

# Original Research Article

## Impacts of anthropogenic activities on the physicochemical quality of water from the Ouangolodougou dam

### ABSTRACT

**Aims:** The main objective of The present study was to assess the impact of human activities on the physico-chemical water quality of the Ouangolo Dam.

**Study design:** Characterization of water from the dam has been firstly done. Identification and location of anthropogenic activities has been assessed.

**Place and Duration of Study:** Department of geosciences, SODECI laboratory. The sampling and analyses were carried out during rainy season in September 2021 and the second during dry season in January 2022.

**Methodology:** The methodology adopted consisted firstly in characterizing water from the Dam and comparing its compliance with WHO drinking water supply standards, and then in determining the quality and pollution indices in order to assess the level of quality and the degree of pollution of this resource. Finally, a survey was carried out in the catchment area of the dam in order to identify and locate anthropogenic activities likely to pollute the water of this resource.

**Results:** The results of the reviled that characterization show that the water is relatively neutral with an The average value of pH of 6.9 and a relatively low electrical conductivity (124.83  $\mu\text{S/cm}$ ), The presence of trace metals, such as iron ( ) mg/L and arsenic ( ) mg/L, with concentrations from 0.18 to 3.29 mg/L, for iron ( ) mg/L and from 0.03 to 0.21 mg/L, for arsenic ( ) mg/L, Compounds such as nitrate ( ) mg/L, and phosphorus ( ) mg/L, have respective concentrations from 0.32 to 1.6 mg/L) and from 0.1 to 0.42 mg/L. pesticides POP ( ) mg/L ,POH ( ) mg/L have respective mean values of 0.002 mg/L and 0.001 mg/L. The ? quality (94.81 and 147.66) and organic pollution (3 and 3.33) indices indicate that the dam is of very poor water quality in rainy periods and not drinkable in dry periods while having an average degree of pollution over the 2 seasons. Agricultural practice in the immediate perimeters is the main pollutant (49%), followed by artisanal activities (27%) and households (24%).

**Conclusion:** This study has shown that human activities (precisely agriculture) represent the most important source of pollution of the water from the Dam of Ouangolo. It is thus important to raise awareness among the population around the Dam on dangers about this situation.

**Keywords:** Ouangolodougou Dam water, Anthropogenic Activities, Pollution.

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# 1. INTRODUCTION

In the 1970s, Côte d'Ivoire began building several small multi-use dams in the north to cope with water shortages caused by climate change. These small reservoirs, including the one in Ouangolodougou and Korhogo, are used in general for several purposes such as hydro-agricultural (irrigation), pastoral (watering), hydraulic, hydrological [1], or treated to supply drinking water to the population [2] (Agbani, 2013). However, over time, these infrastructures undergo various pressures related to the anthropization of landscapes, precisely agriculture, industry, rapid urbanization and population growth [3][4][5]. Indeed, these pressures, with a socio-economic nature coupled with natural processes (soil erosion, precipitation, evaporation, run-off of river waters) lead to a significantly degradation of the quality of these water resources [6], posing serious problems for the population [7], in particular the difficulty of treatment at drinking water treatment plants [8]. It is therefore essential to maintain an undeniable quality of these water resources in order to preserve the environment and the health of populations [9]. A non-exhaustive but precise knowledge of anthropogenic activities inducing a qualitative degradation of water resources would constitute a non-negligible basis for their protection and preservation. This study was initiated with main objective to assess the impact of human activities on the physico-chemical quality of the dam's water. The specific objectives are:

- Assessing the level of water pollution from the Ouangolodougou Dam
- Identify human activities likely to pollute this water resource.

## 2. MATERIAL AND METHODS

### 2.1 Material

#### 2.1.1 Data collection Material

The equipments used for data collection comprise essentially:

- survey sheets to collect geographical and household information;
- plastic bottles with a capacity of 1,5 L for sampling;
- a container for samples transportation;
- GARMIN Etrex 10 for GPS data collection;
- a cooler for conditioning sampled water.

#### 2.1.2 Analysis equipments

The equipments that have been used for analysis include:

- Multi-parameter for pH, temperature, dissolved oxygen, conductivity, suspended solids, turbidity in situ measurement;
- HACH/DR 1900 spectrophotometer for laboratory analyses;
- glassware as laboratory consumables;
- STATISTICA 7.1 and EXCEL for data statistical processing;
- QGIS 3.18 for mapping.

## 2.2 Methods

### Collection and Preservation method

#### 2.2.1 Dam Water quality and pollution assessment

##### 2.2.1.1 Dam Water Quality analysis

The first sampling was carried out during rainy season in September 2021 and the second during dry season in January 2022. In each season, four samples were taken at different depths of the dam (surface, medium and depth). Samples collected were subsequently stored in a container with a cooler at 4°C before being transported to the laboratory for chemical analysis.

Water quality ~~Some~~ parameters such as pH, temperature, electrical conductivity and dissolved oxygen were measured in situ using a multi parameter. Analyses of other parameters were carried out in SODECI laboratory by using a HACH/DR 1900 spectrophotometer. It concerns chemical oxygen demand (COD), the biological oxygen demand (BOD<sub>5</sub>), nitrate (NO<sup>3-</sup>), nitrite (NO<sup>2-</sup>),

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ammonium (NH<sub>4</sub><sup>+</sup>), metals such as dissolved iron (Fe), manganese (Mn), total phosphate (PO<sub>4</sub><sup>3-</sup>), lead (Pb), arsenic (As), cyanide (CN), mercury (Hg), organohalogenated (POH) and organophosphorus (POP) pesticides, and carbamates (CAR). Analyses were according to specific methods in Table 1.

**Table 1. Parameters Analysis Methods**

Parameters	Unit	Methods
pH		ISO 10523 V 2008
Temperature	°C	Pt 100
Conductivity	µS/Cm	ISO 7888 V 1985
Dissolved Oxygen	%/mg/L	ISO 5814 V 2012
COD	mgO <sub>2</sub> /L	Tubes fermés
BOD <sub>5</sub>	mgO <sub>2</sub> /L	Respirometric
Nitrates	mgNO <sub>3</sub> -	ISO 7890-3 V 1988
Nitrites	mgNO <sub>2</sub> -	Diazotation
Cyanides	mg/L	Pyrazolone-pyridine AAS ContraA 700 (Flamme)
Iron	mg/L	
Manganese	mg/L	ISO 15586 V 2003
Lead	mg/L	ISO 8288 V 1986
Arsenic	µg/L	ISO 17378-2 V2014
Mercury	µg/L	ISO 12846 V 2012
Ammonium	mg/L	NF T90-015-2 V2000
Total Phosphorous	mg/L	ISO 6878 V 2004
Organohalogenated pesticides	µg/L	EN NF ISO V6468-97
Organochlorinated pesticides	µg/L	EN NF ISO V 11369-97
Carbamates	µg/L	EN NF ISO V11369-97

NF: French Norm, EN: European Norm, ISO: International Organization for Standardization, AFNOR: French Association of standardisation

### 2.2.1.2 Data Statistical analysis

The statistical approach is based on Standard Principal Components Analysis, which can be used to interpret results of physicochemical parameters to determine the likely origin of mineral pollutants that could degrade water quality ([10] Blue, 2005; [11] Koumian, 2009; [12] Ahoussi, 2016). All analyzes (descriptive statistics, correlation matrix, eigenvalues of the correlation matrix and factorial plans) were performed using STATISTICA 7.1 software.

### 2.2.1.3 Determination of Water Quality Index (WQI)

The WQI was calculated using the weighted arithmetic index method proposed by [13]. Eight important parameters (pH, OD, CE, T° C., BOD<sub>5</sub>, PO<sub>4</sub><sup>3-</sup>, NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub>) were retained for this purpose. In this approach, a numerical value called the relative weight (Wi), specific to each physico-chemical parameter, was first calculated using the following equation:

$$W_i = \frac{1}{n}$$

with

$$W_i = \frac{1}{\sum_{i=1}^n (1/W_i)}$$

W<sub>i</sub>: relative weight

k = constante de proportionnalité

n : le nombre de paramètres

S<sub>i</sub> : maximum value of surface waters standard for (Table 2) of each parameter (mg/L) without pH, Temperature and electric conductivity.

**Table 2. Drinking water guidelines [14].**

Parameters	Units	WHO guideline
Température	°C	25
Conductivité	µS/cm	2000
Turbidité	NTU	5
pH	-	6.5<pH<8.5
NO <sub>3</sub> <sup>-</sup>	mg/L	50
NO <sub>2</sub> <sup>-</sup>	mg/L	3
SO <sub>4</sub> <sup>2-</sup>	mg/L	250
PO <sub>4</sub> <sup>3-</sup>	mg/L	5
F <sup>-</sup>	mg/L	1,5
Cl <sup>-</sup>	mg/L	250
Na <sup>+</sup>	mg/L	≤150
Mg <sup>2+</sup>	mg/L	50
Ca <sup>2+</sup>	mg/L	100
NH <sub>4</sub> <sup>+</sup>	mg/L	≤0,5
Fe <sup>2+</sup>	mg/L	0,3
K <sup>+</sup>	mg/L	≤12

Then, a quality rating scale (Q<sub>i</sub>) was calculated for each parameter by dividing the concentration by the norm of that parameter and multiplying the whole by 100 as in the following equation:

$$Q_i = \left( \frac{C_i}{S_i} \right) \times 100$$

Q<sub>i</sub> : Quality rating scale for each parameter

C<sub>i</sub> : Concentration of each parameter (mg/l)

Then, the overall water quality index was calculated by the following equation:

$$WQI = \frac{\sum_{i=1}^n (W_i \times Q_i)}{\sum_{i=1}^n W_i}$$

Finally, Table 3 was used to determine dam water quality class.

**Table 3. Water type and possible use according to WQI [15].**

WQI class	Water type	Possible use
0 – 25	Excellent quality	Drinking water, irrigation and industry
> 25– 50	Good quality	Drinking water, irrigation and industry
> 50– 75	Bad quality	Irrigation and industry
> 75– 100	Very bad quality	Irrigation
> 100	Non-potable water	Appropriate treatment required before use

#### 2.2.1.4 Determination of Organic Pollution Index (OPI)

Organic pollution index (OPI) of dam water was determined using method proposed by [16]. The principle is to first divide the values of the polluting elements (ammonia, BOD<sub>5</sub>, and phosphates) into 05 classes, with average contents of these three parameters obtained during laboratory analyzes. Then, determine corresponding class number for each parameter using arithmetic mean proposed by Leclercq (Table 4). Finally, overall organic pollution index of dam water was determined through arithmetic mean of pollution classes of all parameters.

**Table 4. Organic pollution index classification [16].**

Classes	NH <sub>4</sub> <sup>+</sup> (mg/l)	BOD <sub>5</sub> (mgO <sub>2</sub> /l)	PO <sub>4</sub> <sup>3-</sup> (µg/l)	IPO	Organique Pollution
5	< 0,1	<2	< 15	4,6 – 5,0	Null
4	0,1 – 0 ,9	2,1 – 5	16 – 75	4 – 4,5	Weak
3	1 – 2,4	5,1 – 10	76 – 250	3,0 – 3,9	Moderate
2	2,5 – 6	10,1 – 15	251– 900	2,0 – 2,9	Strong
1	> 6	> 15	< 900	1,0 – 1,9	Very strong

#### 2.2.2. Identification of human activities concerning the dam water pollution

A survey was carried out and consisted in submitting a questionnaire to actors in different fields of activity but also in houses around the dam. The objective was to investigate the factors likely to pollute dam water (agricultural, artisanal, industrial activities, and the management of household waste and municipal wastewater), according to Dam wwater quality and pollution assessment. During this survey, coordinates details of visited sites were recorded using GPS. Through CSV format of EXCEL, QGIS 3.18 was used to generate a map of these various activities. Mapping of anthropogenic activities in the dam watershed was done. The agricultural sites are marked by squares of green colors. Blue diamonds show the presence of handicraft activities. Blue arrows and red crosses indicate respectively the flow of water towards the dam and the presence of household waste.

### 3. RESULTS AND DISCUSSION

#### 3.1 Dam Water quality and pollution assessment

##### 3.1.1 Dam Water analysis

##### 3.1.1.1 Physico-chemical Parameters

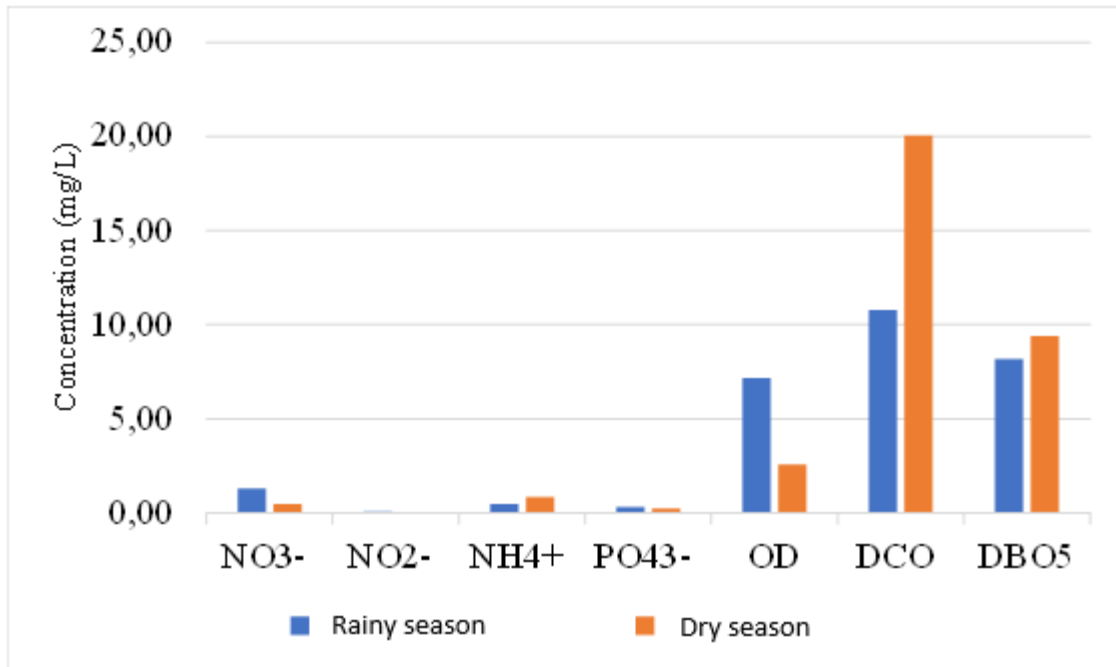
Results show that The pH ranges from 6.1 to 8.2 with a mean of 6.9 in the WHO range (6.5 to 8.5). This shows a less aggressive nature of the dam's waters. Temperatures range from 22.57 to 30.4°C, with an average of 26.57°C, which is close to the WHO guide value (25°C). Electrical conductivity values ranged from 82.3 to 152.11  $\mu\text{S}/\text{cm}$  with a mean of 124.83  $\mu\text{S}/\text{cm}$ , are lower than the WHO average (2000  $\mu\text{S}/\text{cm}$ ). This means that the water in the dam is weakly mineralized. In the two campaigns, pH did not show any significant difference, temperature was slightly higher in the rainy season while conductivity remained higher in the dry period (Table 5). These values differ from the results found in Lobo (Daloa) waters that are used for human consumption with conductivity ranging from 192.3  $\mu\text{S}/\text{cm}$  to 316  $\mu\text{S}/\text{cm}$  [17]. This difference may be due to a dissimilarity of natural factors such as climate, vegetation, geology and also activities carried out in the vicinity of resources. pH values at the Ouangolo Dam could also be explained by the presence of bicarbonates which have a buffering capacity in water or by the degradation of organic matter [18]. As for the temperature, the variation of (22.57 to 30.4° C.) would be related to the temperature of the region. For example, high water temperatures (> 30 °C) are thought to be due to sunshine in the outer layers during the rainy season. As a factor in modifying the chemical and biological properties of water by acting on its density, on the solubility of gases, on the dissociation of dissolved salts, and on biochemical and biological reactions [19] (Makhoukh et al., 2011; [20] Akil et al., 2014), this high value could affect the organoleptic properties of water. In fact, this could explain the drop in conductivity in rainy period.

Variation of  $\text{NO}_3^-$  (0.32 to 1.6),  $\text{NO}_2^-$  (0.04 to 0.1), OD (0.7 to 7.94) and  $\text{PO}_4^{3-}$  (0.1 to 0.42) remains as large but in accordance with WHO standards. Mean concentrations of  $\text{BOD}_5$  (from 3.8 to 16) and  $\text{NH}_4^+$  (from 0.1 to 2.7) are respectively 8.8 and 0.67 mg/L, which are higher than WHO guide values (5 mg/L for  $\text{BOD}_5$  and 0.5 mg/L for  $\text{NH}_4^+$ ). Based on  $\text{BOD}_5$  average value and according to [21], dam's water quality would be poor. These results are similar to those of [22]. for surface waters near cotton production areas of Aplahoué in Benin. Seasonal mean of COD values (between 5.86 and 30.7) is near to the limit of required standard (20 mg/L). The high values of these parameters reflect a high organic contents in dam waters. This could be related to the discharge of municipal wastewater that is drained by runoff. It could also be due to nitrogen-based fertilizers used in crops farm around the dam. Concentrations of these 3 chemical parameters ( $\text{NH}_4^+$ ,  $\text{DBO}_5$  and DCO) vary according to season and are higher in dry period (Figure 1). This could be explained by the fact that, during dry periods, there is not only an intensification of crops farm around the dam (intensive use of chemical fertilizers), but also during this period, municipal effluents that are discharged into this resource are more concentrated.

**Table 5. Physic parameters level of Dam water**

	Temperature (°C)	pH	EC ( $\mu\text{S}/\text{cm}$ )
Rainy season	29.925	7.425	99.025
Dry season	23.2175	6.375	150.6275

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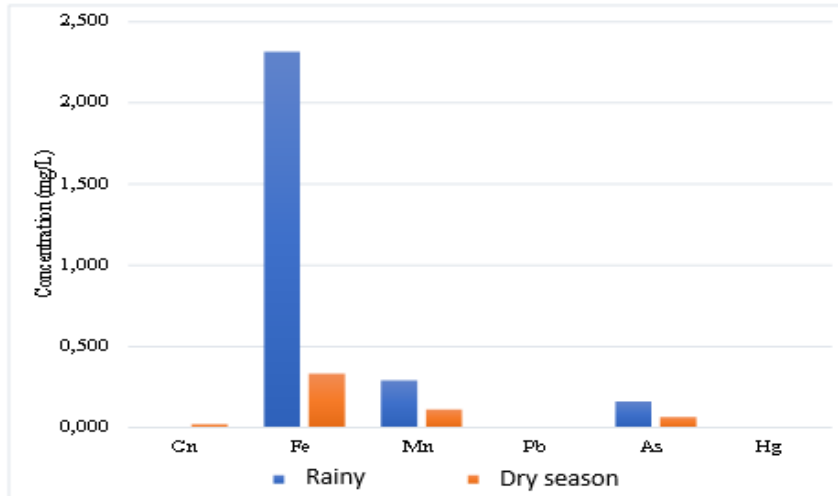


**FIG. 1. Chemical parameters contents in dam water**

Graphically representation of water quality parameters

### 3.4.1-2 Metal trace elements

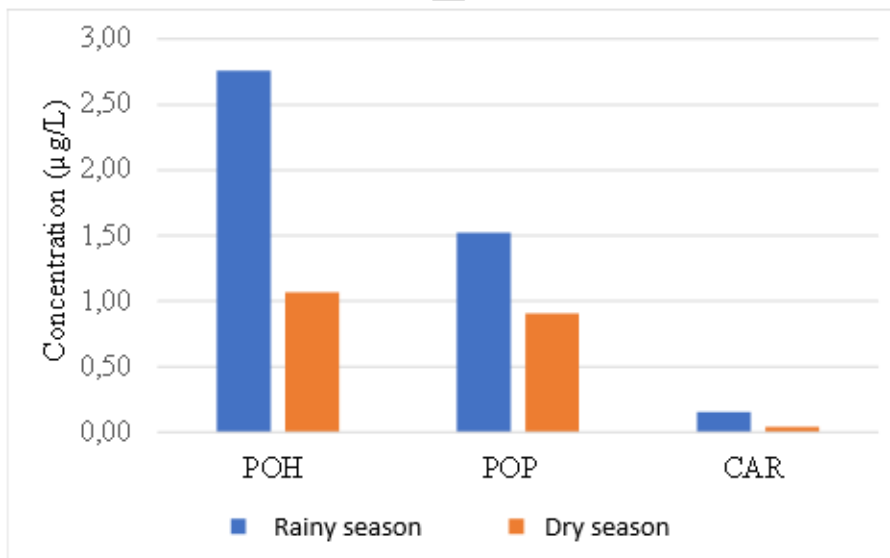
Figure 2 shows that contents range from 0.18 to 3.29 mg/L for iron (Fe) and from 0.03 to 0.21 mg/L for arsenic (As), respectively with a mean of 1.4 mg/L and 0.11 mg/L. These values are far above the WHO guideline values of 0.3 mg/L for iron (Fe) and 10 µg/L for arsenic (As), posing a real health risk to populations. In fact, the primary source of heavy metal contamination in the environment has been determined to be the exponential increase in human population, the proliferation of industrialization, and the expansion of agricultural activities [23] [24]. In the absence of industrial activities in this area, the origin of arsenic could be attributed to agricultural activities or municipal effluent discharges into the dam [25] [26]. In addition, the high iron concentration could be attributed to the transport by run-off (high content in the wet and dry seasons) of weld and cutting debris from scrap metal shops.



**FIG. 2. Heavy metals contents in dam water**

### 3.4.4.3 Pesticides

Studied pesticides are organohalogen (POH), organophosphorus (POP) and carbamate (CAR). POHs and POPs have mean values respectively of 0.002 mg/L and 0.001 mg/L, above WHO standard for pesticides (0.1 µg/L), and have high concentrations in both wet and dry seasons (Figure 3), with the lowest pesticide concentrations dry seasons. Similar results have been found by [27]. Indeed, this could be the result of pesticides (to control pests) that are drained during the rainy season and that remain persistent in the dam water during the dry period. Because of the use of this resource as drinking water, attention should be paid to pesticides level or focusing on the necessity of comprehensive monitoring and regulatory measures to protect aquatic ecosystems [28] because once pesticides reach water bodies, they can impact the whole ecological food chain, since other animals, including humans, feed on aquatic animals that may be contaminated [29].



**FIG. 3. Pesticides contents in dam water**

### 3.1.1.4 Statistical data analyses

Standard Principal Component Analyses in table 6 shows the correlation between the parameters taken two by two. Excellent correlations of (-0.95) between T°C and CE, (-0.9) between CE and POH, (0.9) between T°C and (NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>), then between Fe and (NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>). There is a very strong correlation of (0.8) between pH and (NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, Fe), between T°C and (Fe, As), (-0.8), between CN and (T°C NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>), (0.8) between CN and (CE, Pb), between POH and As, between CBT and Mn (0.8). Strong (-0.7) correlations between T°C and COD, between Fe and CE, between CN and (POH, POP), between CE and CAR, (0.7) between pH and (T°C, As, PO<sub>4</sub><sup>3-</sup>), between COD and Hg. Between NO<sub>3</sub><sup>-</sup> and (POH, CAR), Mn and CAR, and between CAR and (POH, POP). Negative correlations between parameters would mean that these parameters evolve in an antagonistic manner. Indeed, when the temperature rises, this would lead to a decrease in the EC, COD and cyanide content in the dam. The correlation between CE and Fe, POH shows that these two parameters are very active in the mineralization of dam water. Correlations of T°C with NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup> and POH would mean that the increase in temperature directly leads to an increase in the content of NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup> and POH. The relationship between POH and As, POP and Fe and NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup> also means that these elements are involved in the mineralization of the dam water.

Table 7 shows that the axes F 1, F 2 and F 3 express respectively 49.33%, 15.70% and 12.13% of the total variance of the data with respective eigenvalues equal to 8.88, 2.82 and 2.18. These three factors, expressing more than half of the cumulative eigenvalues (77.17%) are therefore sufficient to analyze the factorial designs.

**Table 6. Parameters correlation matrix**

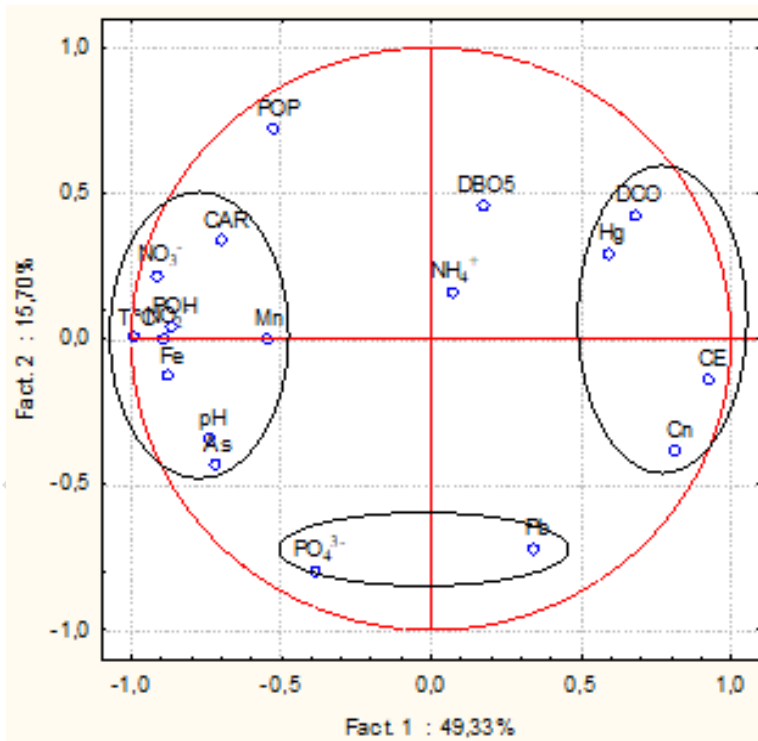
	pH	T°C	CE	DO C	DBO s	NO <sub>3</sub> <sup>-</sup>	NO <sub>2</sub> <sup>-</sup>	CN	Fe	Mn	Pb	As	Hg	NH <sub>4</sub> <sup>+</sup> *	PO <sub>4</sub> <sup>3-</sup> -	PO H	PO P	CA R
pH	1																	
T°C	<b>0,7</b>	1																
CE	-0,5	<b>0,95</b>	1															
DOC	-0,4	<b>-0,7</b>	<b>0,7</b>	1														
BOD s	0,1	-0,2	0,3	<b>0,8</b>	1													
NO <sub>3</sub> <sup>-</sup>	<b>0,8</b>	<b>0,9</b>	<b>0,8</b>	-0,5	0,1	1												
NO <sub>2</sub> <sup>-</sup>	<b>0,8</b>	<b>0,9</b>	<b>0,8</b>	-0,5	-0,1	<b>0,8</b>	1											
CN	-0,5	<b>-0,8</b>	<b>0,8</b>	0,4	0,02	<b>-0,8</b>	<b>-0,8</b>	1										
Fe	<b>0,8</b>	<b>0,8</b>	<b>0,7</b>	-0,5	-0,04	<b>0,9</b>	<b>0,9</b>	-0,6	1									
Mn	0,3	0,5	0,5	-0,2	0,1	0,5	0,2	-0,2	0,4	1								
Pb	-0,2	-0,4	0,4	-0,1	-0,3	-0,5	-0,4	<b>0,8</b>	0,2	0,04	1							
As	<b>0,7</b>	<b>0,8</b>	0,6	-0,6	-0,2	0,5	0,6	-0,6	0,5	0,3	0,1	1						
Hg	-0,5	-0,6	0,5	<b>0,7</b>	0,4	-0,5	-0,4	0,3	0,5	-0,3	0,3	0,5	1					
NH <sub>4</sub> <sup>+</sup> PO <sub>4</sub> <sup>3-</sup>	-0,1	-0,1	0,2	-0,2	-0,2	0,1	-0,3	0,03	0,3	0,01	0,1	0,2	0,5	1				
-	<b>0,7</b>	0,4	0,2	-0,5	-0,3	0,2	0,3	0,01	0,5	0,3	0,3	0,6	0,2	-0,2	1			
POH	0,5	<b>0,9</b>	<b>0,9</b>	-0,5	-0,03	<b>0,7</b>	0,6	<b>-0,7</b>	0,6	<b>0,7</b>	0,3	<b>0,8</b>	0,5	-0,1	0,3	1		
POP	0,002	0,5	0,6	-0,3	-0,1	0,6	0,4	<b>-0,7</b>	0,3	0,3	0,6	0,1	0,3	0,4	-0,4	0,4	1	
CAR	0,2	0,6	<b>0,7</b>	-0,3	0,01	<b>0,7</b>	0,5	-0,4	0,6	0,8	0,1	0,1	0,4	0,05	-0,1	<b>0,7</b>	<b>0,7</b>	1

**Table 7. Eigenvalues of correlation matrix**

	Eigenvalues	Eigenvalues %	Cumulation	Cumulation %
F1	8,88	49,33	8,88	49,33
F2	2,83	15,70	11,71	65,03
F3	2,18	12,13	13,89	77,17
F4	1,57	8,73	15,46	85,90
F5	1,10	6,12	16,56	92,02
F6	0,89	4,92	17,45	96,94
F7	0,55	3,06	18	100

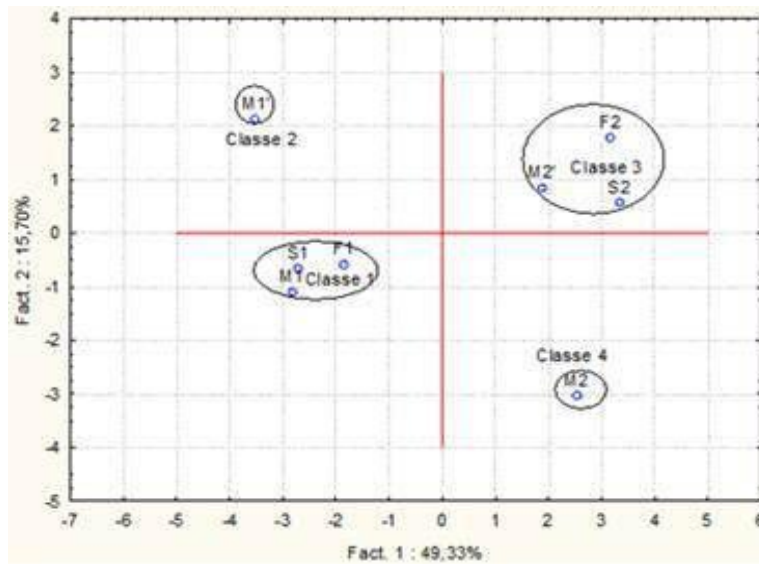
Analysis of the results of the F1x2 factorial plan (Figure 4) shows that this plane expresses 65.03% of the cumulative variance. The factor F1, the most important (49.33%) is determined by two groupings of parameters. The first, in its negative part, is composed of  $\text{NO}_2^-$ ,  $\text{NO}_3^-$ ,  $\text{T}^\circ\text{C}$ , POH, Mn, CAR, Fe, pH and As and the second in the positive plane is determined by Hg, DCO, CN and CE. These groups, marked by a combination of ions and physical parameters, reflect a mineralization of the dam water. This mineralization is mainly related to anthropogenic activities. The presence of nitrate  $\text{NO}_3^-$ , POH and CAR indicates pollution of surface origin. This pollution could be caused by the continued use of chemical or organic fertilizers in agricultural production, septic tanks, animal manure and municipal effluents.

The factor F2 (15.70%) is characterized by a grouping of Pb and  $\text{PO}_4^{3-}$ . These two elements would be in the dam because of human activity and lead pollution. When used as an anti-knock agent in vehicle engine fuels, it is directly contaminated by stormwater runoff from surrounding garages. The two axes can therefore be assimilated to a degree of organic and metal pollution.



**Fig. 4. F1x2 Factorial plan**

The statistical unit space of the F1x2 factor plan (Figure 5) shows four (4) parameter grouping classes. Class 1, which contains three samples from campaign 1 (area, average level 1 and background), groups together samples with high concentrations of Fe, Mn and As. It therefore summarizes natural and anthropogenic pollution. Class 2, marked by the sampling of the average level 2 of campaign 1, indicates a high concentration of POPs. This pollution is linked to agriculture. Class 3 comprising three samples from season 2 (surface, average level 2 and background) is governed by a high concentration of COD and Hg. This reflects domestic pollution. Finally, Class 4, which states that the sampling of the average level 1 of marketing year 2 records the highest concentrations of Pb.



**Figure 5: Statistical units space of F1x2 factorial plan**

Thus, Results of Standard Principal Component Analyzes highlighted contribution of anthropogenic activities to the mineralization of dam water. Indeed, Runoff and evaporation of mineral fertilizers and pesticides used by farmers, run-off of residues from informal sector, atmospheric fallout and discharge of domestic waste and municipal wastewater would be the real pollution sources of dam water. Studies have clearly shown importance of anthropogenic activities in surface waters mineralization [30].

### 3.1.2 Level of Dam water quality and pollution

Tables 8 and 9 successively determine the level of water quality and pollution of the Ouangolodougou dam. After the calculation of the global WQI quality index using the results of physico-chemical analyzes and the standard values of the WHO standard of drinking water, the water quality class of the dam is determined for the two sampling seasons (Table 8). Thus, the values 94.13 and 147.66 determined, describe the dam as very poor quality in rainy periods and undrinkable in dry periods. These are consistent with those of [31] concerning the evaluation of surface water contamination and its impacts on health in the mining districts of Kambélé and Bétaré-Oya. The deterioration in quality is mainly anthropogenic in relation to agricultural activities through leaching of soils with high fertilizer content and urban wastewater discharges [32]. Seasonal qualitative variation has been widely reported in the literature by [33]. Indeed, the high value of the WQI in dry periods is due to the fact that during this period, the water level drops while the municipal effluents remain large and concentrated in the dam. These results are consistent with those of [34][35].

**Table 8. Dam Water Quality Index of \_\_\_\_\_.**

Parameters	(Si)	1/Si	Wi	Rainy season		Dry season	
				Qi	WQI	Qi	WQI
pH	8,5	0,1176	0,0435	87,35	94,81	75	147,66
T(°C)	25	0,0400	0,0148	114,70		92,87	
EC (µs/cm)	2000	0,0005	0,0002	4,95		7,53	
DO (mg/L)	8	0,1250	0,0462	89,74		32,16	
NH <sub>4</sub> <sup>+</sup> (mg/L)	0,5	2,0000	0,7399	98,00		172	
NO <sub>3</sub> <sup>-</sup> (mg/L)	50	0,0200	0,0074	2,59		0,99	
PO <sub>4</sub> <sup>3-</sup> (mg/L)	5	0,2000	0,0740	6,70		4,8	
DBO <sub>5</sub> (mg/L)	5	0,2000	0,0740	164,00		188	
	TOTAL	2,703	1				
	k	0,370					

The results of analyzes of the pollution indicator parameters (NH<sub>4</sub><sup>+</sup>, BOD<sub>5</sub> and PO<sub>4</sub><sup>3-</sup>) were used to determine the pollution class of the dam (Table 9). The results show that organic pollution remained moderate over both periods. This means that the resource is subject to high levels of organic matter (BOD<sub>5</sub>) and phosphate. Discharges of wastewater from the city's effluents increase the content of these parameters and contribute to the degradation of the water quality of the dam [36]. However, the values 3 and 3.33 indicated justify that the pollution is slightly high in the rainy season than dry. At this time, run-off water may increase the organic load of the water.

**Table 9. Dam Water Pollution Index**

Parameters	Rainy season			Dry season		
	Means	Classes	WP	Mean	Classes	WPI
NH <sub>4</sub> <sup>+</sup> (mg/L)	0,49	4	3	0,86	2	3,33
BOD <sub>5</sub> (mg/L)	8,2	3		9,4	3	
PO <sub>4</sub> <sup>3-</sup> (µg/L)	335	2		240	3	

### 3.2 Anthropogenic activities in dam watershed

The main activities identified during the survey, based on information gathered and observations made on the ground, were agriculture, grazing and handicrafts. Market gardening in agriculture (Figures 6 a and b), is mainly carried out in dry season using of mineral and organic fertilizers (animal debris) as fertilizers and chemicals for plant protection treatment (Figure 6 c), which increases organic and mineral pollution of dam water.

Craft includes informal sectors such as car and motorcycle garages, welding and metal-working workshops, vulcanization workshops, etc. Actors in these sectors use different products such as engine oils, fuel, welding and scrap cutting residues in performing their activities. All the waste and residues from these activities are dumped on the ground and carried away by run-off to canals draining in dam direction. In addition, flocks (Figure 6 d) have been seen coming to drink daily, dropping the faeces near or into the dam water. There is also a lack of sanitation and no available protection perimeter, resulting in domestic sewage and solid waste (household waste) being introduced into the dam water.



a



b



c



d

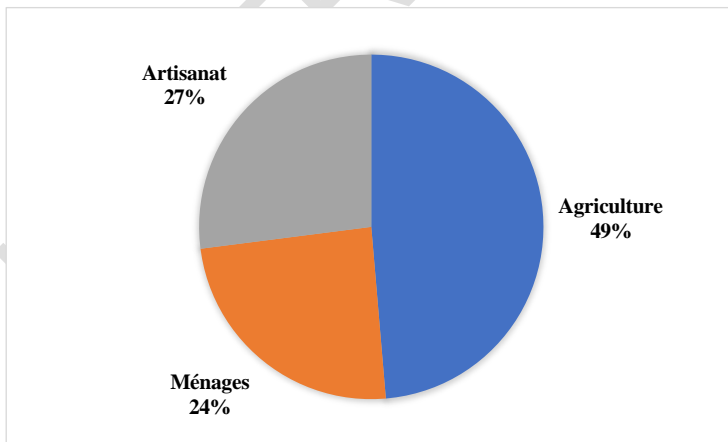
**FIG. 6. Agricultural activities around dam water.....**

Indeed, three main drainage channels were observed during the surveys (Figures 7 a and b). Concerning household waste, it is either dumped by local residents into dam environment or transported from the city by runoff water (Figure 7 c). All these household loads, coupled with climatic phenomena such as temperature and rainfall, increase the aquatic flora of the dam and could be the cause of the eutrophication phenomenon observed in Figure 7 d.



**FIG. 7. Household loads on dam water**

Figure 8 below shows proportion of the three major sources of human pollution observed in the environment near the reservoir. Based on the survey results, agriculture consists the main source of pollution of dam water (49%). Other sources of pollution are craft activities (27%), and domestic waste and waste water (24%).

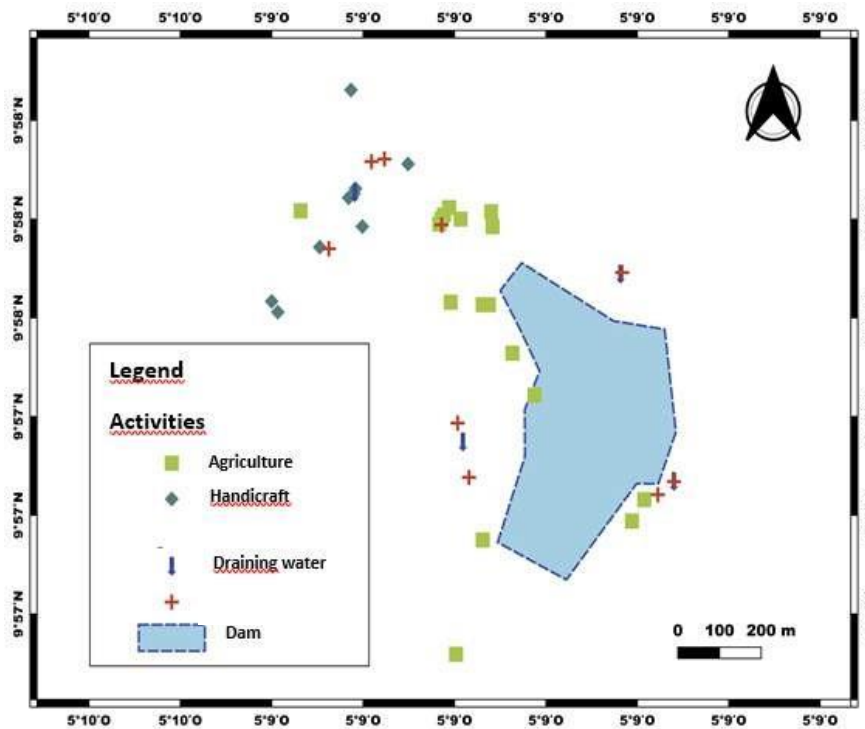


**FIG. 8. Proportion of major**

**sources of dam water pollution**

Figure 9 shows all the activities identified in the geographic surveys. There is a concentration of activities (agriculture, handicrafts, water and household waste) in the northwest part of the dam.

These observations were also made by [37] at the Drébot Lake in Gagnoa where activities, such as farming (market gardening), overgrazing, watering of large livestock, household waste landfills around the lake and drainage of household wastewater from nearby residents to this reservoir, pose risks of pollution of that water intended for consumption [37]. studies of [38] also have shown that grazing activities and intensive agriculture on the lake shores are the degradation causes of this water quality. Works of [39], in the others hand, indicated that informal activities, such as carpentry, catering, bag washing, car garages and sale of charcoal, the source of surface water pollution by producing waste that is discarded directly by the absence of communal collection. Domestic wastes within water perimeter are other cause of surface waters pollution after decomposition and/or percolation [40]. This poses a danger to the ecosystem and biodiversity, such as the mortality of many aquatic species or species whose habitat is linked to the aquatic environment, with the consequent limitation of animal and plant life.



**Fig.9. Anthropic activities repartition in the dam watershed**

#### 4. CONCLUSION

This study showed that the Ouangolodougou dam is characterized by a mean temperature of 26.57°C and a high content of BOD<sub>5</sub> (8.8 mg/L), NH<sub>4</sub><sup>+</sup> (0.67 mg/L), POP (0.001 mg/L), POH (0.002 mg/L), Fe (1.2 mg/L) and as (0.11 mg/L). These mean values are higher than the WHO drinking water guidelines. The assessment of the quality and pollution level leading to classify this resource as very poor quality in rainy periods (WQI = 94.81) and not suitable for drinking in dry periods (WQI = 147.66) with moderate pollution (3 ≤ IPO < 3.9). This state of degradation is directly linked to human activities, such as production of household waste, discharge of municipal wastewater, agriculture in the perimeter of the dam watershed and handicrafts are the real sources of pollution and degradation of the quality of these waters. The contribution of agriculture to this degradation is

linked to the crop protection products and fertilizers that farmers use to grow crops successfully. In order to reduce the pollution and maintain the quality of this water, it is imperative to:

**Recommendation: In paragraph**

- Raise awareness of the household waste proper management through creation of landfills and recycling of household waste;
- Raise awareness among farmers in order to rationally using of fertilizing products;
- Collect all municipal wastewaters for a treatment prior to discharge;
- Construct protective perimeters to retain coarse solid wastes.

It is also important to conduct a microbiological study of dam's water and assess the consequences of this pollution on aquatic life.

### **Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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#### **DEFINITIONS, ACRONYMS, ABBREVIATIONS**

Here is the Definitions section. This is an optional section.

**Term:** Definition for the term