3				**1 312 311 €**

The investment on STA can be divided in three independent projects:

- 1 : retrofitting of coagulation / flocculation and settling + electrical works
- 2 : rehabilitation of filters (with or without implementation of air back wash)
- 3: other works: rehabilitation of chemical plants