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PRODUCTION OF DRINKING WATER via THE FILTRATION PROCESS

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Abstract

The document discusses the importance of good quality drinking water for health and the use of slow sand filtration as a biological purification method. It explains the evaluation of various physico-chemical and microbiological parameters of raw water to determine the appropriate treatment. The study aims to improve the drinking water supply for a low-consumption household using water from the Ikopa River.

The raw water analysis showed that certain parameters like pH, conductivity, and turbidity were beyond acceptable limits, indicating the need for treatment. A detailed sizing of the water treatment plant is described, including components like a turbidity removal unit, microbiological elimination unit, and UV treatment system.

The document also covers the site location conditions, environmental impacts, routine maintenance, and interviews for the treatment system. It emphasizes the importance of various filtration materials like sand and activated carbon in water treatment.

In conclusion, the study highlights the significance of proper treatment methods to ensure clean and safe water. It stresses the role of filtration materials and thorough analysis of water parameters for an effective filtration system that meets health standards.

The document provides detailed bibliographical references, appendices on water characteristics and estimates, and a summary of the slow sand filtration process confirming the reduction of turbidity and microbiological parameters in treated water.

Contents

ABSTRACT **2**

INTRODUCTION **4**

I. RAW WATER **4**

I-1- PHYSICO-CHEMICAL PARAMETERS **4**
I-1-1. PH 4
I-1-2. TURBIDITY 4
I-1-3. CONDUCTIVITY 4
I-1-4. ALKALINITY 4
I-1-5. HARDNESS 5
I-1-6. SUSPENDED MATTER 5
I-1-7. BIOCHEMICAL OXYGEN DEMAND (BOD) 5
I-1-8. CHEMICAL OXYGEN DEMAND (COD) 5
I-2- MICROBIOLOGICAL PARAMETERS **5**
I-2-1. Coliforms fecal 5
I-2-2. Escherichia Coli 5
I-2-3. Streptococci fecal 5
I-3- RAW WATER QUALITY **5**
I-4- DATA ANALYZES **6**

II. SIZING OF THE PROCESSING UNIT **6**

II-1- Reservoir raw water 7
II-2- Treated water tank 8
II-3- Module sizing 8

III. SITE LOCATION CONDITION **9**

IV. ENVIRONMENTAL IMPACTS **10**

V. INTERVIEWS **10**

CONCLUSION **11**

BIBLIOGRAPHICAL REFERENCES **11**

APPENDICES **12**

APPENDIX 01: PHYSICO-CHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS OF RAW WATER **13**

APPENDIX 02: CHARACTERISTICS OF THE FILTER BED **14**

APPENDIX 03: ESTIMATED QUOTES **15**

SUMMARY **19**

INTRODUCTION

Good quality drinking water is essential for health [1]. There are several technologies to make water drinkable, namely the filtration process. Slow sand filtration is a biological purification method. It consists of passing the water to be treated through a filter bed, the most used material is sand [2]. The process provides a simultaneous improvement in the physical, chemical and bacteriological qualities of raw water. On the surface of the bed, the biological membrane is formed, in which the purification process takes place. This method is more economical because it offers the possibility of involving the community in the management, maintenance and operation of the installations [3]. This work is part of improving the drinking water supply of a low-consumption household. The water to be treated comes from the Ikopa River.

I. RAW WATER

The evaluation of the characteristic parameters of raw water indicates its quality and makes it possible to determine the appropriate type of treatment.

I-1- Physico-chemical parameters

I-1-1. pH

The pH of water represents its acidity or alkalinity. The measurement is carried out by an electrometric method using a pH meter [4].

I-1-2. Turbidity

Turbidity is due to the presence of suspended matter (clay, plankton, organic debris). Its determination is done by the electrometry method using a turbidimeter [4].

I-1-3. Conductivity

Conductivity gives the overall mineralization of water. The measurement is carried out by an electrometry method [4].

I-1-4. Alkalinity

The alkalinity of water corresponds to the presence of hydrogen carbonates, carbonates and hydroxides. The alkaline titer TA measures the content of water in free hydroxides and carbonates. The complete alkaline titer TAC corresponds to the content of free carbonate and hydrogen carbonate hydroxides. Alkalinity is measured using a strong acid standard solution in the presence of a colored pH indicator [4].

I-1-5. Hardness

The hardness of the water is linked to the leaching of the land crossed and it corresponds to the calcium (Ca) and magnesium (Mg) content. We speak of the total hardness of water or hydrometric titer (TH). The determination is made by neutralizing a volume of water with a dilute mineral acid [4].

I-1-6. Suspended matter

The suspended solids measurement provides the amount of undissolved substances present in the water. Its determination can be done by centrifugation or filtration [4].

I-1-7. Biochemical oxygen demand (BOD)

The biochemical oxygen demand should make it possible to assess the load of the environment considered in putrescible substances [4].

I-1-8. Chemical Oxygen Demand (COD)

Chemical oxygen demand determines the overall amount of oxygen needed for pollution degradation [4].

I-2- Microbiological parameters

Microbiological analyzes provide information on the health risks of water ; to be drinkable, it must not contain pathogenic microorganisms [6].

I-2-1. Coliforms fecal

Fecal coliforms are bacteria of fecal origin. These are microbiological contamination indicator bacteria and are easily eliminated by disinfection.

I-2-2. Escherichia Coli

Escherichia *coli* are bacteria that are part of the coliform group. Their presence also indicates the presence of pathogenic microorganisms such as bacteria, viruses and protozoa.

I-2-3. Streptococci fecal

Fecal streptococci are present in the feces of humans and animals. Their presence in water also presents an indication of recent fecal pollution.

I-3- Raw water quality

This work was carried out in the laboratory of the Research Unit in Process Engineering and Environmental Engineering (URGPGE) of the Faculty of Sciences of the University of Antananarivo The following table presents the physicochemical and bacteriological characteristics of the water to be treated.

Table 01: physicochemical and bacteriological characteristics of raw water

	MES (mg/L)	Turbidity (NTU)	EC (µS/cm)	pH
Sample	68,059	174,365	253,98	7.28
VMA	<30	<5	1 <3000	6.5 – 9.5
	BOD5 (mg/L)	**COD (mg/L)**	**Fecal coliforms (CFU/100 mL)**	
Sample	24,358	50,762	100 <	
VMA	<5	<20	0	
	Escherichia. Coli (CFU/100 mL)		**Fecal streptococci (CFU/100 mL)**	
Sample	10 <		10 <	
VMA	0		0	

Source : Authors

I-4- Data analyzes

According to the results of the analyzes carried out, the pH of the raw water is acidic and meets the standard required by the Malagasy state. The conductivity is of the order of 254.981 **μ** S/cm and the value also respects the potability standard. The turbidity is 172.365 NTU, means the raw water is turbid. The turbidity value is higher than the VMA and this confirms that the water must be treated before use. The BOD is 4.358 mg/L and the COD content is 50.762 mg/L. These values exceed the admissible limits and designate the importance of the organic polluting load. For the bacteriological parameters, the result showed that the raw water does not meet the potability standard and requires prior treatment.

II. Sizing of the processing unit

The treatment plant is sized for a production of drinking water of 0.5m 3 per day and is operated for 3 hours.

II-1- Reservoir raw water

The raw water tank has a capacity of 16 m3 and is divided into two compartments. With a filling frequency of four times per week, the plant can treat 3072m 3 of raw water per year. The treatment unit is supplied by pumping.

II-2- Treated water tank

The tank can have a capacity of 0.5m 3 .

II-3- Module sizing

Taking into account the quality of the raw water, the treatment plant includes:

- A turbidity removal unit
- A microbiological parameter elimination unit
- UV treatment; the system includes a stainless steel treatment chamber containing a 450L/h UV lamp , operation would be continuous in the event of disinfection. The lifespan of the lamp is estimated at one year.

The treatment unit is made on three plastic drums and in series with a capacity of 100L. The choice concerns the following criteria;

- Easy to handle ;
- Not very sensitive to temperature variations;
- Facilitates cleaning of filter components (gravel, sand and activated carbon);
- The system maintains the content of certain parameters such as color, pH, turbidity, BOD, COD and pH; unlike those built in concrete.

The module consists of a slow sand filter in series with an active carbon filter, which is preceded by a filter with variable particle sizes and is completed by a treatment chamber equipped with a UV lamp according to the following figure.

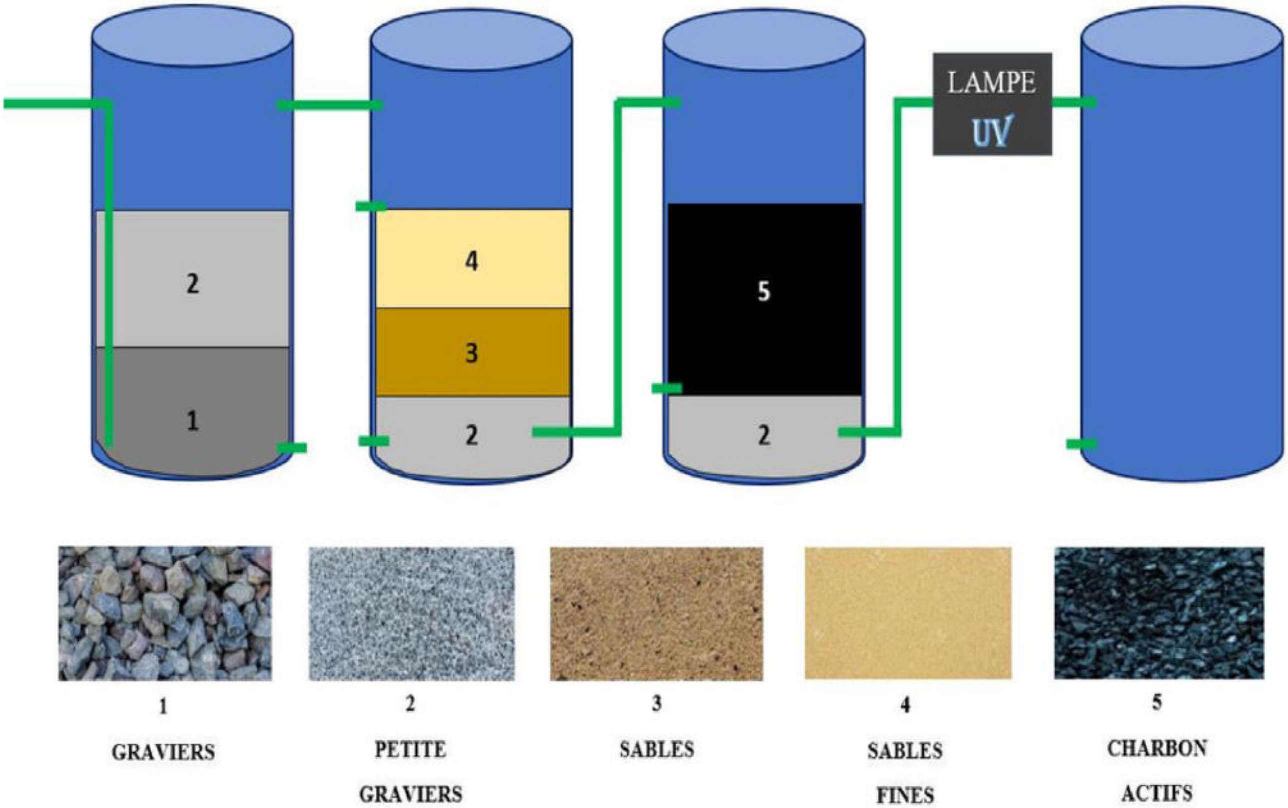

Figure 01 : simplified diagram of the processing unit

The following table presents the characteristics of each module

Table 02: module characteristics

Tanks	Component	Weight (kg)
1	Separation gravel	144
	Drainage gravel	24
2	Fine sand	50
	Sand	50
	Separation gravel	24
3	Charcoal	20
	Separation gravel	24
UV lamp	Disinfection	

Source : Authors

III. Site Location Condition

The processing module is equipped with several components. The installation must respect the following conditions:

- Location having a surface area greater than that of the proposed module. It must be well protected, secure and above all fenced;
- Good accessibility to facilitate control, servicing and maintenance of equipment;
- At least 5m away from surrounding buildings and especially trees;
- Outside of a flood-prone and sunny area;
- The existence of a technical room for the location of materials and equipment , and of a supervisor specializing in the subject, is recommended;

Building A of the EGS faculty of the University of Antananarivo was chosen for the location of the treatment site according to the following coordinates:

- Position: 18°54'49''S 47°33'03''E
- Elevation: 1335.54m

Considering the characteristics of the processing module, the station has the following dimension;

- Length of 3.5m
- Width of 2.1m
- Height of 2.5m

The following figure shows the simplified diagram of the treatment station:

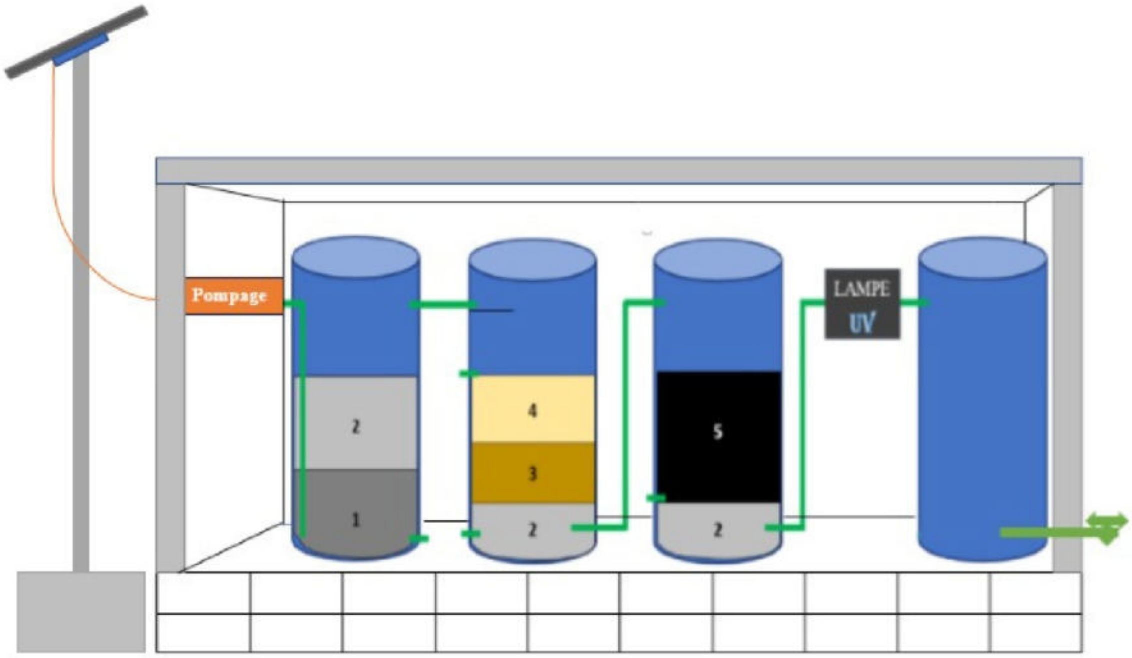

Figure 02

IV. Environmental impacts

The description of the treatment station allows certain measures to be respected, so here are some obligations and prohibitions; minimal noise, soil pollution, destruction of fauna and flora, especially ornamental plants, and also worker safety. Consumption of water treated by the sand filtration process does not present any health risk for consumers.

V. Interviews

Interviews can be done weekly, monthly or even annually. Routine maintenance includes operating the valves, checking the pumps and monitoring the quality of the treated water (perform once a week). For special maintenance, we focus on replacing the components of the filtration module (sand, gravel, activated carbon, lamp, etc.) to be carried out two to three times a year depending on the conditions of the equipment.

CONCLUSION

Water quality depends on the treatments applied, including physical, chemical and biological methods to remove contaminants. Filtration materials, such as sand, activated carbon and membranes, play a crucial role in the effectiveness of these treatments. Physicochemical parameters such as pH, conductivity and turbidity, as well as microbiological parameters, are essential to assess and improve water quality. An in-depth analysis of these parameters is necessary to correctly size a filtration prototype. Thus, a well-designed filtration system ensures clean, safe water that meets health standards.

BIBLIOGRAPHICAL REFERENCES

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[4] lozère.fr. Departmental analysis laboratory. Physico-chemical analyzes of water.

[5] LAURE Semblat . Water purification guide, National Federation of granting authorities and FNCCR authorities (2007).

[6] Houda JARID, Karam AMZIL. Optimization of sand filtration for the treatment of drinking water at the Guemassa CMG mining company (June 2012).

[7] BAKKARI Meriem, KERROUM Siham. Wastewater treatment by sand filtration (2016).

APPENDICES

Appendix 01: Physico-chemical and microbiological characteristics of raw water

The following table presents the quality of the water to be treated

Settings	Raw water	Unit	VMA
Ph	7.28		6.5 – 9.5
Conductivity	253,981	µS/cm	3000
Turbidity	174,365	NTU	5
Suspended matter	68,059	mg/L	30
Ammonium	0.192	mg/L	0.5
Magnesium	4,087	mg/L	50
Calcium	3,126	mg/L	200
Potassium	2,484	Mg/L	12
Full Alkalimetry Title	3,095	°F	-
Total hardnesses	24,751	°F	-
Nitrate	0.267	mg/L	50
Nitrite	0.089	mg/L	0.1
Sulfates	6,574	mg/L	150
Phosphates	0.396	mg/L	0.5
BOD	24,358	mg/L	5
COD	50,762	mg/L	20
Total coliforms	100 <	CFU/100 Ml	0
Fecal streptococci	10 <	CFU/100 mL	0
Escherichia coli	10 <	CFU/100 mL	0

Sources : Authors

Appendix 02: Characteristics of the filter bed

- **Filtration module components**

The first components of the filter are the support gravels. They retain the sand and facilitate the distribution of washing water. Depending on the dimensions or particle size characteristics of the filter material, filtration can be carried out at the surface or at depth [7]. The process has three components, the first of which is composed of round sands of variable particle size favoring the reduction of turbidity, the second uses granular activated carbons allowing the improvement of organoleptic qualities and the last component concerns diatomaceous earths for the elimination of biological pollutants.

Granulometry

Determination of the size of the aggregates and their distribution according to their size.
The following table presents the characteristics of the sands used.

Effective diameter d10 (mm)	0.52
Effective diameter d60 (mm)	0.71
Uniformity coefficient (CU)	1,365
Finish modulus (%)	4.78
Permeability (K)	0.375
Porosity (e)	0.062

Sources : Authors

- **Coal active**
  - **Preparation**

Activated carbon is also a carbon-based material, obtained by calcination and activation of wood. As a very good adsorbent of organic matter, it also allows the elimination of compounds responsible for color, tastes and odors, and also organic micropollutants. The preparation consists of the carbonization of the precursors followed by grinding and sieving of the grains according to the particle size of 0.4 to 1 mm. Chemical activation consists of dehydration in an acidic medium at 500°C.

- **Regeneration**

Regeneration is done with steam allowing the surface of the grains to be unclogged and sterilized.

- **Simulation**

With the physico-chemical and microbiological characteristics of raw water, turbidity, MES and especially microbiological parameters largely exceed drinking standards. The process used is slow filtration, in fact, the water slowly passes through the layer of fine sand and the largest particles are stopped on the surface of the sand. Microbiological parameters are eliminated by activated carbon components. Our study confirmed the reduction of turbidity, suspended matter and also the total elimination of microbiological parameters.

The following table summarizes the characteristics of the filter layers.

Component by location	Dimensions (mm)	Thickness (cm)
Charcoal	d<0.2	40
Fine sand	0.4<d<0.5	20
Sand	0.5<d<1	10
Separation gravel	4<d<8	10
Drainage gravel	10<d<15	10

Appendix 03: Estimated quotes

- **Physico-chemical and bacteriological analyzes of water before treatment**

The following table presents the estimate for the physicochemical analyzes of raw water before treatment:

Settings	PU (MGA)	Quantity	Amount (MGA)
pH	20,000	01	20,000
Conductivity	20,000	01	20,000
Turbidity	20,000	01	20,000
Suspended matter	20,000	01	20,000
Ammonium	50,000	01	50,000
Magnesium	50,000	01	50,000
Calcium	50,000	01	50,000
Potassium	50,000	01	50,000
Full Alkalimetry Title	50,000	01	50,000
Total hardnesses	50,000	01	50,000
Nitrate	80,000	01	80,000
Nitrite	80,000	01	80,000
Sulfates	80,000	01	80,000
Phosphates	80,000	01	80,000
BOD	150,000	01	150,000
COD	150,000	01	150,000

Total coliforms	30,00	01	30,000
Fecal streptococci	0	01	30,000
Escherichia coli	30,00	01	30,000
	0	**Total (excluding VAT) Ariary**	**1,090,000**
	30,00	**Total Euro**	**227**

Sources : URGPGE Laboratory 0

 Physico-chemical and bacteriological analyzes of water after treatment

The following table presents the quote for the physicochemical analyzes of raw water after treatment

Settings	**PU (MGA)**	**Quantity**	**Amount (MGA)**
pH	20,000	01	20,000
Conductivity	20,000	01	20,000
Turbidity	20,000	01	20,000
Suspended matter	20,000	01	20,000
Total coliforms	30,000	01	30,000
Fecal streptococci	30,000	01	30,000
Escherichia coli	30,000	01	30,000
	Total (excluding VAT) Ariary		**170,000**
	Total Euro		**36**

Sources : URGPGE Laboratory

 Materials and equipment for installation

The following table presents the list of equipment

Settings	**PU (MGA)**	**Quantity**	**Amount (MGA)**
Bricks	180	5,000	900,000
Cements : Orimbato	38,000	2	76,000
Lova	35,000	6	210,000
Gravel	1,500	70	105,000
Sands	1,100	100	110,000

Protective grid (iron)	400,000	1	400,000
Boards	5,000	4	20,000
Doors	500,000	2	1,000,000
Window (PVC)	350,000	1	350,000
Madrie	15,000	4	60,000
Sheet metal (0.20)	45,000	4	180,000
Real estate	500,000	1	500,000
Complete solar panel	1,200,000	1	1,200,000
Drums (100 L)	110,000	4	440,000
Tank(500L)	500,000	1	500,000
Labor	800 000	1	800 000
	Total (excluding VAT) Ariary		**5,575,000**
	Total Euro		**1,157**

Sources : Authors

The following table shows the list of consumables

Settings	**PU (MGA)**	**Quantity**	**Amount (MGA)**
Gravel	1,500	4	6,000
Separation gravels	3,000	6	18,000
Sands	1,100	3	3,300
Fine sands	2,000	3	6,000
Activated carbon	600,000	1	600,000
UV lamp	1.5 million	1	1.5 million
Pipes	20,000	8	160,000
The stop valve	25,000	4	100,000
Elbow	2,000	10	20,000
Node	4,000	4	16,000
Suppressor pump	400,000	1	400,000
	Total (excluding VAT) Ariary		**2,829,300**
	Total Euro		**587**

Sources : Authors

- **Quote summaries**

	Preliminary project		
Settings	**PU (Euro)**	**Quantity**	**Amount (Euro)**
Raw water diagnosis	227	1	227
Follow up	36	1	36
	Realization		
Settings	**PU (Euro)**	**Quantity**	**Amount (Euro)**
Facility	1,157	1	1,157
Consumables	587	1	587
	Process		
Settings	**PU (Euro)**	**Quantity**	**Amount (Euro)**
Interviews	-	-	-
	Total (excluding VAT) Ariary		**9,664,300**
	Total Euro		**2007**

Sources : Authors

SUMMARY

The slow sand filtration process is a technique recently used for water purification. Using this technology, our study confirmed a considerable reduction in some physicochemical parameters such as turbidity from 172 NTU to 3 NTU, MES from 30 N to 2.4 N. In addition we observed that the microbiological parameter are eliminated. This allowed us to propose water treatment of the Ikopa river with a view to supplying drinking water for small-scale uses. The system includes 4 modules in series, the first of which contains gravel weighing 168 kg, the second contains sand of variable dimensions weighing 100 kg, the third contains activated carbon. And the last constitutes the treated water tank.

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